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DEMAND MANAGEMENT & BUILDING OCCUPANT RESPONSE TO CHANGES IN HEATING AND COOLING

Final report of research trials for the Monash University Microgrid

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EXECUTIVE SUMMARY 4
INTRODUCTION 6
Why focus on heating and cooling systems? 7
Communication as a component of Demand management 7
FIELD TRIALS 9
Trial approach 9
Study 1: The impacts of different HVAC strategies on occupant response 9
Study 2: The effectiveness of communication on HVAC changes 10
Study measures 13
RESULTS: GENERAL FINDINGS 14
Occupant survey 14
Faculty Service Manager survey 15
BEIMS (Pulse report) requests/complaints 16
RESULTS STUDY 1: IMPACTS OF DIFFERENT HVAC STRATEGIES 17
Occupant survey 17
RESULTS STUDY 2: EFFECTIVENESS OF COMMUNICATION 22
occupant survey 22
CONCLUSION & RECOMMENDATIONS 23
General findings 23
Impacts of different HVAC strategies 24
Effectiveness of using communication to building occupants 24
Limitations and key considerations 25
REFERENCES 26
APPENDIX A 27
Communication / posters 27
APPENDIX B 28
Example of building occupant survey 28
APPENDIX C 34
Example of Faculty Service Manager survey 34
APPENDIX D 37
Building 82: New Horizons building 37
Building 94: Woodside building 40
Building 92: Learning & teaching building 43

Demand management and building occupant response to changes in heating and cooling - Final report of research trials for the Monash University microgrid

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Declarations of Conflict of Interest

The authors have no conflicts to declare.

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EXECUTIVE SUMMARY

This report describes research that has been conducted for the Monash Buildings and Property Division with support received from the Victorian Government's Microgrid Demonstration Initiative. BehaviourWorks Australia undertook a field trial with the aim of gaining a better understanding of occupants' experience of potential alterations to the control of building heating and cooling systems and their behavioural response under microgrid test conditions.

Research objective

Our aim is to provide guidance on how to engage with users with regards to possible alterations to HVAC control during microgrid operation and support the development of the on-site microgrid at Monash University's Clayton campus. Findings will assist the Monash Buildings and Property Division with managing both building user comfort and energy demand optimally to maximize the benefits of the Monash Microgrid by understanding the flexibility in demand response, while ensuring customer satisfaction.

Trial approach

A field trial was undertaken in the period of 10 May – 6 June in conjunction with techno-economic analysis work investigating building occupants' experience of air temperature changes resulting from slight alterations of HVAC temperature settings across eight selected buildings on Monash University's Clayton campus.

Two sub-studies were conducted investigating different research question.

- Study 1 used a quasi-experimental design across half of the eight buildings included in this trial, to test the impact of two different HVAC strategies – widening of upper and lower temperature settings (dead bands) by up to 2°C, and pre-heating or pre-cooling buildings in advance of the normal heating and cooling requirements – on occupant response.
- Study 2 explored the effectiveness of on-site communication with occupants via posters displayed across four of the eight selected buildings in terms of reach and exposure to poster content.

Summary of key findings and recommendations

1. **There were no notable differences in building occupants' average self-reported thermal comfort levels before and during the trial period.**
   Results indicate that the tested changes to HVAC operation did not make occupants more uncomfortable. Both before and during the trial period around 2/3 of occupants' report that they feel "comfortable" or "comfortably cold or warm", while around 1/3 of occupants' stating they felt "too cold or warm" or "much too cold or warm".

2. **On average, there were no observable differences in how willing occupants are to accept the temperatures they experienced during the trial period (i.e. with slightly altered HVAC settings) in comparison to those experienced under the current standard.**

3. **There was no noticeable behavioural response from building occupants.**
   Both before and during the trial period the large majority of occupants was engaging in self-regulation behaviours to maintain comfort.

