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Article

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Does every hotel room need a minifridge? Empirical evidence from consumer self-reports and an automatic sensor-based system measuring electricity consumption and guest use

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ABSTRACT

Most hotel rooms contain a minifridge. Manufacturing, operating, and disposing of minifridges is environmentally unsustainable, and costs money. Given the potential to reduce carbon emissions by reducing the number of hotel minifridges, we ask whether it is necessary to provide minifridges in each room. We collect (1) electricity consumption and guest use data for 19 minifridges across four hotels using a newly developed automatic monitoring system, and (2) survey data to gain insights into hotel guests' stated preferences. Results indicate that electricity use is independent of minifridge use and that only a subset of hotel guests use the minifridge. Most guests prefer having a minifridge, but do not react negatively to it not being available. It may be worth reviewing the current default inclusion of minifridges and considering alternative minifridge provision systems.

1. Introduction

The substantial environmental cost of tourism activity is universally acknowledged: "In a 'business-as-usual' scenario, tourism would generate through 2050 an increase of 154% in energy consumption, 131% in greenhouse gas emissions, 152% in water consumption and 251% in solid waste disposal. This is why sustainability must now define tourism development in the 21st century" (UNWTO, 2024).

The urgent need to transform the tourism sector to become more environmentally sustainable is reflected in target 12.b of the United Nations Sustainable Development Goals, which calls for nations to "develop and implement tools to monitor sustainable development impacts for sustainable tourism" (United Nations, 2023). In most businesses that have committed to monitoring their environmental performance, data is still entered manually. This is a labour-intensive process that is prone to human error. Automatic systems that capture continuously and without the need for human intervention the environmental performance of tourism businesses remain rare and include: systems that can be used to estimate water use in hotel showers (Pereira-Doel, Font, Wyles & Pereira-Moliner, 2019; Tiefenbeck, Wörner, Schöb, Fleisch & Staake, 2019), a plate waste measurement system that captures how much uneaten food was left behind by people in a dining room and how many people entered the dining room to automatically

calculate plate waste per person per day (Dolnicar, Gray, Grün, Li, & Portmann, 2023) and a system that can automatically capture electricity use by room heaters plugged into a power point (Dolnicar et al., 2023). Additionally, commercial products are available for aspects of sustainable operations that promise substantial cost savings, such as food waste generated in kitchens (e.g., Winnow, 2023). The present study adds one more such automatic measurement system to this toolbox and presents – for the first time – empirical data relating to minifridge electricity consumption in hotel rooms and the use of minifridges by hotel guests.

The overarching aim of this study is to determine whether reducing the number of minifridges provided by hotels is a viable approach to making hotel operations more environmentally sustainable without risking consumer backlash. Specifically, the aims of this study are (1) to introduce an automatic measurement system for capturing, simultaneously, the electricity consumption of hotel fridges and the use of hotel minifridges by hotel guests, (2) to use this system for the collection of empirical data on both energy consumption and use, and (3) to provide information on the importance tourists assign to having a minifridge at their tourist accommodation.

If tourists (or segments of tourists) do not view minifridges as important and energy consumption is substantial, alongside the CO₂ emissions caused by producing the device and the waste generated by disposing of it, accommodation providers could consider alternative

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service provision approaches. This study draws attention to the amount of electricity used by routinely providing minibridges in tourist accommodation (even when rooms are not occupied) and points to substantial variation in tourist appreciation of these devices across segments. As a result of this empirical analysis, tourist accommodation providers could rethink the need to routinely provide minibridges in every room, instead designing more customised guest packages where people who do not require a minibridge are checked into – possibly slightly discounted – rooms without such devices. Such an approach has the potential to reduce the burden of the tourism industry on the environment without reducing guest satisfaction.

