Transitioning to smart sustainable tourist accommodation: service innovation results

Christopher Warren

Griffith Institute For Tourism

Griffith University, Gold Coast campus, Parklands Drive, QLD 4222 Australia

Susanne Becken

Griffith Institute For Tourism

Griffith University, Gold Coast campus, Parklands Drive, QLD 4222 Australia

Khoi Nguyen

Griffith School of Engineering

Griffith University - Gold Coast Campus, Parklands Drive, QLD 4222 Australia

Rodney Stewart

Griffith School of Engineering

Griffith University - Gold Coast Campus, Parklands Drive, QLD 4222 Australia

Corresponding author is Dr Christopher Warren: christopher.warren2@griffithuni.edu.au

Abstract

This research experiment is the first study to provide detailed insights into resource use by guests staying in self-contained B&B style accommodation. Self-contained accommodation is a neglected yet important sub-industry in the hospitality sector, as it represents the largest and fastest growing share of accommodation providers in many regions. The study provides valuable data from a smart metering system, collecting data every minute over four seasons and indicates sustainable consumption opportunities using renewable energy, guest behaviour change and eco-conservation. Our results reveal that guests, when exposed to sustainability advice and communication (i.e. Intervention Group), saved 27% electricity, 22% gas, 22% water and 10% firewood. Differences between Intervention and Control Groups were also observed in terms of daily peak consumption and seasonal patterns. There are further saving

opportunities, but findings also highlight social practice complexities to navigate guests' individual thermal comfort knowledge and daily routines. Transitions can be achieved through advanced smart services for direct and indirect customer feedback and host training. This paper is the first to detail findings from smart meter monitoring using high resolution at tourist accommodation, providing new insights into social practices and analysis of water energy nexus.

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(7939 words)

1. Introduction

The tourism industry needs to transition to more sustainable social practices as its growth and associated resource use have increasingly detrimental consequences. Tourism is booming with 1.322 million international visitors in 2017 and a growth rate of over seven percent (UNWTO, 2018). Tourism's growth comes with a considerable resource footprint, for example from the travel component but also from tourist accommodation (Becken, 2013; Scott et al., 2008). Indeed, hotels and other types of accommodation can be some of the most energy intensive buildings (Eras et al., 2016), and global carbon emissions from hotels alone amounted to about 150Mt of CO₂ (carbon dioxide) in 2014 (Global Sustainable Tourism Dashboard, 2017). Tourism's energy consumption is forecast to double by 2040 (Gössling and Peeters, 2015).

The accommodation category of self-contained peer-to-peer Bed & Breakfast (B&B) style accommodation has seen particularly strong growth, demonstrated, amongst others, by the rapid rise of platforms like Airbnb with over 200,000,000 members in 65,000 cities (Dolnicar, 2018). In those self-contained types of accommodation, guests have considerable autonomy over management of the 'asset' and facilities, and as a result the level of resource use. However, very little research has been done on this type of accommodation, despite some interest in sustainable accommodation more broadly (Becken and Dolnicar, 2016; Warren and Becken, 2017). Sustainable accommodation relates to "a business which provides overnight facilities for tourists, monitoring environmental, social and economic impacts and takes responsible action to minimise the negative and maximise the positive

impacts, by involving the customers as a partner, to producing a better holiday experience,” (Warren, 2012, p.41).

A recent review of the relevant academic literature highlighted several other major gaps. Warren and Becken (2017) found that there is insufficient guidance on what initiatives different types of accommodation can take to reduce resource consumption, in particular in relation to small scale self-catering accommodation types. Specifically, there was a dearth of studies on the human element of resource saving, both in relation to staff and guest behaviours. The review recommended more interdisciplinary approaches that integrate interactions between buildings and infrastructure, technology, and behaviour for cleaner production, reiterating earlier calls for inter-disciplinary research in sustainable tourism to capture inherent complexities (Budeanu et al., 2016). The lack of socio-technical energy research is not specific to tourism, but has been identified in other fields of practice (Higginson et al., 2014). Social factors are an important missed opportunity because environmental attitudes of managers have been found to significantly affect a firm’s environmental innovation progress (Long et al., 2017). Moreover, research shows that consumers can apply self-control when a product or service elicits a pre-commitment towards sustainability (Thaler, 1980).

Guest behaviour accounts for a significant share of resource use at accommodation and therefore represents a critical element of sustainable tourism. Understanding environmental attitudes of visitors is therefore important (e.g. Brownlee et al., 2014; Juvan and Dolnicar, 2014), but in itself is unlikely to lead to measurable changes. Instead, it is crucial to further our holistic understanding of ‘accommodation as a social practice’. This means that research needs to take into consideration the available amenities, understand the level of guests’ know-how to use such facilities, and place the savings potential into the particular context of the location of the business (Shove, Panzar and Watson, 2012). As argued by Shove et al. (2012),

researching or changing social practices must also consider people's values and emotions, and the meaning they derive from certain activities. The social practices of 'staying at tourist accommodation', involves guests performing a series of routines that include, for example everyday life routines (personal hygiene, eating, sleeping) or extraordinary activities (e.g. ordering room service). A key factor is that these routines occur in unfamiliar places, both in terms of climatic zones but also in relation to specific equipment (e.g. heating) (Warren, Becken and Coghlan, 2016). Understanding visitors' social practices is therefore an important step towards transitioning tourist accommodation towards lower resource consumption. This research posits that providing eco-friendly equipment is equally important as offering guests the advice and know-how to use it.