Recommendation 1: The tested HVAC control strategies can be applied across Monash campus as an appropriate strategy for dynamic control during peak times to allow for greater flexibility and maximize the benefits of the microgrid. Implementation of a broader scheme, however, should best be accompanied by close monitoring of temperatures and/or lodged requests at least in early stages. This will allow to quickly detect unforeseen irregularities or differences between buildings (or areas within buildings) and respond pro-actively to ensure appropriate engagement with occupants. We recommend this particularly given the fairly high proportion of occupants indicating that they were experiencing discomfort before (as well as during) the intervention and qualitative insights that suggested variability between and within buildings.

4. **There was a significant difference in the trends of comfort between the two tested treatments (HVAC strategies: widening of temperature dead bands vs. pre-heating/pre-cooling of buildings) over time.**
   Results suggest that occupants in the widen dead band condition tended to experience greater discomfort over time, while occupants in the pre-heating condition tended to experience less discomfort over time.

   Recommendation 2: While both tested HVAC strategies are appropriate, a strategy using pre-heating or pre-cooling buildings may be slightly more appropriate than widening of dead bands and is worth investigating further. However, due to the small number of buildings in each treatment condition and that fact that buildings vary on a large number of parameters (e.g. building age, thermal mass and insulation properties) which can influence building temperatures and perceptions of comfort, we recommend further investigation for a more robust understanding of the differences between both strategies, which could be done alongside a broader roll-out.

5. **Posters displayed on-site were not a highly effective form of communication to building occupants, creating awareness among only 10% of respondents who had seen and read the poster.**

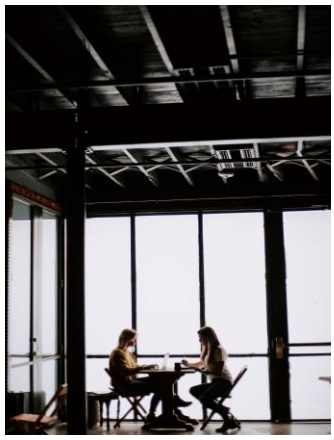
   Recommendation 3: Based on the experiences of the buildings included in this trial, active engagement with building occupants in the lead up to HVAC control changes is not necessary. If communication was planned, based on this study we recommend a multi-channel approach which alongside posters/notices displayed on-site includes more direct forms of communication where practicable. However, communication strategies that actively engage with request or complaints, explaining reasons behind changes and reassuring that the concern will be attended to, may be more appropriate.

   Recommendation 4: The insights developed here are specifically intended to provide guidance for the Net Zero Initiative team for developing the Monash microgrid and maximizing its benefits through ensuring optimal functioning. More broadly though, our findings on the staff and students experience when using Monash University buildings can also provide useful insights for the Buildings and Property Division and the general operation of heating and cooling systems.

Beyond providing guidance for the development of the Monash University microgrid, it is hoped that key lessons from our field trial experimentation can provide useful behavioural insights for other microgrid projects.

INTRODUCTION

This report details research that has been conducted for the Monash Buildings and Property Division with support received from the Victorian Government's Microgrid Demonstration Initiative. BehaviourWorks Australia undertook a field trial with the aim of gaining a better understanding of building occupants' experience of potential alterations to the control of heating and cooling systems under microgrid test conditions.



Demand side management strategies aimed at shifting or reducing energy consumption at peak times are considered a key component for the effective and efficient functioning of microgrids. The use of heating and cooling (HVAC) systems in particular poses a promising avenue for the implementation of energy-efficiency and load shifting strategies because of the high energy loads these systems tend to be associated with. In many contexts, HVAC systems are centrally controlled rather than by the individual user. In these cases, understanding how alterations of building heating and cooling systems from standard settings affect user experience is essential to ensure acceptable comfort levels are maintained.

The objective of the research described in this report is to provide guidance on how to engage with occupants regarding possible changes to HVAC control during microgrid operation and to support the development of the on-site microgrid at Monash University's Clayton campus. The development of the Monash microgrid, whereby 20 buildings will operate primarily on clean energy, forms part of the university's ambitious Net Zero Initiative which strives to reach net zero carbon emissions by 2030. With solar power generated on-site, wind energy sourced off-site, and battery storage the Monash microgrid will reduce demand on the broader grid, reduce electricity costs and reduce the universities carbon emissions. Intelligent technology will help maximise the use of the energy across buildings and interact with the external markets (Monash University, 2020).