2. Literature review

Hotels, motels, and other lodging options have the largest negative environmental impact of all sectors of the tourism industry. Every year, the average five-star hotel generates between 160 and 200 kg of CO₂ per square meter of hotel room space (Sharma, 2023). Environmental sustainability, therefore, has become a priority for hotels. Prioritising sustainability also benefits hotels financially because they can benefit from reduced water, waste disposal, food-purchase, and electricity costs. Hotels can conserve energy by attempting to alter guest behaviour or through technological solutions, such as by replacing old devices with more energy efficient ones (Teng, Horng, Hu, Chien and Shen, 2012). In terms of attempts to alter guest behaviour, a hotel could, for example, give guests incentives for saving energy (Dolnicar, Knezevic Cvelbar, & Grün, 2019) or penalise them for using too much (meta-analysis; Greene, Demeter, & Dolnicar, 2023). Air conditioning accounts for almost 40% of a building's electricity use (Jiang et al., 2020), while some interventions aimed at prompting hotel guests to set the room thermostat to an economical temperature have been effective (Idahosa & Akotey, 2021), it has proven nearly impossible to prompt guests to switch off the air conditioner completely at any point during their stay, especially at very hot or very cold geographical locations. The alternative – removing air conditioners altogether – would not be acceptable from a guest satisfaction point of view, leaving little improvement potential in terms of air conditioning.

Minibridges also account for a significant proportion of electricity use in hotels; they operate continuously, irrespective of guest use. Historically, minibridges accounted for up to 10 % of the electricity use of a hotel (HORESTA, 2005). In 2004, there were between 50,000 and 60,000 of them operating in Switzerland alone, “resulting in an electricity consumption of about 24 GWh/a and electricity cost of about 4.8 Mio. CHF/a. Additional electricity consumption for air conditioning due to the minibar waste heat is not yet included in these figures” (Nipkow, Busch, Herzog, Paris, & Perincioli, 2004). According to a more recent estimate, operating one hotel minibridge costs about 30 Euros a year, with older models costing as much as 76 Euros. In a hotel with 250 rooms this equates to an annual cost of some 20,000 Euros (von Petersdorff-Campen, 2022).

The academic literature offers little insight into the negative environmental consequences of routinely providing minibridges in guest rooms at tourist accommodations. Most work on the energy consumption of minibridges has been conducted for government agencies (e.g., Brueniger, 2004, 2005; Nipkow et al., 2004) or takes the form of case studies of refurbishments at individual hotels (e.g., Adams, Ives, & Junglas, 2012). Instead, research attention has primarily been directed towards investigating the value tourists derive from having access to a minibridge in their room. This body of work has identified meaningful differences in value derived across tourist market segments. For example: Business travellers value a minibridge with free beer and wine substantially more than leisure travellers (Masiero, Heo, & Pan, 2015). In contrast, for the market segment of backpackers, the availability of a minibridge ranks last on a list of important accommodation features (Albattat & Amer, 2016). Not only does the importance of the minibridge vary across tourist segments, it appears that the importance has also

dropped over time. Even before COVID, when minibridges were temporarily perceived as a contamination risk (Sampson, 2022), a TripAdvisor study concluded that they were the least important hotel amenity with only 21% of study participants indicating that it is important to them (Ola, 2019).

Yet, tourism accommodation providers are hesitant to remove minibridges, possibly because some hotel franchise chains and some star grading systems prescribe the need for a fridge to be in a hotel room (e.g., UTracks, 2023), and because – at least historically – having a minibridge enabled a hotel to charge a higher room rate (e.g., Schamel, 2012). For small and medium sized hotels in Croatia, for example, the minibridge was seen as one of the core attributes that allowed accommodation providers to charge more for the room (Mandić & Jurun, 2018). This finding is confirmed by a study investigating hotels located in Stockholm, where the minibridge was among the hotel features that show a significant association with higher room rates (Kefela, 2014). There is also the idea that energy can be saved by removing minibridges from individual rooms and replacing them with shared amenities areas at the hotel or floor level (Sharma, 2023). Again, this might force hoteliers to charge less for rooms, and especially for upmarket hotels a shared amenity area would not reflect their intended image.

More recently, there appears to be a trend away from stocked minibridges, possibly because the sales revenue is insufficient to cover the additional staff cost associated with managing them (Gebicki, 2017; Sampson, 2022). COVID has provided further arguments against minibridges because of the need to minimize the time cleaning staff spends in guest rooms (Sampson, 2022). Yet, despite all these developments, minibridges in tourist accommodation still represent the norm.