The main source of energy use in tourist accommodation is electricity, accounting for about 70% of total energy use (Becken et al., 2001; Warren and Becken, 2017). The second most important energy source is gas, which is commonly used for heating water and cooking, and wood as an important fuel in rural areas (Nepal, 2008). In addition to energy use and associated carbon emissions, consumption of other resources is of interest as well. Water, in particular, can be a limited resource in some environments, and through the water energy nexus, carries considerable embodied energy which can be reduced by conservation of water use (Becken and McLennan, 2017; Lam, et al., 2017). There is considerable resource conservation potential in B&B style accommodation, as demonstrated in Australia by DEWHA's (2008) who estimate that household saving potential is substantial, in particular in relation to space heating, appliances, water heating, and space cooling. All of these involve the complexities of social practice in everyday life, but we have yet to understand if such ambitions can be translated into the holiday context (Barr, Shaw and Prillwitz, 2010).

One challenge in influencing guest behaviour is that we cannot see how guests are currently consuming resources 'behind closed doors' (Juvan and Dolnicar, 2016). Since human

behaviour is a critical factor of resource consumption (Nguyen and Aiello, 2013) we need to learn if guests respond to education and skills transfer to adjust their behaviour and, in particular, improve actions related to their thermal comfort and routines. This is because much focus has been given to technological efficiencies in accommodation (Becken, 2013; Warren and Becken, 2017), but little research considers the important role of conserving resources due to behavioural changes (Vidmar, 2010). While eco-efficiencies focus on maintaining the same service experiences but with fewer resources, eco-conservation is the guest's deliberate action to lower their resource use by changing the experience and/or how they use particular technology. Social practices research could positively contribute to eliciting the potential for guests to choose eco-conservation whilst staying at accommodation. Examining the impact of behavioural changes amongst guests requires sophisticated monitoring systems. To capture potentially small reductions in resource use, it is necessary to monitor utilities at a high frequency (Eras et al., 2016). This can be achieved by using intelligent technologies to monitor consumption in 'real time' and provide feedback to both owner and guest at high resolution (Warren, 2018). Thus, the aim of this study is to assess the effects of a persuasive smart service intervention on guests' resource use. This research provides important empirical insights for B&B style businesses that seek to transition towards more sustainable practices and service delivery. This leads to three specific questions:

Q1. Can guests be persuaded to adapt their behaviour to use fewer resources, and are there seasonal differences?

Q2. Do guests modify their daily routines whilst on holiday to comply with the host's request to use fewer resources?

Q3. What is the impact of communication of responsible practices on peak guest demand during their stay?

This research makes several major contributions: a) we present for the first time detailed findings from an innovative smart service system that assesses electricity, gas, firewood and water use at self-catering B&B style accommodation, thus addressing a major knowledge gap (Coles, et al., 2016); b) we generate new insights into social practices that are relevant to self-catering accommodation and identify the need to improve guests competencies; c) we provide data to assess the importance of the water energy nexus, actual savings and alternative energy use in response to particular behavioural interventions; and d) we identify peak demand periods and associated conservation benefits (Lam, et al., 2017).

2. Theoretical background

2.1 Social practices

The theory of social practice seeks to understand how people interact with their environments and how in turn, material and geographic context influence common behaviours. Social practices research is also seeking to design interventions that effectively alter practices towards more sustainable outcomes (Higginson et al., 2014). A social practices approach towards reducing resource use at self-catering accommodation implies that, rather than studying individual decision making, it is the guests' activities and routines (e.g. cooking, washing, heating) that are at the centre of analysis, as these ultimately determine resource use. Higginson et al. (2014) examined how different elements of practices, such as people's skills and competencies, technologies, infrastructures, ideas and meanings, combine and how these can inform energy models for modelling or modifying future demand.

Social practices can be a single practice or a multitude that form a 'block' (Reckwitz, 2002) or a 'network' (Higginson et al., 2017). Transitions may occur when all elements of materials (e.g. building design, equipment), competency (e.g. the host of tourist accommodation to

deliver a particular service) and meaning (e.g. the comfort provided by an open fire) are linked together simultaneously and performed by individuals who are the carriers of the practice (Shove et al., 2012). Innovative changes can occur when practices mesh with new features and resources (Urry, 2011), which is the essence of our inquiry.

The meaning of holiday-related practices is particularly relevant to this research, because the holiday in itself represents a social practice with a high, if not non-negotiable, priority in many people's lives (Kantenbacher et al., 2017). And whilst many tourists claim to have high levels of environmental awareness and concern, the well-researched value-action gap indicates that these are rarely put into practice (Barr et al., 2010). One explanation is that people lack the infrastructure (e.g. recycling facilities at their accommodation) and the skills and know-how to save resources (Warren et al., 2017). Thus, understanding the current practices might help redesign systems towards increased resource conservation.