Findings from this study will assist the Net Zero Initiative and Buildings and Property Division (BPD) with managing both building user comfort and energy demand optimally to maximize the benefits of the Monash microgrid. It supports an understanding of the flexibility in demand response, while ensuring customer satisfaction. The study also contributes to a better understanding of potentially required behavioural interventions to ensure thermal comfort levels and explores the potential use of posters to communicate a dynamic control of HVAC systems to occupants. The research presented in this report forms part of a larger research project investigating the role of human behaviour for optimal functioning of microgrids.

Beyond providing behavioural insights to inform the development and operation of the Monash microgrid, it is hoped that sharing key lessons from our field trial experimentation provides guidance on individuals' experience of thermal comfort that can benefit other microgrid projects and the energy transition more broadly.

WHY FOCUS ON HEATING AND COOLING SYSTEMS?

Heating and cooling systems play a central role to load-shifting or demand reduction because they tend to be associated with high energy use (Aghniaey & Lawrence, 2018), especially if they maintain a narrow range of internal temperatures perceived as most comfortable for building occupants (Hoyt, Lee, Zhang, Arens, & Webster, 2005). However, previous studies indicate that occupants are comfortable with much wider variation in temperatures than conventionally managed for, and a wider 'temperature band' in HVAC settings can bring about significant energy savings (Arens, Humphreys, de Dear, & Zhang, 2010). The potential amount of savings has been quantified as up to 10% of energy per degree (Celsius) included in the temperature band (Hoyt, Lee, Zhang, Arens, & Webster, 2005). A primary objective of this trial is thus to gain a better understanding of building occupants' perceptions of thermal comfort, willingness to accept potential changes and behavioural response.

Aside from understanding the human behavioural response to building temperature settings deviating from standard settings, a key learning objective from this trial is to understand the extent to which HVAC energy consumption timing may vary both within and across a prolonged period of days or weeks. In other words, the research is interested in both the magnitude and duration of HVAC power and energy temporally shifting from the standard pre-determined settings, and how this influences building temperatures and comfort. These outcomes are driven by several factors, including the thermal mass and insulation properties of individual buildings. To this end, the behavioral trials described in this report were undertaken in conjunction with techno-economic work led by the Monash Net Zero Initiative. Combining the present findings on how occupants respond to changes in HVAC settings with the research on the energy or thermal response of buildings[1] will allow for the development of a daily energy shifting algorithm strategy that maximises energy objectives (e.g., lowest cost, maximum use of renewables) whilst also ensuring the building environment remains within acceptable comfort limits. This report discusses the impact of different HVAC strategies on occupants' experience and behavioural response (for the outcomes of the techno-economic component, please see the *Operational Market Trials Report*). A discussion of the broader objective achieved through the integration of both trials is outside the scope of this report.

COMMUNICATION AS A COMPONENT OF DEMAND MANAGEMENT

The use of communication to microgrid users as a means to support optimal microgrid functioning and encourage participation in demand response programs has been discussed among practitioners and academics. Several field studies on microgrids have investigated the role of communication in the form of explicit messages or traffic lights signaling the grid state (Fulhu, Mohamed, & Krumdieck, 2019; Kohlhepp et al., 2019; Martin, 2020). Others have likewise argued that communication plays an important role for effective microgrid operation, for example through a simple DSM metering-control system at each household showing the grid situation (Martin, 2020; Shakya, Bruce, & MacGill, 2019) or broader forms of communication with the community, or education, to create awareness and understanding (Kuhnel et al., 2020; Numminen & Lund, 2019). Practitioners involved in microgrid projects in Australia similarly point to education and the provision of feedback on energy use as potential avenues of intervention (Klemm, Tull & Smith, 2020). This is supported by findings from a Singaporean Eco-living Program that used a combination of leaflets and stickers to raise awareness among energy users and demonstrated this to be effective, resulting in a 15.8% reduction in average consumption (He & Kua, 2013 as cited in Fuhlu et al. 2019, p. 28). To our knowledge, it has not yet been investigated if communication can be equally effective for alternative forms of demand response, such as users accepting slightly higher variations in building temperatures than usual as is the interest of this study. A secondary objective of this trial was thus to explore whether communication of potential changes to HVAC operation can be effective.

