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DATA NOTE

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Survey data on university students' experience of energy control, indoor comfort, and energy flexibility in campus buildings

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Abstract

Due to large energy consumption and equipped building control systems, the majority of campus buildings have the potential to increase energy efficiency and provide energy flexibility. Among the three main types of occupants in the campus buildings (researchers/teachers, students, administration/management), students spend most of their time on learning activities in the campus buildings, and the energy performance can influence their learning performance. Therefore, this paper conducts a questionnaire targeting student occupants at a large engineering faculty in a Danish university to investigate occupants' experience of energy control, indoor comfort, and options of energy flexibility in campus buildings. In total, 267 fully completed and usable questionnaires were received. The dataset is available in.xlsx format, and the questionnaire that was used to collect the data is also provided together.

Keywords: Questionnaire, Dataset, Campus building, Students' experience, Energy control, Indoor comfort, Energy flexibility

Introduction

Occupants' activities and behaviors influence building energy consumption and energy use (Billanes et al. 2018). According to Yoshino et al. (2017), there are six factors that mainly influence the energy consumption in buildings: (1) climate, (2) building envelope, (3) building services and energy systems, (4) building operation and maintenance, (5) occupant activities and behavior and (6) indoor environmental quality provided. For instance, an occupant's interaction with building systems and the available systems, plays a significant role in influencing the total energy use of buildings (Hong et al. 2016; Ma et al. 2017a). Literature has investigated occupant behaviors from the perspectives of user behavior, attitudes, consumption patterns, etc. (Sovacool 2014; Ma and Jørgensen 2018). Research shows that occupants' behaviors significant impacts on energy use (e.g. HVAC, lightings, appliances and building controls) (O'Brien and Gunay 2014). However, the understanding of occupants' behaviors is insufficient both in building design, operation and retrofit (Hong et al. 2016). This challenge does not only influence the design and strategies of the building energy efficiency but also energy flexibility.

According to the IEA EBC Annex 67, the energy flexibility of a building is 'the ability to manage its demand and generation according to local climate conditions, user needs, and energy network requirements' (Jensen et al. 2017). Buildings can supply flexibility services in different ways, and the buildings' ability to provide energy flexibility is influenced by several factors (Junker et al. 2018; Ma et al. 2017b): (1) its physical characteristics, e.g. thermal mass, insulation, and architectural layout, (2) its technologies, e.g. ventilation, heating, and storage equipment, (3) its control system that enables user interactions, and the possibility to respond and react to external signals, e.g. electricity price or CO_2 factors, and (4) the occupants' behavior and comfort requirements. Therefore, occupants take important roles in the building's energy flexibility. Occupants spend around 80% to 90% of their time indoors (Kjærgaard et al. 2016), and they occupy and use the building technologies (Masoso and Grobler 2010). Their acceptance and adoption of the energy flexibility solutions in buildings influence the performance of building energy flexibility (Billanes et al. 2017).

So far, occupancy comfort has primarily been considered for energy efficiency and not demand response (Chen et al. 2015), and occupant comfort has only been addressed to a limited extent in the research of energy flexible buildings (Behl and Sometimes 2015). To activate energy flexibility in building, value co-creation is important that occupants need to adopt the energy flexibility solutions (Tanev et al. 2010; Christensen et al. 2019). In the research on energy flexibility in buildings, the occupants' adoption of the energy flexibility one of the remaining questions is to know whether occupants would accept the frequent changes in energy use based on external signals, e.g., electricity market price signals (Dréau and Heiselberg 2016; Ma et al. 2018). Occupants' energy consumption patterns, comfort and preferences vary due to occupants' behaviors, and changing consumer behaviour is a challenge in building energy flexibility (Zanjani et al. 2015). However, many experiments have relied on the assumption of 'the occupants will accept a control of the indoor temperature based on an external signal' (Dréau and Heiselberg 2016). Therefore, there is an urgent need to investigate the occupants' roles and acceptance of the energy flexibility in buildings.