2.2 Thermal comfort and everyday life

In the past, predictive modelling techniques have been used to determine optimal thermal comfort using steady-state comfort methods of experimental 'climate chambers' (Fanger, 1970). This approach incorporates subjective opinions of comfort by large groups of building occupants as well as air temperature, radiant temperature, air movement, humidity and occupants' activity and clothing. However, over the last twenty years there has been an increasing realisation that 'Adaptive Behaviour' is just as an important factor in energy saving as buildings design and eco-efficient technologies (De Dear et al., 2013). Adaptive behaviour involves occupants i) acclimatising to environment, ii) taking adaptive action, for example opening windows, and iii) adjusting their expectations (psychological) (De Dear, Brager and Cooper, 1997). These types of behavioural adaptation align well with the core elements of social practice theory.

Research shows that individuals apply a complex range of thermal comfort behaviours in their own home (Tweed, Dixon, Hinton and Bickerstaff, 2013) leaving them prone to wanting to apply the same practices to unfamiliar tourist accommodation. However, complex (or unfamiliar) systems can hamper achieving thermal comfort and actually increase resource use as occupants fail to adapt. For example, comparative studies have shown that some occupants opt to run air conditioning for long periods of time when natural ventilation would be more effective (Ambrose and James, 2014). Such excessive heating or cooling behaviour has been found to negate advanced standards of home energy ratings (Ambrose et al., 2013). Adaptive behaviour also changes throughout the year to optimise thermal comfort whilst minimising resource use. Thus, a key concern with self-catering B&B style accommodation is that guests are unaware of their (real time) resource use (Juvan and Dolnicar, 2014) or have not been effectively engaged by hosts who are insufficiently energy literate (Coles et al., 2016).

As is the case for everyday life, new social practices and phenomena (e.g. charging multiple devices) in accommodation add to energy use – often during peak demand periods (Gram-Hanssen, 2013). Usually, people are not aware of escalated energy use, especially when behaviours are socially accepted (e.g. watching television, using appliances) (Ambrose et al., 2013). Changing social practices have also increased water use, for example moving from weekly baths to daily showers (Shove, 2009). On the reverse side, research shows that people can moderate their water use in time of drought conditions (Brownlee, et al., 2014; Lam et al., 2017) and cut their shower use by 27% when informed of their rate of consumption (Stewart et al., 2013). These findings suggest that changes can occur to social practice and daily routines, but we have yet to establish whether guests in holiday accommodation are able and willing to make these changes (Barr et al., 2010).

3. Method

3.1 Case study context

To meet our study's aims we conducted an experiment at a 4.5-star-rated property, purpose-built for accommodating tourists. The B&B style business is located 2 hours south from Sydney, Australia, in a temperate coastal region. There are marked temperature differences between seasons: winter nights reach temperatures below 5 degrees Celsius and summer days reach above 30 degrees. The business has four cottages that provide comprehensive self-catering facilities (see Table 1 for an overview of cottage design/equipment). The accommodation business is marketed to people whose meaning for their holiday is seeking relaxation in a rural setting and who are attracted by the properties' natural surroundings, recreational opportunities for families and interior cottage design. Importantly, despite being eco-certified, the firm does not use its environmental credentials for eco-marketing. Thus, the customer base is not likely to be biased towards environmentally conscious travellers. As well as maintaining its own website, the accommodation is promoted using a variety of on-line travel agents, Airbnb and Stayz.com, which typically promote holiday homes and self-contained style accommodation in this region. Guests can choose their level of interaction with the hosts after check-in.

Table 1

3.2 Data collection

To measure resource consumption at high resolution, all four cottages were monitored using smart meters (Gram-Hanssen, 2013; Stewart, et al., 2013). The sub-meters measure electricity, gas and water through digital metres, and firewood by digital scales. The cottages are all on the same site and use similar star rated appliances, levels of insulation, box pelmets and thermally backed curtains, and collect rainwater, but there are also some differences in

size, building material, internal layout and bath sizes. Two of the cottages are identical in terms of materials and design (Billabong and Jumbuck), but they have different aspects to the sun.

The smart service intervention combined data analysis with communicating responsible practices, both verbally by the host and using a printed information sheet to increase guests' competences to save resources. Those guests selected for the intervention received a personalised welcome by the host when they arrived, where the host provided direct advice in the form of a presentation tour of the building, its pro-environmental amenities and their energy/water consumption. Guests were told that all fiscal savings were donated to two local wildlife charities. This was felt necessary to motivate guests through the alignment of values. The host encouraged guests to apply adaptive behaviours, then delivered a daily sheet by 07:30 am each morning containing feedback on guests' resource use on the previous day, comparing guest party other guests previously, plus advisory tips. No further interaction was formerly applied unless the guests sort additional advice.