[1] This is undertaken via a machine learning Neural Net model to create a counter-factual digital twin. For more details see the *Operational Market Trials Report*.

In the following sections, this report details our research methodology, findings from the field trial and provides recommendations to support microgrid development and operation.

FIELD TRIALS

A field trial was undertaken in the period of 10 May – 6 June in conjunction with techno-economic analysis work investigating building occupants' experience of air temperature changes resulting from slight alterations of HVAC temperature settings.

TRIAL APPROACH

In collaboration with the Net Zero Initiative team two weeks during the month of May 2021 (17-30 May) were selected during which to implement changes to HVAC control in eight selected buildings on Monash University's Clayton campus.

The overarching aim of the research trials was to gain an understanding of building occupants' experience of changes to HVAC settings and their engagement in self-regulation behaviours.

The following questions were investigated:

- What are occupants' self-reported thermal comfort levels before and during the trial period?
- To what extent are users willing to accept building temperatures if alterations to HVAC operation would be allowing slightly higher/lower temperatures than the current standard?
- To what extent are building occupants' engaging in self-regulation behaviours?

Besides the general research interest, two distinct study components were conducted to investigate separate sub-questions. While all study components are reported here, it is important to note that the primary focus of the conducted research trials was study 1.

Study 1: The impacts of different HVAC strategies on occupant response

Using a quasi-experimental design across half of the eight buildings included in this trial, study 1 tested the impact of different HVAC strategies on occupant response (see Figure 1). Specifically, the study component investigated the following questions:

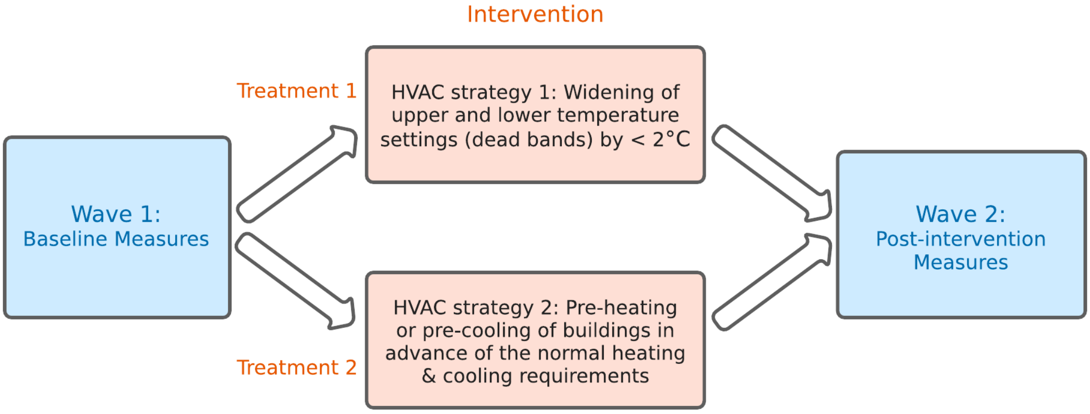
- Are there differences in how different HVAC strategies influence occupants' self-reported
    - thermal comfort levels,
    - willingness to accept these temperatures going forward,
    - negative impact on work performance, and
    - behavioural response?

We compared two slightly differing intervention treatments that were applied across the four selected buildings as shown in Figure 1:

- *Treatment 1:* Widening of upper and lower temperature settings (dead bands) by up to 2 degrees C,
- *Treatment 2:* Pre-heating or pre-cooling buildings in advance of the normal heating and cooling requirements.

The applied HVAC strategies were chosen in close collaboration with the Net Zero Initiative team and the implementation was led by the team. Table 1 shows which buildings were included in study 1, the treatment condition these were assigned to and their main usage or purpose.

Figure 1. Design of the quasi-experimental study 1



Except for the Faculty Service Managers of these buildings, none of the occupants were informed that the tests were occurring. This was to avoid occupants' possible knowledge of a trial influencing their perception of building temperature and then generating behavioural responses that might not be 'normal'.