There are three basic types of buildings from the energy perspective: industrial, commercial and residential buildings (Samad and Kiliccote 2012). Different types of buildings can provide different energy flexibilities, and the occupants in different types of buildings have different energy use patterns, comfort and preferences (Ma et al. 2021). Commercial buildings have an important role in the demand side energy flexibility because of their high energy consumption, variety of energy flexibility resources, and centralized control via building control systems (Ma et al. 2017c).

One type of commercial buildings is the campus building. Campus buildings consume large energy, and the majority of campus buildings are equipped with building control systems (Ma et al. 2019). Building control together with an energy management system (EMS) can increase the energy efficiency of campus buildings and the potential of providing energy flexibility to the grid due to larger automation in the energy control (Barbato et al. 2016; Christensen et al. 2019). There are three types of occupants in the campus buildings, researchers/teachers, students and administration (including management). Students perform learning activities in the campus buildings, and the energy performance (e.g. indoor comfort) can influence their learning performance. To investigate occupants' experience of energy control, indoor comfort, and options of energy flexibility in campus buildings, this questionnaire targets student occupants at a large engineering faculty in a Danish university.

Methodology

Sampling

The questionnaire includes one background section and five main sections:

- Section Energy knowledge and university policies Knowledge of university energy policies and activities
- Section Opinions on University energy policies and activities University energy policies and activities
- Section Building control system Building control in classrooms
- Section Opinions on indoor comfort in classrooms Indoor comfort and energy control on campus
- Section 5 Distributed energy resources on campus

The questionnaire was distributed by emails via the secretary at the faculty to all students enrolled at the faculty in 2019. According to Facts and Figures by the university (Syddansk Universitet: Facts and Figures 2017), there were 3556 students at the end of 2016. In total, 267 fully completed and usable questionnaires were received, resulting in a response rate of 7.9%.

The distribution of the surveyed students on the educational progression shows that bachelor and master students are 68.9% and 31.1% (shown in Table 1). This distribution corresponds exactly to the distribution of bachelor and master graduates from the faculty of engineering at the university in 2016 and thus verifies that the data collected is representative. The genders for the surveyed students are 78.3% and 21.7% for male and female, and the age distribution are 76.4%, 19.1%, 3.7% and 0.8% for 18–25, 26–31, 32–40 and 40+. These distributions are to be expected when conducting a survey of the faculty of engineering at a university.

Table 1 Background of the surveyed students

Gender	Male	78.3
	Female	21.7
Age	18–25	76.4
	26–31	19.1
	32–40	3.7
	40 +	0.8
Degree	Bachelor student	68.9
	Master student	31.1

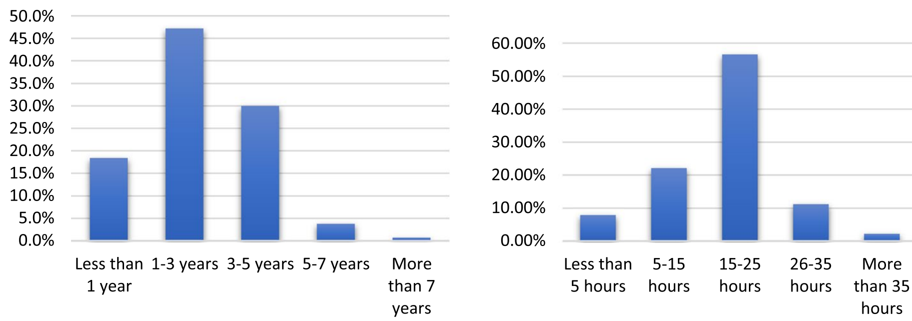

Fig. 1 Enrollment length (left figure) and hours per week (right figure) the surveyed students spend on campus

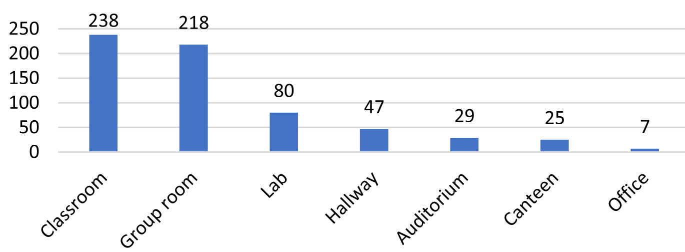

Fig. 2 Locations of occupants' time spending

Most surveyed students have been enrolled at the university for 1 to 3 years (47.2%). A large number of respondents have been enrolled for 3 to 5 years (30%). Few surveyed students have been enrolled for more than 5 years (3.8% for 5–7 years, and 0.7% for more than 7 years) and 18.4% have been enrolled for less than a year. The result corresponds to the result of the education distribution of surveyed students.