Persuasive communications, which included encouraging a pre-commitment, were applied to 114 guest parties (the Intervention Group). An additional 207 guest parties did not receive any communication (Control Group). There were 2.5 guests per group on average. After a guest made a reservation and details of arrival and choice of cottage were recorded, parties were randomly selected to participate in the intervention or to function as a control. The result of this method was that each cottage hosted a random selection of both Intervention and Control Groups. Since cottages are different in design and performance, it was important not to allocate all Intervention participants to the same cottage and all Control guests to another. Since guests arrived and departed on different days an exact allocation between the Intervention and Control Groups was not practical.

Smart meter data were collected every minute, and a spreadsheet for each utility was generated along with information on when the cottages were occupied or not. As a precaution, meters were also manually read at each cottage before and after each guest stay. There were several occasions when the transmitter did not function (cleaners of guests inadvertently using plug sockets, power cuts, wind). This resulted in some sets being removed from the sample so that the final sample for the Intervention Group was N= 114 for electricity and wood and N= 113 for water and gas. The Control sample was N= 207 for electricity and wood, and N= 203 for water and N= 205 for gas.

3.3 Data processing and analysis

Some initial data cleaning was necessary, in particular in relation to firewood, where it was found that minor changes in weight (i.e. <0.01 kg) were recorded, but only reflected changes in moisture content of firewood in response to fluctuating inside temperature. These differences were eliminated. To create a more manageable dataset, all resource use data was aggregated to 15 minute intervals and the delta between intervals was calculated to record consumption in respective unit (e.g. kilo Watt hours or litres). Furthermore, occupancy data were generated based on the assumption that guests checked in at 3pm on day of arrival and checked out at 11am on day of departure. The spreadsheet was amended accordingly with a binary variable (1= occupied; 0= empty). Descriptive and explanatory analysis was undertaken using IBM SPSS statistics 24 program.

Resource use was analysed using ANOVA to compare daily consumption between the intervention and control groups, both over the project duration and by season. Resource consumption data were then analysed to estimate likely water end use, for example for baths, taps or toilet flushes. This involved taking the flow rates and disaggregating the data into discrete water use events involving calculating information like volume and the use of other resources like gas (see Stewart et al., 2013). The following steps were involved: i) identifying

periods of time where gas and water consumption occurred at the same time to derive use of hot versus cold water; ii) considering the volume consumed to attribute hot water usage under 10 litres to hot taps and over 10 litres to baths and showers; iii) attributing cold water use to either toilet, cold tap, cold shower, clothes washer or dishwasher; iv) examining all water events between 11 pm and 6 am to find a typical volume of toilet events and then identify toilet signals across all cold water usage data; v) attribute all remaining cold water events based on their volumes whereby <10 litres would be a cold tap, >30 litres indicates a cold shower/bath, and all remaining events would be 'other'.

4. Results

4.1 Can guests be persuaded to adapt their resource use behaviour?

This research shows that there were significant differences in resource use between the Intervention and Control Groups. Measured across the whole year, the Intervention Group consumed on average 27.4% less electricity than the Control Group (ANOVA: $F=18.294$; $df=1, 316$; $p<0.001$). Moreover, the standard deviation was significantly lower for Intervention Group (Mean 0.11 kWh/p/d and Std. Deviation 0.05), indicating that the Control Group (Mean 0.15 kWh/p/d and Std. Deviation 0.09) included some guests with very high levels of electricity usage. A similar pattern of reduction was observed for water and gas. For water reduction was 21.6% (ANOVA $F=17.463$; $df=1, 314$; $p<0.001$) and Standard Deviations reduced from 1.42 to 0.8 Litres per person per day. Gas consumption also decreased significantly by 22.3% for those guests who received the intervention (ANOVA $F=13.889$; $df=1, 319$; $p<0.001$).

There were also differences in firewood consumption, although data were separated for the cottages, because Rose Cottage is a larger building and has two log fires, whereas the other cottages have similar square meterage and one fire each. The Intervention Group in Rose

consumed on average 10% less firewood than the Control Group (ANOVA: $F=0.184$; $df=1,78$; $p=<.669$), but this difference was not statistically significant. However, in the other three cottages, guests from the Intervention Group consumed 38% less firewood than the Control Group (ANOVA: $F=4.909$; $df=1,239$; $p=<0.028$). The Intervention Group in Rose may have chosen to use both fireplaces to avoid usage of the reverse cycle air conditioner (as recommended by hosts), resulting in a similar amount of firewood being consumed as the Control Group (who used more electricity).

A seasonal comparison of electricity revealed consistently reduced electricity usage by the Intervention Group in spring (35%), summer (21%), autumn (22%) and winter (22%), compared with Control Group (Figure 1). The difference in standard deviations between the groups was most marked in autumn and winter. Spring shows a higher electricity use, which could be due to extended use of reverse cycle air conditioner by the Control Group in the mornings and evenings to keep warm in early spring instead of using firewood, which is more heavily consumed in winter (Figure 2). The log fires (slow burning combustion stoves) require setting and there is a time delay from lighting for the room to heat up. It is therefore possible that the Control Groups sought *quick relief* by turning on the air conditioning system. Likewise on warmer spring days Control Group appeared more likely to have used air-conditioner to cool the cottage, compared with Intervention Group.