Table 1: Overview of buildings included in study 1 and assigned treatment condition

Building No.	Building Name	Building usage	Treatment condition
92	Learning and Teaching Building	Teaching / Student - mixed use	Widening of dead bands to a maximum of + / - 2°C
93	Biomedical Learning and Teaching Building	Research & Staff offices	Widening of dead bands to a maximum of + / - 2°C
94	Woodside Building (TED)	Teaching / Student - mixed use	Pre-cooling & pre-heating[2] within limits of current setpoint or dead bands
82	New Horizons Building	Research & Staff offices	Pre-cooling & pre-heating[1] within limits of current setpoint or dead bands

Study 2: The effectiveness of communication on HVAC changes

Study 2 explored the effectiveness of communication on HVAC changes across the second half of the eight buildings included in this trial, addressing the following question:

- Can on-site communication to building occupants be effective in terms of its reach and dissemination of behaviourally informed messages to occupants?

Occupants of the four buildings included in this study component (see Table 2) received communication informing them of ongoing trials. While the differing intervention treatments in terms of HVAC settings described above were also applied across these buildings, our primary interest in this component was

[2] In building 94 and 82, the applied HVAC strategy was pre-heating; in building 32 pre-cooling was implemented.

to explore whether the use of on-site communication to inform occupants and to encourage the acceptance of temperature changes and a behavioural response through tailored messaging could be effective in reaching a large proportion of occupants and communicating key messages.

Table 2: Overview of buildings that received communication (poster) and information on HVAC operation changes

Building No.	Building Name	Building usage	Details on HVAC strategy employed in these buildings
24	Western Science Lecture Theatres Building	Lecture rooms	Widening of dead bands + / - 2°C
25	Eastern Science Lecture Theatres Building	Lecture rooms	Widening of dead bands + / - 2°C
26	Information Technology & Faculty of Science Building	Teaching / Student - mixed use	Widening of dead bands + / - 2°C
32	Engineering Lecture Theatre Building	Lecture rooms (mostly smaller labs)	Pre-cooling & pre-heating within limits of current setpoint or dead bands

We tested the impact of posters or notices hung up in various locations across the selected buildings. Posters or notices displayed in buildings are a common approach to inform building occupants, particularly in settings where direct communication is impossible or impractical (e.g. in public spaces like airports or shopping malls with frequently changing building users).

A poster was specifically designed for the purpose of this trial. The poster informed building occupants about temperature testing and included messaging drawing on prior research on the drivers of user participation in demand response programs – such as community and social benefit (Alvina, Bai, Chang, Liang, & Lee, 2017; as cited in Gyamfi & Krumdieck, 2011), grid security (i.e. reducing the risk of power outages), and environmental benefit (Gyamfi & Krumdieck, 2011). Accordingly, the poster included messaging describing the strain HVAC systems place on the local network in peak demand periods, the benefits for local grid stability/efficiency appealing to a sense of community, as well as the benefits to the environment. Lastly, the poster included a call for action, asking occupants' support and preparation for eventual changes. Figure 2 shows examples of posters displayed across the selected buildings (See Appendix A for the poster).

Our trial did not provide a complete assessment of the effectiveness of this communication. We did not assess whether the communication influenced occupant's perceptions (e.g., perceptions of comfort or willingness to accept more extreme temperatures) or the impact on their behaviour. Instead, our focus was on whether or not occupants were even aware of the posters and whether or not they read the poster and the contained messages, an important first step by which communication influences perceptions and behavior.

Figure 2. Examples of building where posters were displayed

Study measures

To measure occupants' experience of thermal comfort and their behavioural response during the trials, four main data collection streams were implemented:

1. Wave 1 (baseline) and Wave 2 (post-interventions) surveys of building occupants (staff and students) in selected buildings (see Appendix B for the survey),

2. Wave 2 (post-intervention) survey of Faculty Service Managers about their perceptions of occupants' comfort levels and coping behaviours during the trial period (see Appendix C for the survey),

3. Records of occupant complaints and requests for checks or repairs of HVAC systems (through the BEIMS system/PULSE report and specific requests to the Faculty Service Managers).