Regarding the number of hours per week the surveyed students spend on campus (Fig. 1b), 56.6% of surveyed students spend 15–25 h per week, and 22.1% spend 5–15 h, 11.2% spend 26–35 h, and 2.2% spends more than 35 h a week. Only 7.9% of surveyed students spend less than 5 h a week. Among 267 surveyed students, the top two places that students spend most of their time on campus are the classrooms and the group rooms (as shown in Fig. 2). The result corresponds to the typical workload and locations in terms of teaching hours and locations at the Faculty of Engineering.

Measurement

For the measure definition, interviews with 10 students were conducted to ensure content validity. In addition, two energy staff responsible for the energy management at the university were interviewed to validate our constructs from a building and energy management perspective. The survey design was developed based on the literature and interview analysis results.

To validate the quality of the survey results, this research designed three questions to test surveyed respondents' competence in energy-related knowledge and experience with energy activities and management in campus buildings. The analysis result is presented as the descriptive analysis result in the next section.

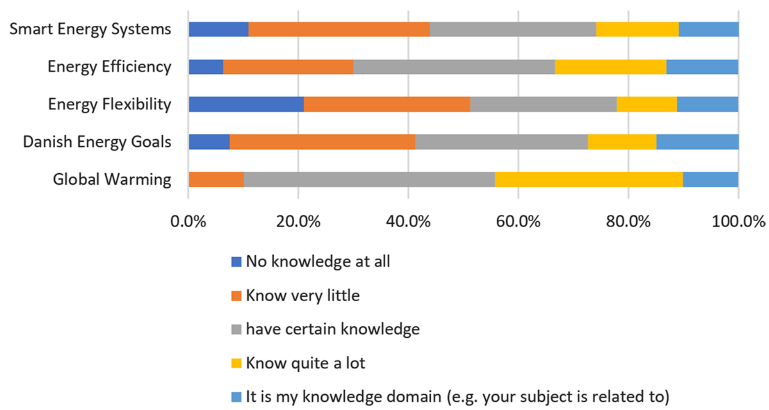

Fig. 3 The percentage of surveyed occupants' knowledge in the energy domain

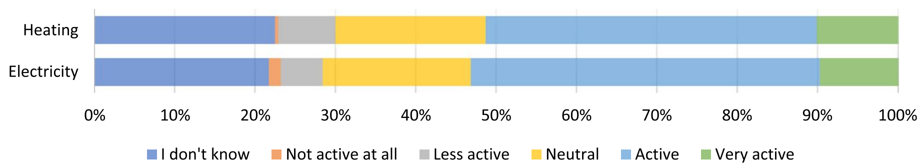

Fig. 4 Students' believes on university energy activities

Preliminary results

Energy knowledge and university policies

Knowledge of energy terms

As shown in Fig. 3, we found that, on average, the surveyed students have competence knowledge (have certain knowledge or more) on global warming ($t\ (266) = 8.9$, $p \le 0.0005$), and have less knowledge (know little or none) on energy flexibility ($t\ (266) = -5.1$, $p \le 0.0005$) and smart energy systems ($t\ (266) = -1.5$, $p < 0.05$). meanwhile, they have certain knowledge on energy efficiency ($t\ (266) = 1.5$, $p = 0.134$) and the Danish energy goals ($t\ (266) = -0.89$, $p = 0.373$).