Figure 1 here

Not surprisingly, firewood consumption showed marked seasonality with about half of all wood being burned in winter (50.7% for Intervention and 53.2% for the Control Group) (Figure 2). The Intervention Group consumed less firewood overall, but recorded higher firewood use in autumn (3.4 kg/day) than Control guests (2.8 kg/day). This could be a result

of the host engaging with guests to explain how to use the fire effectively and recommending its use over air-conditioning system. Despite the warm temperatures in summer, guests appeared to use the log fires. Possibly, this is explained by a combination of a cool evening after extended hot weather and psychological rewards of enjoying a fire. The hosts have noticed that European expatriates and migrants enjoyed log fires in the Australian summer holidays, which correspond to Northern Hemisphere Christmas period. This appears to have contributed to the Control Group using two thirds of the equivalent autumn fire wood quantity in summer, compared to Intervention Group using equivalent of one third of their autumn firewood in summer.

Figure 2 here

Seasonal gas consumption showed noticeable differences (Figure 3), with the Control Group using more gas in winter and spring and least in summer, while the Intervention Group's consumption appeared more evenly distributed across the year with a dip in summer. Generally, gas consumption was lowest in summer. This is partly explained by the fact that storing water in outside tanks means that in summer the water has to be heated from a much higher base temperature compared with winter. Comparing each season's gas use, the Intervention Group consumed significantly less gas than the Control Group in spring (ANOVA: $F=6.8$; $df=1, 112$; $p<0.010$) and summer (ANOVA: $F=4.3$; $df=1, 91$; $p<0.039$). However, the difference was not statistically significant in winter. These results follow trends for water usage (see below).

Figure 3 here

Water showed similar trends to gas (Figure 4), whereby the Intervention Group's consumption appeared more balanced across the year. Again, the differences between the two groups in spring (ANOVA: $F=9.4$; $df=1, 111$; $p<0.003$) and summer (ANOVA: $F=3.7$; $df=1, 91$; $p<0.055$) were significant, but not in winter (ANOVA: $F=2.9$; $df=1, 60$; $p<0.094$) or autumn (ANOVA: $F=1.5$; $df=1, 48$; $p<0.213$). This could be attributed to Intervention Group switching from bath to shower use thinking they are saving water whilst still consuming resources.

Overall, findings revealed strong seasonality in guest resource use and substantial differences in consumption levels between those guests who received responsible communication advice and were persuaded to conserve and the Control Group. However, there are also complexities within the site, seasonality and the type of guest routine carried out at different times of the year which influence the specific level of savings.

Figure 4 here

4.2 Resource use of daily routines

The second question addressed people's routines while on holiday and whether these could be modified to comply with request to use fewer resources. To examine changes in routines, which form part of social practices, a focus on water was taken because of the opportunity to analyse distinct 'events' of water consumption. This involved taking the flow rates and breaking them down into discreet water use events involving calculating information like volume and the use of gas involving identifying duality of water and gas use times, considering volume of water, attributing cold water use and examining water events during the day. As described earlier, water use patterns were disaggregated into four end use categories, namely bath, shower, toilet and other (combining tapes, dishwasher, laundry). The

samples were split into two groups to reflect the facilities of the cottages and guest type. To test whether there was a significant difference in consumption practices between the one-bedroom and two-bedroom cottages these were differentiated as well. The two-bedroom cottages are often used by small groups or young families who are likely to use more than the couples staying in the one-bedroom cottages. The Intervention and Control Groups were each compared for the two-bedroom cottages (Rose and Fleur) with small baths, and Rose having a second toilet with inbuilt water saving sink/cistern (Table 1). A comparison was also made for on the one-bedroom cottages, Jumbuck and Billabong, with larger baths.

Findings revealed that in both types of cottages, guests' used most water for showering (Figure 5). In the two-bedroom cottages other activities (i.e. dishwasher, laundry, sinks) caused higher water use than bathing. The one-bedroom cottages have larger baths, and bathing accounted for a similar share of water use as other water events. The Intervention Group's routines in the two-bedroom cottages used significantly less water than the Control Group for bathing (ANOVA: $F=9.75$; $df=1, 161$; $p<0.002$) and toilet (ANOVA: $F=6.2$; $df=1, 161$; $p<0.014$), the difference in shower use was only significant at the 10%-level (ANOVA: $F=3.5$; $df=1, 4161$; $p<0.069$) and other water consumption was similar.

The one-bedroom cottages' results were different. The Intervention Group's routines used significantly less water than the Control Group for showering (ANOVA: $F=5.1$; $df=1, 156$; $p<0.025$), other water using routines (ANOVA: $F=4.6$; $df=1, 155$; $p<0.033$) and bath water (at a 10%-level, ANOVA: $F=2.6$; $df=1, 156$; $p<0.103$). There was no difference in toilet use (ANOVA: $F=.06$; $df=1, 156$; $p<0.796$). During the host's familiarisation tour of the one-bedroom cottages it was noted that many female guests indicated they were looking forward to using the large bath. The majority of guest parties accepted the request to take shorter showers to save water. The general water use result could be partly explained by economic

use of the dishwasher and mindful use of taps, as such tips were on occasion integrated into the intervention.