The wave 1 (baseline) and wave 2 (post-intervention) occupant survey asked them to rate their level of thermal comfort (Buratti, Palladino, & Ricciardi, 2016) during the past two weeks. The occupant survey also covered occupants' willingness to accept the current temperature conditions moving forward, any negative impact on work performance, complaints of others in the building about temperatures, and engagement in self-regulation behaviours such as the choice of clothing types and use of personal heating/cooling devices, as well as background questions and whether or not the occupant had seen and read the poster. The survey did not mention to occupants that temperature control tests had been conducted during that month.

RESULTS: GENERAL FINDINGS

Drawing from the occupant survey, the Faculty Service Manager survey and the data on formally lodged requests/complaints, we investigate whether the introduction of changes to the temperature settings impacted occupants' perceptions and behaviours. Please note, a detailed breakdown of the data for each building can be found in Appendix D.

OCCUPANT SURVEY

Sample characteristics

Across both waves of data collection, 790 surveys were returned across all eight buildings. Of these, one survey was excluded due to the participants age (<18 years) and 56 (7.1%) surveys were excluded as the participant was not in the building during the study period. The final sample comprised 733 surveys.

There was a notable variety in the number of completed surveys across buildings. Almost half (44.9%) of surveys were from building 92, with only 0.5% of surveys coming from building 25 and no surveys included for building 26, and was therefore exclude this from the analysis.

Table 3: Number of included surveys per building

	Building						
	24	**25**	**32**	**82**	**92**	**93**	**94**
No. of included surveys	14	4	27	178	329	18	163
% of all surveys	1.9%	0.5%	3.7%	24.3%	44.9%	2.5%	22.2%

Discomfort

Our results show only very minor differences in the average self-reported occupant comfort level during the trial period (mean = 2.04; SD = .93[3]) in comparison to before the trial (mean = 2.11; SD = .95).

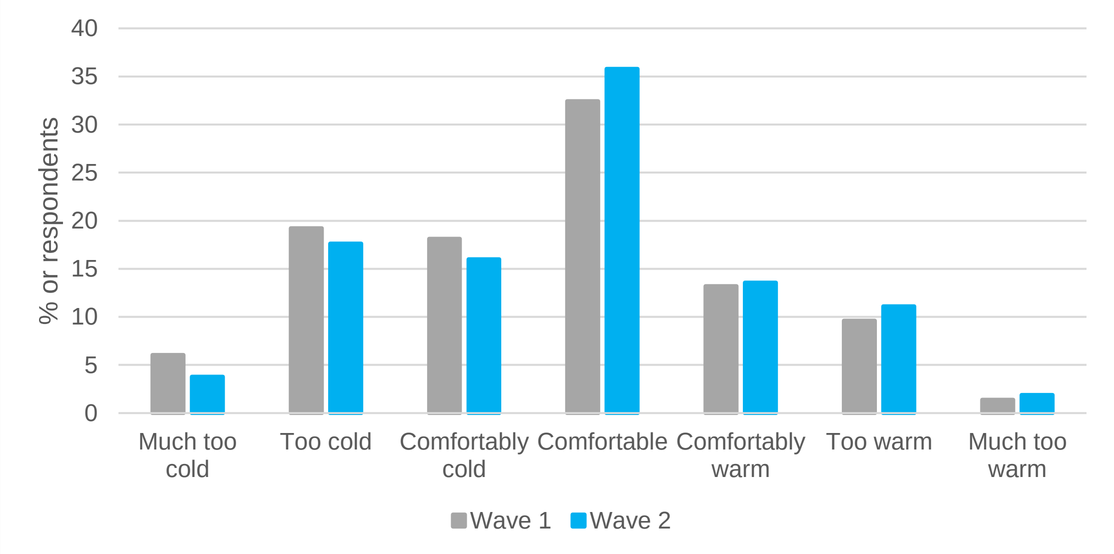
Figure 3 shows a more detailed breakdown of comfort levels across both waves. The wave 1 (baseline) survey showed that prior to the trial period the majority of respondents (63.7%) experienced acceptable levels of comfort either stating they were comfortable (32.4%), comfortably cold (18.1%) or comfortably warm (13.2%). However, around a quarter of respondents (25.2%) stated that they were too cold or much too cold. Another 11% reported being too warm or much too warm.