3. Method

We adopted a mixed-methods approach involving a survey study in which we investigated self-reported demand for minibridges in tourist accommodation across different tourist segments. Additionally, we pioneer wireless sensor technology to measure the actual electricity use of 19 minibridges in four hotels. This is necessary because the electricity use reported for new fridges, which is used to assign an energy star rating, is measured under standardised laboratory conditions. In hotels, however, many factors impact electricity use, including room temperature. Room temperature is influenced by room orientation (north versus south), the size of windows, the type of curtains or blinds, heater and air conditioner use by hotel guests, and outdoor temperature. Two of the hotels where we conducted the measurements are located in Tasmania, which has a cool temperate climate, with the other two located in Southeast Queensland, which has a subtropical climate. Three hotels provide midrange accommodation and have unstocked minibridges in guest rooms. In the midrange hotels, the model of the minibridge installed differs from room to room. The fourth hotel is upmarket and offers a stocked minibridge.

We acknowledge that 19 minibridges are a relatively small sample, but note that it is neither the aim of this study to provide generalisable results about minibridge electricity consumption and guest use, nor is it our aim to make statements about both these aspects for heterogeneous subsets of hotels or tourist market segments. Rather, we aim to determine whether reducing the number of minibridges provided in hotel rooms is, in principle, a viable approach hotels could adopt to operate in more sustainable ways and save money without undermining guest satisfaction. The sample of 19 minibridges is sufficient to provide insights about the potential for such an approach.

In addition to measuring electricity, we also use wireless sensor technology to measure how often and when the door of the minibridge has been opened. This is an objective measure of use, once corrected for opening the door by cleaners once a day. All sensor measurements were approved by the university's ethics committee (2022/HE000566). We report data collected between 4th April 2023 and 27th July 2023.

3.1. The automatic, continuous measurement system

The minifridges in the hotel rooms are equipped with two types of sensors. The first sensor is a smart power plug (Netvox R809A) which measures electricity, specifically the cumulative energy consumption in kWh, with a measurement accuracy of $\pm 3\%$. This sensor is plugged into the power point located behind the minifridge. The electrical cord of the minifridge is then plugged into the sensor. In this application, we use the power point sensor only to collect data on electricity consumption. The sensor has the ability, however, to also be sent instructions, thus enabling remote control of the minifridge, if required. This function was harvested in an experiment that aimed at reducing room heater electricity use in a residential student college (Dolnicar et al., 2023).

The second sensor is a smart magnetic contact switch (Milesight WS301), which detects the opening and closing events of the minifridge door and reports them in real-time with a time-stamp of one-second resolution. The sensor consists of two parts. Both parts have sticky tape on them, allowing simple installation on the minifridge. In the case of the hotel minifridges in this study, we glued the opening sensors under the fridge – one part at the bottom side of the door, the other part opposite that location under the main body of the fridge. The sensor sends a signal when the two parts are separated, indicating that the door has been opened.

All sensor data is transmitted wirelessly and securely via a LoRaWAN IoT (Internet of Things) network (Haxhibeqiri, De Poorter, Moerman, & Hoebeke, 2018). LoRaWAN, in contrast to other wireless networks such as WiFi, has very low power consumption, resulting in a very long sensor battery life of multiple years on a single charge. Furthermore, LoRaWAN's Chirp Spread Spectrum modulation technique achieves a high communication range, which allowed us to provide sufficient coverage for all sensors in one hotel with the deployment of a single LoRaWAN gateway (access point). To complete the setup of our LoRaWAN system, we further deployed our own cloud-based Network and Application Server, hosted on Amazon Web Services (AWS).

The sensor data, after its transmission via LoRaWAN, is stored and processed on our cloud-based database and data analytics platform, which we implemented using the Elasticsearch database (Gormley & Tong, 2015), and our own custom software implemented in the Python programming language. From this data, we calculate relevant metrics for each individual minifridge, in particular the cumulative daily energy consumption and the daily number of door open/close events.

3.2. Survey study

The survey data complements the objective physical measurements obtained from sensors. Survey data is required because sensors cannot measure latent psychological constructs, such as the importance people attach to having a minifridge in the room or if they use the minifridge, what purposes they use it for (e.g., storing medication, storing baby milk, storing food for personal consumption). We acknowledge that self-reports from survey studies can be affected by a wide range of biases. We have designed the questionnaire in a way to minimize the risk of that occurring (Dolnicar, 2013). We also acknowledge that it would be ideal to collect a survey from the same sample as visited the hotels in the field study. However, this is not feasible because it is becoming increasingly difficult to receive an adequate number of survey responses from guests (Ali, Kim, Ryu, & Donovan, 2021). Further, the hotel managers and owners typically do not wish to burden their guests with surveys.