The size of the baths between the two-bedroom and one-bedroom cottages likely accounts for the variation in total bath water consumed per person. The difference in water use for showering would be specifically driven by longer showers as shower fittings and pump pressure across the property are similar. Looking at the consumption of the Control Groups by cottage type suggests that showering routines on holiday may be different for the type of guest group/stay experience. There was a 17% difference between the Control Groups' shower water use, when comparing cottage types, with one-bedroom cottage guests using more water. The Intervention guests in the two-bedroom cottages chose to use considerably less bath water indicating that they may have showered instead. These findings suggest that guests carry out routines in different ways, which affect water use, depending on their holiday type, and they are also prepared to modify them when asked.

Figure 5 here

Similarly to water consumption, it was possible to disaggregate the use of gas. Considering the combined use of gas and water, gas usage was divided into heating for water and gas usage for cooking (the rest of gas usage). Overall one quarter of gas usage was for cooking and three quarters for heating water. As a result, guest activities related to water use were therefore directly reflected in gas consumption. In the one-bedroom cottages, and in line with the reduced water consumption, the Intervention Group used significantly less gas for water heating (ANOVA: $F=4.7$; $df=1, 156$; $p<0.031$), but also for cooking (ANOVA: $F=4.0$; $df=1, 156$; $p<0.046$) compared with the Control Group. A significant reduction in gas for hot water was also observed for the two-bedroom cottages (ANOVA: $F=7.7$; $df=1, 161$;

$p < 0.006$), indicating that guests took shorter showers and used less bath water compared with the Control Group. The routine to prepare meals across the sample in these cottages did not result in a significant saving from the Intervention Group (ANOVA: $F = .96$; $df = 1, 161$; $p < 0.327$) and demonstrates a sustainability challenge for self-contained accommodation.

4.3 Changes in peak demand

Water and electricity were analysed by combining the 15-minute data into hourly segments to provide a 24-hour report from 00:00 (1) to 23:59 (24). Water usage has two distinct demand peaks. Overall the Intervention Group compared to the Control Group used less electricity throughout the day, particularly in the daytime and evening, while water use was lower during the evening peak time. There was a noticeably high level of water use through the very early morning and breakfast time period for both groups, with the Control Group consuming 80 L/p/hr at 07:00 when the Intervention Group consumed 66 L/p/hr (Figure 6). The pattern clearly shows that little water is consumed from midday (check-out is by 11:00) to 14:59 when check-in begins. During these periods guests who are staying multiple days appear generally to not be in their cottages as both the Intervention and Control Group's water use is low. Peak evening demand at 20:00 manifested in the Intervention Group using 102 L/p/hr, 20% less than the Control Group at 128 L/p/hr. Demand then quickly tailed off for both groups.

Figure 6 here

Electricity use was also collated over a 24-hour period to compare hourly consumption by guest for different groups (Figure 7). Electricity-consuming activity increased during early hours of the morning to reach a morning peak at 07:00. Electricity use was low during the day but increased again after 16:00 to reach an evening peak at 20:00 and decrease thereafter.

The Control Group used more electricity throughout the day than the Intervention Group. Their morning peak grew higher to 164 Wh/p/hr at 07:00, which is 20% above the consumption of the Intervention Group. By 11:00, the Intervention Group used only 67 Wh/p/hr; 42% less than the Control Group. Generally cottages appear unoccupied midday to mid-afternoon but Control guests continue to record energy use between 71-88 Wh/p/hr, while the Intervention Group usage was 51-56 Wh/p/hr, close to the base level (refrigerator/freezer). This suggests that some amenities were left on by Control Group when the cottage was unoccupied. All cottages have key tags which cut power to all systems except dishwasher and washing machine. Whilst it is possible that the Control Group's electricity use during day time is explained by running either of these devices, it is more likely that they left the key tag in place to maintain electricity for other equipment, such as air conditioning, light or charging of equipment. The findings suggest that Intervention guests took additional resource saving measures (turning off appliances and lights) when not required, but further research is required to ascertain this.

Figure 7 here

5. Discussion

This research took a multidisciplinary approach to examine the impacts of an innovative smart service intervention on resource consumption delivered at self-contained B&B style accommodation. Our aim was to assess whether guests' social practices transitioned to more sustainable consumption following the provision of eco-friendly amenities, resource conservation advice with feedback, and by aligning host-guest values. This approach built on social practices theory by modifying how guests interacted with their material environment,

how they developed their skills and derived meaning from changing behaviour (Shove et al., 2012). As argued by Higginson et al. (2014), modifying practices and the routines within them, can have significant benefit for energy savings.