In the wave 2 (post-intervention) survey, slightly more respondents (65.4%) reported that they experienced acceptable comfort levels during the trial period either stating they were comfortable (35.8%), comfortably cold (16%) or comfortably warm (13.6%). The proportion of respondents

[3] Greater mean score indicates greater discomfort. A scale of 2 or less indicates comfortable, while a scale of 3 or more indicates uncomfortable.

indicating that they were too cold or much too cold (21.4%.) was slightly lower than at baseline. In contrast, the proportion of those being too warm or much too warm was slightly higher post-intervention with 13% (in comparison to 11% at baseline).

Figure 3: Comfort levels at baseline (wave 1) and during the trial period (wave 2)



Unwillingness to accept temperature

With regards to occupants' willingness to accept current temperature moving forward we find no notable differences between average scores in wave 2 (post-intervention: mean = 2.94, SD = 1.34[4]) and wave 1 (baseline: mean = 2.89; SD = 1.35). At both times around 15% of respondents indicated that they were very unwilling (baseline: 11.5%; post-intervention: 11.4%) or extremely unwilling (baseline: 3.3%; post-intervention: 3.8%) to accept current temperatures moving forward.

Self-regulating thermal comfort through behaviours

At wave 1 (baseline) the majority of respondents (82.1%) report having engaged in self-regulation behaviours to achieve thermal comfort over the past 2 weeks (including choice of clothing, use of powered heating or cooling devices), whereas less than a fourth (17.9%) state that they have not undertaken any behaviours.

At wave 2 (post-intervention) the number of respondents stating that they have engaging in self-regulation behaviours was slightly lower (79.9%) than before the intervention, with 20.1% reporting no self-regulation behaviours during the trial period.

FACULTY SERVICE MANAGER SURVEY

Five surveys were completed by building managers, pertaining to three buildings.

Perceptions of comfort

Most building managers tended to view occupants as being comfortable with the temperature before and during the trial period. However, there was variability, with two surveys reporting discomfort at

[4] Greater mean score indicates a greater unwillingness to accept temperatures moving forward. A scale of 3 or less indicates a willingness to accept temperature, while a scale of 4 or more indicates an unwillingness to accept temperatures

both time points, and with greater discomfort during the trial period. Moreover, most building managers tended to feel that occupant complaints/requests increased during the trial period.

Perceptions of appropriateness

Nearly all of the building managers felt that the trialed temperature would be appropriate at selected times moving forward, and none felt that these changes would be unsuitable across other buildings on campus.

BEIMS (PULSE REPORT) REQUESTS/COMPLAINTS

In the pre-trial period (3-26 May 2021), there were three temperature-related requests or complaints in the BEIMS system from occupants of two of the buildings included in the trial (Buildings 82 and 92) both mentioning too warm or hot temperatures.

In comparison, over the trial days:

- There were 15 complaints across 5 of the 8 buildings included in this trial, which is an increase from the 3 complaints in the pre-trial period (see Table 4),
- Building 82 (New Horizons) occupants lodged the highest number of requests/complaints (n=7) with some mentioning too warm temperatures (e.g. "New Horizons accommodation temperature is reading as high as 27 Deg C in some areas. with the whole building being extremely warm throughout.") while others too cold temperatures (e.g. "New Horizons office 306 extremely cold."),
- No requests/complaints were lodged for buildings, 24, 25, 26, 32, 93, and 94 prior to the trial period,
- No requests/complaints were lodged for buildings 24, 25, and 93 during the trial period.

Table 4: Number and type of lodged requests/complaints per building in pre-trial and trial period

	Pre-trial period (3-16 May)		***During trial period (17-30 May)***				
Type of complaint	B82	B92	B26	B32	B82	B92	B94
Too cold	0	0	2	1	2	1	0
Too warm	2	1	0	0	5	1	2
Other*	0	0	2	0	0	0	0
Total	**2**	**1**	**4**	**1**	**7**	**2**	**2**

* The other comments were a general comment HVAC was not working, and one asking why nothing been done since earlier requests/complaints.