Four-hundred respondents aged between 21 and 82 ($M_{\text{age}} = 45.10$; $SD = 13.78$) completed a four-minute survey through the Prolific crowdsourcing platform, which has been demonstrated to generate high-quality online survey data, especially in comparison to the commonly used MTurk platform (Peer, Brandimarte, Samat, & Acquisti, 2017; Peer, Rothschild, Gordon, Evernden, & Damer, 2022). Survey participants received £9 per hour (60 pence for four minutes) in compensation for their time for completing the survey, which was

approved by the university's ethics committee (2023/HE001199). Most respondents resided in the UK (97%) with the remaining participants living in Australia. More than half identified as female (58%) with 40% identifying as male and the remainder as non-binary or choosing not to disclose their gender. Most respondents (58%) indicated having an average income; 24% indicated their income was below average.

At the beginning of the survey, respondents imagined the last time they stayed at a hotel. To assist respondents with recalling those memories, they reported how long ago they stayed at the hotel, how many nights they spent at the hotel, what type of hotel it was, what the weather was like outside during their stay, what the purpose of their trip was, and who they travelled with. Respondents then indicated whether the hotel room they stayed at was equipped with a minifridge. If so, they additionally reported if they used this minifridge and for what purpose (e.g., buying snacks, storing their own food, storing medication).

Respondents who reported that their hotel room was equipped with a minifridge, answered the question "How would you feel if there was no minibar or minifridge in the hotel room?" for six negative emotions (annoyed, upset, hostile, dissatisfied, irritated, sad) and two neutral emotions (unphased, unworried). Respondents rated each emotion on a slider scale from 0 (not at all) to 100 (extremely). This rating system was adapted from the Positive Negative Affect Schedule (Watson et al., 1988). Next, respondents saw the following scenario: "Imagine you are staying in a hotel room where there was no minibar or minifridge, but the hotel offers to bring one into your room for free if you needed it. How do you feel about this?" and responded on the same emotions as above. They also indicated if they would, in such a scenario, request a minifridge. Finally, respondents indicated how hygienic they felt hotel minifridges are using a slider scale ranging from 0 (Not hygienic at all) to 100 (Very hygienic) to record their answers. The survey concluded with a few demographic questions on age, gender, country of residence, and income.

4. Results

4.1. Minifridge electricity consumption

Across all four hotels, the average electricity consumption of one minifridge was 539.83 WH per day. The electricity use varies substantially across minifridges, as shown in Fig. 1. One of the benefits of the automatic measurement system we introduce in this article is that minifridges that use more electricity than others (see S-312 and S-307 in Fig. 1) can be identified by hotels and fixed or replaced with more energy-efficient models. This represents a practical benefit beyond the mere environmental performance monitoring and reporting function of the system.

The Pearson correlation coefficient between electricity consumption and door opening events as recorded by the wireless door opening sensor across all minifridges is 0.03 ($P = 0.2454$). This correlation is negligible and is accompanied by a substantial P -value that suggests that the connection between electricity use and door opening, as measured by the wireless door opening sensor, is not significant. This observation is further exemplified in Fig. 2b, which illustrates both the electricity use and door opening activity for one minifridge only.

4.2. Observed guest use of minifridges

Fig. 2a shows, for each minifridge, the distribution of how many times it has been opened. On average, each minifridge is opened 2.005 times a day when corrected for opening by room cleaning staff and 2.67 times when opening by room cleaning staff is counted also. Cleaning staff opening of the minifridge does not increase the number of average openings by 1 because of variations in room occupancy. Variability across fridges is substantial, as illustrated in Fig. 2a: Hotel guests in room N-303 have opened the minifridge most frequently in the monitoring time period, whereas minifridge use as measured by door opening has been very low in rooms L-417, L-617 and S-308. This observation is