Opinions on University energy policies and activities

82.8% of students believe the university has made an effort toward implementing energy savings (shown in Fig. 4). Although more than 20% of surveyed students do not have ideas about how active the university is in the energy efficiency of electricity and heating compared to other industries or commerce in the same city. The rest surveyed students, on average, believe the university is more active than others on the energy efficiency of electricity ($t\ (211) = 9.96$, $p \le 0.0005$) and heating $t\ (206) = 11.96$, $p \le 0.0005$).

92.1% of surveyed students do not know university policy regarding energy savings or energy efficiency, and 98.1% do not know any university energy savings incentive for the staff and the students. However, 80.9% of the surveyed students think students should take responsibility for energy savings at the campus, and 83.1% of surveyed students think the university should inform their employees and students regarding their energy policies.

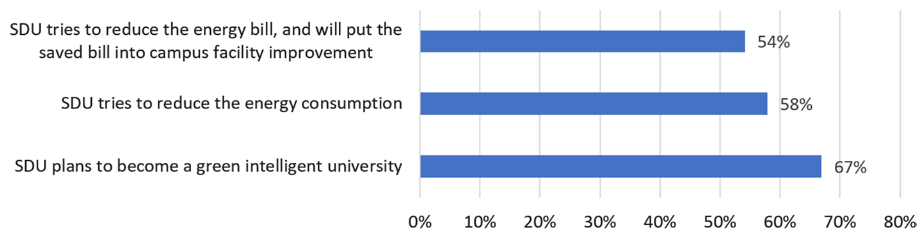

Fig. 5 Students' motivation for accepting frequent indoor quality changes

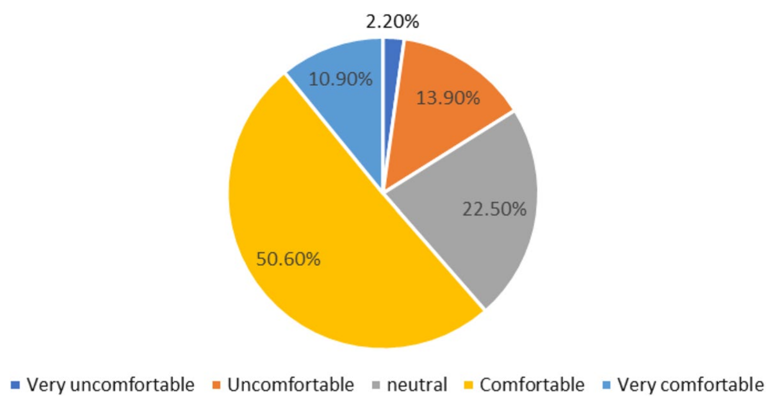

Fig. 6 Students' opinions on indoor comfort in classrooms

Occupants' preferences on students' motivation for the acceptance of energy flexibility in campus buildings

According to Fig. 5, more than half of surveyed students believe 'University plans to become a green intelligent university', 'University tries to reduce the energy consumption', 'University tries to reduce the energy bill, and will put the saved bill into campus facility improvement' can motivate students to accept frequent indoor quality changes. Meanwhile, the image of 'green intelligent university' is the most popular motivation for students to accept frequent indoor quality changes. Comparatively, financial benefits to the university or students (reducing energy consumption, or saving energy bills to invest more in on-campus facility improvement) are less attractive for surveyed students.

Indoor comfort

Opinions on indoor comfort in classrooms

61.5% (comfortable or very comfortable) surveyed students are satisfied with the comfort level in the classrooms (shown in Fig. 6). Meanwhile, the surveyed students are satisfied with the current energy control on campus, and they think that the building system (e.g., shade adjustments) on campus does not disrupt their work. Although some surveyed students think that automatic light adjustment affects their concentration and work, many students still believe the automatic light adjustment is acceptable for their studies. However, female students have statistically significant less satisfied compared to male students regarding light distribution ($U = 55{,}055$, $p = 0.034$). Surveyed students slightly disagree that the rooms and campus, in general, are well ventilated.