The findings suggest that guests who received the intervention did change their practices to achieve more sustainable outcomes. Recognising the limitations inherent in a case study approach, this quasi-experiment provides much needed evidence that innovation in the service sector that specifically addresses all elements of social practices (Urry, 2011) can yield considerable outcomes for sustainable production and consumption. Results reveal that the Intervention Group achieved significant savings across all four seasons and resource types, including during peak daily demand periods. Analysis enabled us to compare water use and gas end uses (shower, bath, toilet, other systems), providing the first example of the resource intensity of practices by guests staying in self-catering B&B style accommodation. We now discuss the significance of the findings in more detail.

5.1 Benefits of smart metering

Compared to reading monthly or quarterly utility bills the smart metering system provides a superior audit method. By undertaking individual cottage monitoring, across four utilities, and four seasons, patterns of consumption were clearly identified providing greater insight and opportunities for sustainable services. Smart metering also enables researchers to monitor and compare guest groups and test interventions scientifically in ‘real world’ situations rather than through modelling (De Dear et al., 2013). This method would be suitable for measuring retrofitting buildings, testing new inventions, measuring carbon reduction or planning renewable energy installations. Since guests will conserve, smart metering can record reduction in resource quantities during the course of the day, identifying reduced peak demand and calculating optimal energy storage requirements.

5.2 Conservation actions and resource use

Tourist accommodations' current reliance on technologies may deliver initial savings but these are likely to be outweighed by the sector's growth (UNWTO, 2018). Our study shows that providing guest-focused eco-technologies, allows tourism firms to break through the 'green ceiling' of pure technology-based approaches. Moving from efficiency towards conservation (e.g. not using air condition but opening the window instead) has added benefits of lower capital expenditure than new technologies, and without the associated manufacturing and disposal impacts. Besides, eco-conservation minimises existing equipment use to increase system durability and may decrease maintenance. Conserving resources thus has much broader carbon reduction benefits.

Guests' behavioural changes involved acclimatising to the local weather and using pro-environmental amenities (windows, ceiling fans, showers). The measurable reduction is a significant finding for tourist accommodation, a service industry built around the traditional hospitality principle of not intruding or inconveniencing guests' comfort (Chathoth et al., 2014). As a result, resource use in accommodation is often high (Eras et al., 2016), and this study challenges the belief that guests cannot be engaged. The importance of identifying new ways of conserving resources in accommodation should not be underestimated because in many destinations tourism accounts for a significant – and often inequitable – share of local consumption (Becken, 2014). For example, San Diego welcomes 34 million visitors (San Diego Tourism Authority, 2018) to a destination of 1.3 million inhabitants (Suburban Stats, 2017) that records one of the most energy intensive water supplies (Lam et al., 2017). Communities that are already facing resource constraints could develop campaigns for visitors to encourage resource use practice based on the principle 'consume like a local'. They can also be encouraged to apply self-control (Thaler, 1980).

The experiment also indicates that guests can accept a wide range of inside temperatures, and there could be further opportunities for daily resource management in hotels beyond Eras et

al.'s (2016) proposition to combine local weather and thermal comfort energy planning and provide a greater level of inside temperature flexibility. However, this should take into consideration individual guests' special needs and tolerances (Warren, et al., 2016).

Providing more flexible temperature ranges instead of fixed room temperatures as is common for many hotels, in addition to comfort-related advice and tools, might address an important issue of guests often sleeping poorly because of uncomfortable inside temperature (Pallesen, et al., 2015) and too complex HVAC systems (De Dear et al., 2013).

Hosts/managers may underestimate the challenge of delivering a comfortable stay in a carbon-constrained world, and they have to develop their own resource literacy (Coles et al., 2016) to build credibility with the guest and have the capacity to deliver helpful advice. The investment hosts make can add to the visitor experience (Budeanu et al., 2016), for example the novelty of combined water efficient toilet basins (several guests were taking photos of this amenity). The value alignment between host and guest within this smart service experiment points to opportunities for a more holistic sustainable consumption which could be extended to other areas of sustainability, for example food waste or transport emissions.

5.3 Modifying routines whilst on holiday

This study allowed us to look 'behind closed doors' at guests' routines and practices. We found that holiday experience and make-up of guest party influence behaviours and resource consumption. For some guests, especially those who chose to cater for themselves, dishwashers, taps and laundry can account for a high share of water and gas usage showing how embedded habits and activities play an important part in resource consumption, even when guests are encouraged to save. The host sought to increase guests' competency, for example by advising them to use right sized utensils for hob size to minimise waste.

However, it is likely that there are still some barriers in shifting existing practices, meaning that eco-efficient technologies continue to play a large role.

Peak demand patterns show that the intervention managed to reduce demand when guests apply their daily routines that they are likely to carry with them from home (e.g. morning hygiene, preparation of breakfast and dinner). The fact that savings were achieved during these periods, indicates that guests chose to moderate consumption at a time when their regular motivations would have been more attuned to consumption. The meaning of ‘conserving’ was motivational and moderated their needs. During the daytime, electricity use also differed significantly between the two groups. Here, the Intervention guests were competent to apply energy saving technologies (key tags and Green Switch) to reduce standby energy use.