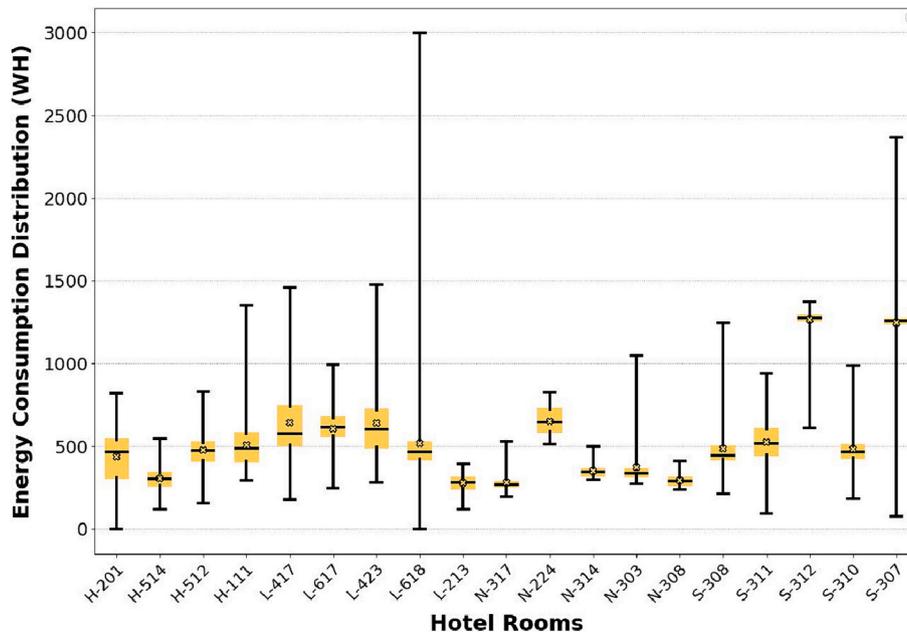
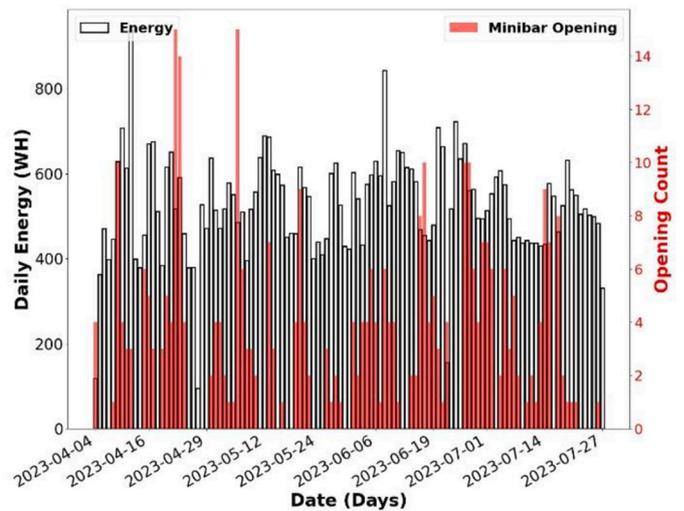
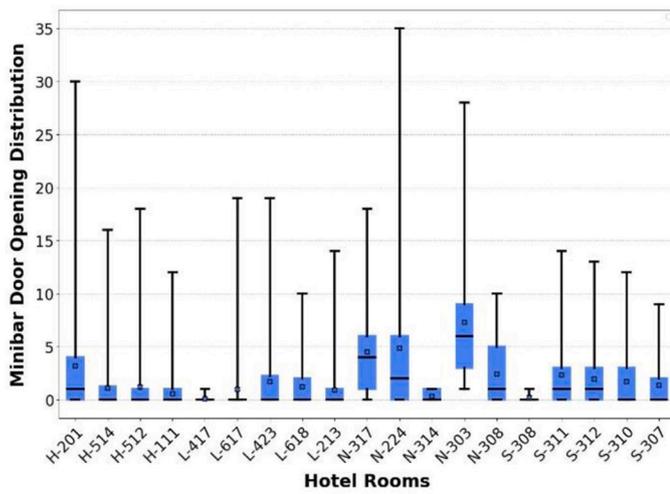


Fig. 1. Electricity use per day per minifridge (April 4th, 2023 to July 27th, 2023).



a. Door opening activity of minifridges.

b. Electricity use and door opening per day for one minifridge.

Fig. 2. Minifridge use and energy consumption.

important because it points to the existence of consumer heterogeneity, suggesting that some hotel guests may highly value having a minifridge, while others may not need it at all.

Fig. 2b integrates, for one single minifridge, the opening count (in red) with the electricity use (in gray). As can be seen, electricity use is relatively independent of how often the minifridge is opened (in line with the correlation analysis presented above). This means that the electricity consumption and the carbon emissions caused are not dependent on the actual guest value derived from the minifridges. Rather, both the cost and environmental impact occur independent of guests appreciating the fact that a minifridge is available to them in their hotel room. This observation, combined with the insight of substantial consumer heterogeneity in terms of the use of the minifridge, calls into question the need to equip every single room in a hotel or motel with a

minifridge.