Occupants' preferences on frequent changes in indoor comfort

On average, surveyed students do not agree (the section is 'maybe not' in the questionnaire) either to change the classroom temperature or ventilation frequently. Meanwhile, surveyed students slightly disagree with adjusting lighting frequently in classrooms, but on average, they remain neutral. However, female students significantly disagree with the frequent lighting changes ($U = 4618.5$, $p = 0.004$). The surveyed students believe the frequent changes in indoor comfort in classrooms can influence teaching and learning performance (test value = 4 (maybe), ($t(266) = 3.5$, $p = 0.001$)).

Occupants' preferences on locations of indoor comfort can be frequently changed

Hallways and canteens are the top two places the surveyed students choose and believe can be adjusted frequently and not influence students' activities (shown in Fig. 7). Other areas, such as classrooms, auditoriums, labs, group rooms, and offices, are not positive for students to accept the frequent changes in temperature, light or ventilation. The surveyed students think lighting can be frequently changed compared to temperature and ventilation in hallway and canteen. However, it is the opposite when the situation refers to other locations, e.g., classrooms.

Building control system

Awareness of control systems installed in classrooms

The surveyed result (in Fig. 8) shows that, on average, the surveyed students are fully aware of the control systems installed in classrooms and their control options. For instance, the heating settings in classrooms are centrally controlled by the energy department in the university, and 63.74% of surveyed students are aware. Meanwhile, 80.5% of students are aware that there is no cooling thermostat installed in the class.

Opinions on energy control in classrooms

95.5% of surveyed occupants believe that they have full or partial control over lighting, but 61.8% and 63.7% of surveyed occupants believe that they have no control over cooling or heating (Fig. 9). On average, compared to male students, female students believe that they have less control over lighting ($U = 4471$, $p \leq 0.0005$), cooling ($U = 5147$, $p < 0.05$), and heating ($U = 5147$, $p < 0.005$). Nevertheless, the surveyed students don't

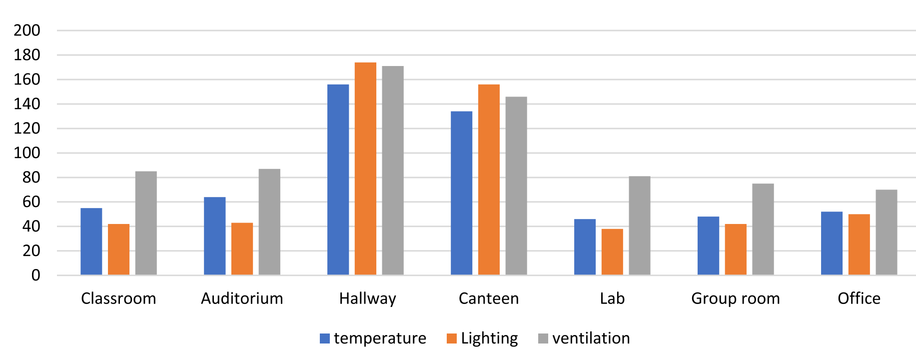

Fig. 7 locations on campus that surveyed students agree to change the indoor climate frequently