5.4 Future research directions

The value of approaching resource saving from a sociological perspective is that it provides new insights into conservation potentials beyond technological solutions of efficiency (Higginson et al., 2014). However, this study provides only the first step, and more research is required to develop and test smart service interventions with a focus on changing social practices. These are likely to differ for different types of accommodation, cultures, and environments. Experiments should also explore the level of education, information and advice required to enable staff and guests to effectively use cleaner production systems. How exposure to such interventions might affect people’s attitudes is another important avenue for future research, one that would deliver evidence on tourism’s potential as a showroom for sustainable innovation. Future research should also consider that the extent to which managers of accommodation are able and willing to innovate is likely to influence not only environmental but also economic performance (Long et al., 2017). So governments and destinations should introduce coordinated regulations and training to stimulate managers’ environmental innovation capabilities. The development of such programs and the evaluation of their effectiveness deserve further research.

6. Conclusion

The smart service intervention successfully persuaded guests to use significantly less electricity, firewood, gas and water during the day and during peak demand periods. Those guests who received the intervention achieved thermal comfort by taking adaptive behaviours using less electricity and firewood. They also adjusted their daily routines using less water and gas for bathing, showers, toilet use and other water amenities. The nature of holiday experience sought by guests affects the areas where water and energy can be saved because practices will have different meanings and motivations for different guest types. Cooking and kitchen routines and their associated consumption were not significantly reduced by the intervention indicating a requirement for further eco-efficient technologies and greater levels of advice. Our results show that it is possible to transition tourist accommodation social practices towards cleaner production by hosts providing the materials, advice and pre-commitment to enable guests to change their practices for eco-conservation benefits.

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Table 1 Cottage facilities for heating/cooling and amenities for daily routines that form part of the wider social practice of staying at tourist accommodation

Features	Name of cottage			
	Rose	Fleur	Jumbuck	Billabong
Bedrooms	2	2	1	1
Wall mounted a/c	1	1	1	1
Wood fires	2	1	1	1
Dual flush toilet	1	1	1	1
Water saving toilet	1	0	0	0
Full kitchen	1	1	1	1
Bath size (L)	120	90	160	160
Separate shower	1	1	1	1
Dishwasher with eco setting	1	1	1	1
Washing machine	1	1	1	1
Size square metres	100	78	69.5	69.5
Max occupancy	5	4	2	2
Fly screens	Yes	Yes	Yes	Yes
Ceiling fans	3	3	2	2
Key tags	Yes	Yes	Yes	Yes
Power Off stand by switch	1	1	1	1

Figure 1. Daily per-person electricity consumption for Intervention and Control groups by season.

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Figure 2 Daily fire wood consumption for Intervention and Control groups by season.

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Figure 3 Daily gas consumption for Intervention and Control groups by season.

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Figure 4. Daily per-person water consumption for Intervention and Control groups by season.

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Figure 5. Daily water consumption per person for one-bedroom and two-bedroom cottage for control and intervention samples.

Figure 6 Hourly per-person water consumption for the Intervention and Control groups.

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Figure 7. Hourly per-person electricity usage for each cottage for Intervention and Control groups.

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Seasonal usage

	Spring	Summer	Autumn	Winter	Overall
Intervention	1.56	1.57	1.64	1.72	1.61
Control	2.41	1.99	2.11	2.23	2.22

Seasonal

	Spring	Summer	Autumn	Winter	Overall
Intervention	4.92	1.22	3.42	9.81	4.50
Control	6.49	1.91	2.80	12.73	5.87

Seasonal usage

	Spring	Summer	Autumn	Winter	Overall
Intervention	0.12	0.09	0.12	0.14	0.12
Control	0.16	0.12	0.13	0.16	0.15

Seasonal usage

	Spring	Summer	Autumn	Winter	Overall
Intervention	111.1	113.5	112.0	109.2	111.6
Control	149.4	140.8	128.3	141.2	142.5

	Bath	Shower	Other	Toilet	Av Total Water	
2 Bed Interven	14.9	42.2	42.2	37.2	4.9	99.2
2 Bed Control	28	49.7	39.1	6.3		123.1
1 Bed Interven	35.2	48	35	9.4		127.6
1 Bed Control	48.4	59.9	41.4	9.4		159.1

Total	Intervention	26	35	47	66	65	58	66	51	37	19	14	9	4	3	7	7	23	55	106	102	46	24	18	13
	Control	25	26	55	72	63	48	81	73	46	20	10	4	1	2	4	9	23	73	111	129	51	23	15	22

Total	Interventio	96	95	105	122	132	134	132	119	101	93	68	62	57	53	51	51	64	93	141	150	91	60	51	47	90
	Control	107	115	129	134	149	152	164	160	140	126	117	108	89	71	73	72	97	139	193	229	114	95	83	92	123

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Transitioning to smart sustainable tourist accommodation: Service innovation results

Christopher Warren, Susanne Becken, Khoi Nguyen, Rodney Stewart

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