4.3. Self-reported guest preference for minifridges

The previous section reports objective data measured by wireless sensors. In contrast, the survey study provides insights into consumer preferences. The survey respondents who participated in the survey study reported last staying at a hotel between 0 and 120 months ago, with most (~89%) having stayed at a hotel within the last year. The typical length of their last hotel stay was between three and four days (M = 3.28; SD = 3.92). Most survey respondents stayed at the hotel for leisure purposes (92%) rather than for business (8%). The outside temperature was hot for 35% of participants, cold for 21%, and just right for the remaining 44%. In terms of travel companions, 40% of the survey

respondents reported travelling with their partner, 34% with their family, 13% alone, 11% with friends and 2% with colleagues. Of those who travelled with family, 60% were accompanied by children under the age of 18. The age of the youngest child they were travelling with ranged from 0 to 17 ($M_{age} = 6.77$; $SD = 5.10$).

More than half the survey respondents (61%) reported that their hotel room was equipped with a minifridge. Of those who had a fridge, 59% said it was stocked with items they could purchase and 60% reported using the minifridge. The 60% usage level supports the insights gained from the sensor data that there is substantial heterogeneity in the need for a minifridge being provided in hotel rooms. However, there was no significant difference in reported minifridge use between business travellers (50%) and leisure travellers (61%; Wald difference in proportions = -0.11 ; 95% CI $[-0.33, 0.11]$). Travelling with children was not significantly associated minifridge use either (65% with children, 59% without children; Wald difference in proportions = -0.06 ; 95% CI $[-0.21, 0.10]$). These findings suggest that there is no simple way of predicting – based on socio-demographic information or travel purposes – which hotel guests value the minifridge and which do not. Of those who report using the fridge, 67% use it to store their own food, 10% purchase snacks contained in the minifridge, 18% use it for both these purposes, and 5% for other purposes, such as storing medications, or the complimentary water bottle provided by the hotel.

Among survey respondents who had a minifridge in their room during their last stay at a hotel, reactions to the hotel not providing a minifridge were not very negative (see Fig. 3). The average value (on a 0 to 100 scale) for feeling *annoyed* when realising that the hotel room does not contain a minifridge is 36.09 ($SD = 31.48$), for *upset* 29.46 ($SD = 28.92$), for *hostile* 16.32 ($SD = 22.23$), for *dissatisfied* 39.42 ($SD = 33.95$), for *irritated* 33.87 ($SD = 32.57$) and for *sad* 26.70 ($SD = 29.95$). The standard deviations for these reactions are high, indicating, yet again, substantial variability in guests' emotional reactions.

Of all survey respondents who had a fridge in their room, 57% indicated they would miss the minifridge if it was not provided by the hotel. There was a moderate-strong positive association between using the minifridge on the last stay and missing it if it was not provided ($\chi^2(1) = 56.67$; Cramer's $V = 0.48$, $p < .001$). If minifridges were provided upon request without a surcharge, survey respondents would not, on average, be particularly *annoyed* ($M = 14.81$; $SD = 23.63$), *upset* ($M = 11.89$; $SD = 21.53$), *hostile* ($M = 10.75$; $SD = 20.88$), *dissatisfied* ($M = 19.71$; $SD = 28.22$), *irritated* ($M = 15.31$; $SD = 23.79$) or *sad* ($M = 12.76$;

$SD = 22.89$). In fact, they would be relatively *unphased* ($M = 60.79$; $SD = 36.68$) and *unworried* ($M = 60.78$; $SD = 38.22$) about such a hotel service feature. Only a small proportion of participants (17.5%) indicated that they would ask for the minifridge in this situation. Most would only ask if they needed it (57%) or would not ask at all (25.5%). Survey respondents, on average, did not have particularly strong beliefs as to whether the fridge was hygienic or not with the mean rating at the centre point of the scale ($M = 50.71$; $SD = 22.19$).

5. Discussion and practical implications

While the daily operating cost of one minifridge is relatively low (16.2 cents, in our study on average), cumulatively running one minifridge in each hotel room continuously costs hotels a substantial amount of money and generates a material amount of carbon emissions. Other reports indicate substantially lower consumption (60KWh per year), which still translates in operating only cost of about 30 Euros per annum per fridge, with energy consumption more than doubling as the minifridge ages (von Petersdorff-Campen, 2022).