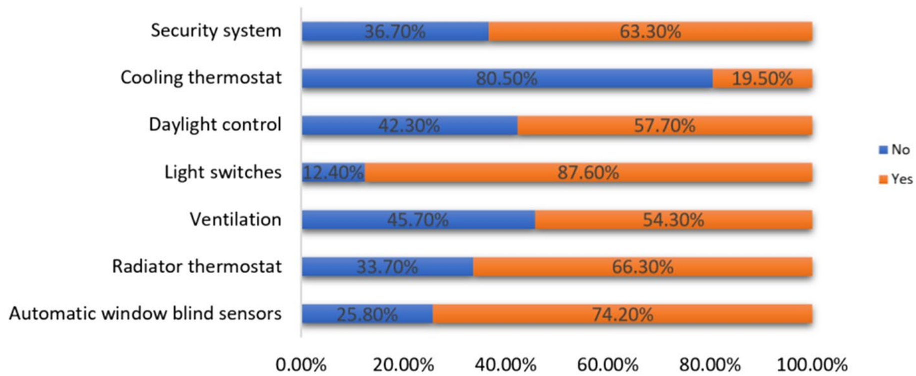

Fig. 8 Awareness of control system installed in classrooms

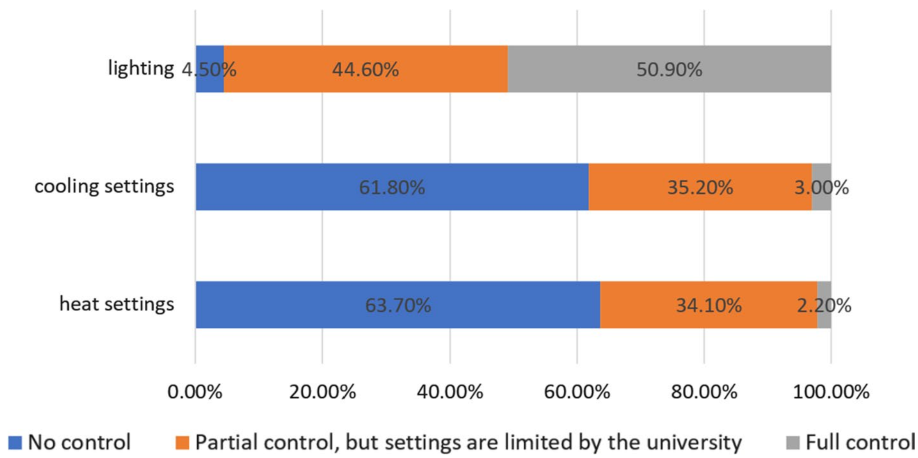

Fig. 9 Students' opinions on indoor climate control in classrooms

think the building control systems significantly disrupt their work ($t(266) = -3.50.$, $p = 0.001$).

Regarding lighting, surveyed occupants think the quality of the lighting is sufficient ($t(266) = 9.44$, $p \leq 0.0005$), and the light is well distributed to all corners of the room ($t(266) = 8.80$, $p \leq 0.0005$), although female students less agree ($U = 55{,}055$, $p \leq 0.05$). Meanwhile, the automatic light adjustment seems like has no significant affect on students' concentration and work ($t(266) = -1.38$, $p = 0.169$). Compared to lighting, surveyed occupants are more sensitive to indoor temperature, that they believe too high or too low temperatures significantly affect their concentration and work ($t(266) = 12.05$, $p \leq 0.0005$), and the temperature changes should depend on locations on campus ($t(266) = 9.99$, $p \leq 0.0005$). One reason is might because the surveyed students don't think the classrooms on campus are well ventilated ($t(266) = -1.96$, $p = 0.051$) since some buildings are old and don't comply with the new building codes.

Distributed energy resources

Occupants' awareness of distributed energy resources on campus

The surveyed result shows (Fig. 10) that only a few students (35%) know there are solar panels installed on campuses, and due to the invisibility of the installed solar panels (on

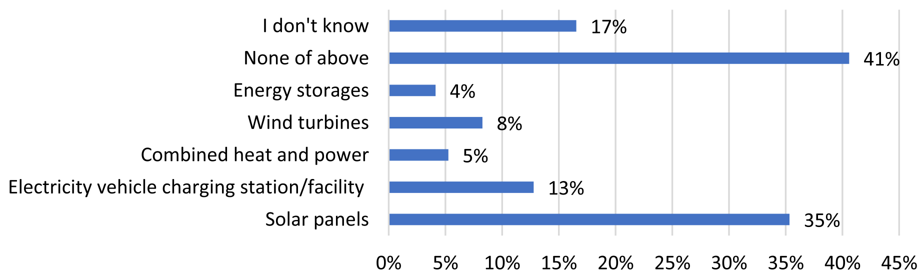

Fig. 10 Occupants' awareness of solar panels installed on campus

the roof) without notice by the university, students do not know the installation of solar panels on campuses. Meanwhile, few surveyed students believe there are other distributed energy resources installed on campuses, although they don't see them. In fact, there are only solar panels installed on campuses so far.

Occupants' preferences on the investment of distributed energy resources on campus

The surveyed students believe that the university should invest in solar panels ($t(266) = 8.78$, $p \leq 0.0005$) and energy storage ($t(266) = 2.586$, $p \leq 0.01$), and they have the neutral option or slightly disagree to invest on electric vehicle charging station/facility ($t(266) = 0.738$, $p = 0.461$) or wind turbines ($t(266) = -1.24$, $p = 0.217$). Meanwhile, they are negative on the investment of combined heat and power ($t(266) = -2.59$, $p \leq 0.01$). 40.8% of survey students believe noises from wind turbines affect their concentration, and 36% believe not. There is no statistically significant relationship between the results and the gender, with two degrees of freedom = 2.10, $p = 0.35$. On average, surveyed students do not think the availability of electric vehicle charging on campus affects their choice of driving electrical cars ($t(266) = -2.21$, $p = 0.028$).

Discussion

The survey analysis results show that the university students are aware of the energy control in the campus buildings, and they are satisfied with the indoor comfort, although they believe that they have little control over heating and cooling in the classrooms. However, the university students cannot tolerate the frequent indoor comfort changes, including temperature, lighting, and ventilation, and think only the indoor comfort of the hallway and canteen can be adjusted frequently and will not influence their study activities. It means that the current building management on campus is averagely acceptable by the university students, and the energy flexibility strategies that significantly change the current state of the indoor comfort in study activities related locations are not recommended.

However, the university students have a positive opinion regarding the university's energy policies and performance, especially compared to other organizations in the same city, and they believe the university plan for a green image and energy saving can improve occupants' acceptance rate of frequent indoor comfort changes. Therefore, it is necessary to consider proper rhetoric for the energy-related research and strategies (e.g., questionnaire design, and communication to occupants), and energy-related strategies and communication should be direct and visible to everyone.

The result regarding the energy-related knowledge also proves the above statement that popular terms in the energy domain, e.g., global warming, are well known by the university students, but not the more professional energy-related terms, e.g., energy flexibility. Regarding renewable distributed energy resources, the university students have not much awareness of solar panels installed on the roofs of several university buildings. Based on the survey result of the energy-related knowledge, although the majority of the university students believe the investment of solar panels and energy storage are feasible but not combined heat and power, it does not indicate they fully understand the economic-technic feasibility of the renewable distributed energy resources.

Conclusion and usage notes

There are two main reasons that the questionnaire was sent to the engineering faculty only: (1) in the selected university, only the engineering faculty has a separated classroom building with project rooms, and other faculties are mainly located together in the connected main building. The majority of the students at the engineering faculty have experience in both older classroom buildings, the main building and the newly built engineering building, but not students from other faculties. (2) The students at the engineering faculty expected to know more about the energy systems and control since the educational programs are technically oriented, and many have related courses. Therefore, their response is expected to represent the above-average knowledge compared to students from other faculties.

However, as shown in the methodology section, gender unbalance is a typical phenomenon in an engineering faculty, and it cannot represent the overall university students. Meanwhile, the engineering faculties in Danish universities usually include three years bachelor programs, two years of master programs, and often include 3.5 years of diploma programs. Therefore, the respondent backgrounds shown in Table 1 do not represent general engineering faculties in other countries.

The data is available in .xlsx format. The questionnaire used to collect the data is also provided together with the data to facilitate ease of understanding of the data. The questionnaire and response dataset are available as Additional files 1, 2 and on Figshare via Journal Energy informatics.

Abbreviations

IEA	International Energy Agency
EBC	Energy in Building and Communities Programme
EMS	Energy Management System

Supplementary Information

The online version contains supplementary material available at https://doi.org/10.1186/s42162-022-00239-y.

Additional file 1: Questionnaire.

Additional file 2: Questionnaire response dataset.

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Author contributions
ZM developed, distributed and collected the survey. ZM conducted the manuscript writing. All authors read and approved the final manuscript.

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Availability of data and materials
The questionnaire and response dataset are available as Additional files 1, 2 and on Figshare via Journal Energy informatics.

Declarations

Ethics approval and consent to participate
Not applicable.

Consent for publication
Not applicable.

Competing interests
The authors declare that they have no competing interests.

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