To illustrate cost and carbon emissions for one of the hotels in our study: assuming that 1 kWh of energy generates 0.5 kg of carbon emissions, one of the hotels involved in this study – a 4.5 star-rated city hotel with 141 guest rooms – generates 13.89 tons of CO₂ emissions annually from operating minifridges in guest rooms alone. The approximate cost for this hotel of running the minifridges amounts to AU \$6659 per year, not including the cost of purchase, maintenance, repair, and disposal (cost savings for the other three hotels are AU\$6817, AU \$2601, and Au\$15,609). If hotel guests demand minifridges in their rooms, it is difficult for hotels to stop providing them. Our data, however, suggest that this may not be the case. Rather, it appears that there is substantial consumer heterogeneity, with some hotel guests needing a minifridge and others not needing it at all. This conclusion emerges from both the analysis of the objective sensor data that counts how often hotel guests opened the minifridge and the survey study, which suggests that just over half of tourists use and value a minifridge. Even among those, this may reflect habit rather than necessity. While our data does not enable us to differentiate between habit and necessity – and tourists, when asked, may not find it easy to actually discriminate between habit and necessity – habit is known to determine 43% of people's behaviours (Wood, Quinn, & Kashy, 2002); it is a construct that has only recently been introduced to tourism research as a potentially strong driver of

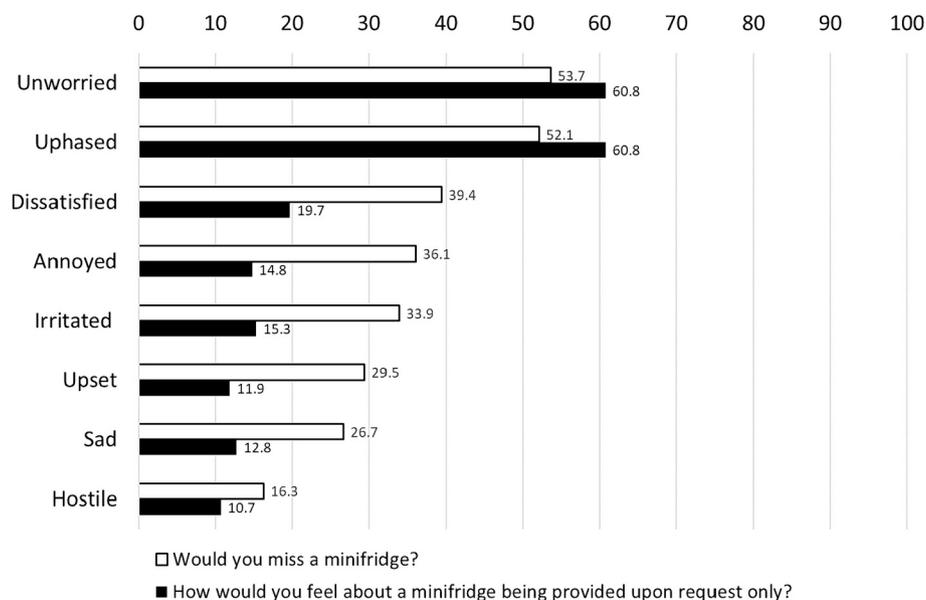


Fig. 3. Average self-reported emotional responses to minifridge not being provided and minifridges being provided only upon request (responses recorded on a 0–100 slider scale).

behaviour (MacInnes, Grün, & Dolnicar, 2021; MacInnes, Ong, & Dolnicar, 2022). Importantly, tourists do not report strong negative emotional reactions when told that there is no minifridge in their room or that is provided upon request only. While this result needs to be interpreted with care given that it is based on self-reported emotional reaction in a hypothetical survey scenario, it nevertheless provides hope for the possibility that hotels could change their operating systems, at least for a subset of their rooms, without facing consumer backlash. Overall, this evidence suggests that it may be unnecessarily expensive and burdensome to the environment to run one minifridge in each hotel room by default. Alternative operating models should be considered.

Several suggestions have already been put forward by von Petersdorff-Campen (2022); they can easily be implemented to avoid running fridges continuously, even if guests do not appreciate it: (1) the deployment of a minifridge robot that can be ordered to come to the room when needed to deliver cold drinks; (2) the use of maxi bars at floor level, which provide access to cold drinks just outside of the hotel room – a concept that is well established in the North American context with ice machines; (3) asking guests at check-in if they require a minifridge and manage room allocations accordingly; (4) offering a movable in-room bar; or (5) introducing digital ordering solutions. Additional approaches could involve: providing snacks and drinks at the hotel bar or reception (Green Travel Blog, 2020); providing what are essentially coolers in the shape of a mini-fridge to fill the void in the hotel cupboard created by removing the minifridge from the room and provide guests – upon request – with ice blocks for cooling; or keeping minifridges turned off, but still available to guests who choose to turn them on. This latter approach is complicated somewhat by the risk of mould developing when the fridge is switched on and off and therefore more suitable for dry climates.

Possibly the most effective action in terms of environmental sustainability, however, might be for policy makers to loosen requirements that exist in some countries, forcing hotels of certain star categories to offer a minifridge in each room. Alternatively, they could put in place rules around which fraction of hotel rooms can be equipped with minifridges. Making this a policy decision takes the pressure off accommodation providers, who can communicate to their guests that they are not permitted to equip each room with a minifridge.

6. Conclusions

This study puts forward a new automatic sensor-based measurement system for capturing – continuously and without the need for manual data entry or correction – the electricity use of minifridges in hotels as well as the number of times the door of a minifridge is opened. This monitoring system is of value to environmental scientists (allowing them to calculate carbon emissions from hotel minifridges), behavioural scientists (allowing them to develop and test in field experiments the effectiveness of behaviour change interventions designed to reduce minifridge electricity use), and hotels, hotel associations, hotel grading systems and policy makers. Findings from this study suggest that hotels, hotel associations, hotel grading systems and policy makers may need to assess whether – in times where climate mitigation is a global priority – providing a minifridge in each hotel room is desirable. Our data suggests that minifridges incur costs and generate carbon emissions at the same level whether they are being used or not. Our door opening data and our survey results suggest that there are distinct market segments of hotel guests; some segments use the minifridge, others do not. Overall, therefore, our observations lead to the question of whether it would be preferable to equip only a subset of rooms in each hotel with minifridges and ask at the point of booking whether guests require a minifridge. This approach would minimize costs for hotels, reduce carbon emissions generated unnecessarily by running minifridges that are not being used, and not undermine hotel guest satisfaction.

The study also showcases the value of the automatic and continuous minifridge consumption and use of measurement systems for monitoring

by environmental scientists, the development and testing of behaviour change interventions by behavioural scientists, and the optimisation of minifridge provision by hotels. The monitoring system could also be used by hotels to identify devices with unusually high electricity consumption for repair or replacement.

The present study has the following limitations: (1) it is based on a relatively small sample of minifridge measurements; (2) it does not capture the full possible heterogeneity across hotel types, hotel locations and guest mix, and (3) it does not use the same hotel guests to obtain the objective physical measurements and the survey findings. The latter is virtually impossible to achieve in today's environment because hotels do not give permission for their guest to be surveyed or interviewed and because the human ethics committee has strict guidelines about the identifiability of respondents. Future work could add valuable empirical insights by (1) equipping a larger set of heterogeneous hotels across more geographical locations with minifridge sensors and, in so doing also capturing a more heterogeneous set of hotel guests, (2) linking guest demographics per room with minifridge use (although we acknowledge that this may be difficult in terms of human ethics approval), (3) investigating empirically the likelihood of hotels to take up alternative models of minifridge provision, and (4) determining the emotional reaction of hotel guests to having no access to a minifridge at actual hotels, which would involve recording the number of complaints because hotels nowadays are rarely open to the idea of their guests being surveyed of interviews.

CRedit authorship contribution statement

Sara Dolnicar: Writing – review & editing, Writing – original draft, Supervision, Resources, Project administration, Methodology, Funding acquisition, Conceptualization. **Danyelle Greene:** Writing – review & editing, Writing – original draft, Project administration, Methodology, Formal analysis, Data curation, Conceptualization. **Siamak Layeghy:** Writing – review & editing, Writing – original draft, Visualization, Software, Investigation, Formal analysis, Data curation. **Marius Portmann:** Writing – review & editing, Writing – original draft, Supervision, Methodology, Funding acquisition, Formal analysis, Data curation, Conceptualization.

Declaration of competing interest

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

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