RESULTS STUDY 1: IMPACTS OF DIFFERENT HVAC STRATEGIES

Drawing from the occupant survey and the lodged requests/complaints data we investigate whether the widen dead band approach and the pre-heating approach have different impacts on occupants' perceptions and behaviours. That is, does one approach appear to be more appropriate than the other.

OCCUPANT SURVEY

Sample characteristics

Across both waves of data collection, 727 surveys were returned for buildings 82, 94 and 92 (i.e., buildings included in Study 1). Of these, one survey was excluded due to the participants age (<18 years) and 56 (7.7%) surveys were excluded as the participant was not in the building during the study period. A further 5 surveys were excluded as the participant reported reading the communication posters (these were excluded as exposure to the poster content may have influenced their responses to the survey). The final sample comprised 665 surveys.

Nearly half (49.5%) of included surveys were from building 92 (widen dead band study condition) while 26.5% were from building 82 (pre-heating condition) and 24.1% were from building 94 (pre-heating condition). There were a similar number of included surveys for wave 1 (48.0%) and wave 2 (52.0%).

Around 22% (n=130) of surveys were completed by a participant who completed both waves of the survey (for the same building), while a small handful of surveys (0.8%) were completed by a participant who completed the survey for two buildings (but only one wave). The majority surveys were completed by staff (68.4%). Most were completed by individuals aged 18-39 years (68.6%) or aged 40-59 years (27.2%) and just over half by people who identify as female (53.4%).

Participants tended to be in the building across various times of the day. Most surveys were completed by individuals who report being in the building during the morning (72.5%), during midday (86%), or during the afternoon (87.7%), with somewhat fewer during the evening (39.5%).

Most surveys where completed by individuals who, when in the building, report spending their time seating (95.2%). Participants also reported standing (39.2%), slow-paced walking (58.5%) and some reported fast-past walking/high physical activity (8.7%).

Discomfort

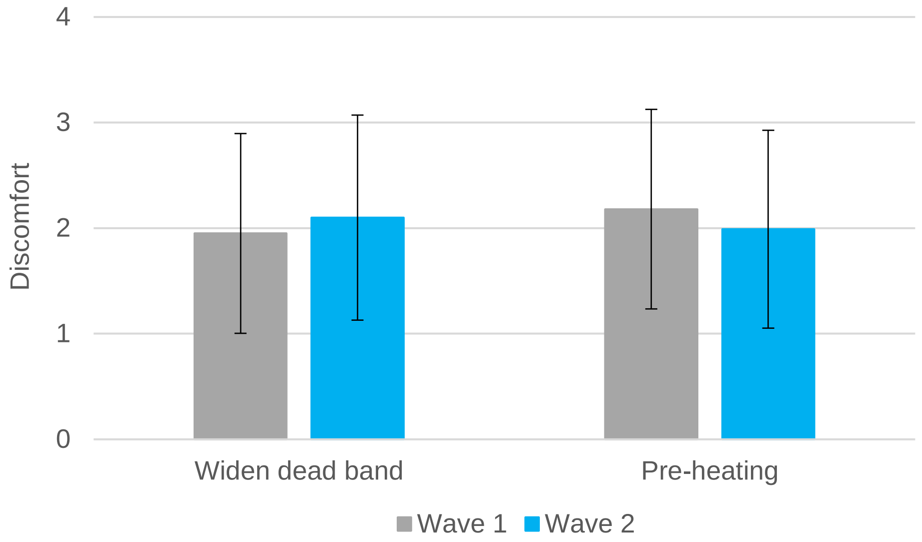
Overall, most occupants tended to feel comfortable with the air temperature in the building, with 65.3% of surveys reflecting either comfortable or comfortably warm/cold. However, 27.9% reported the temperature being too cold/warm and a further 6.8% reported the temperature being much too cold/warm.

There was a significant difference in the trends of comfort between the study conditions over time (b = .348, SE = 0.14, p = 0.018)[5]. In other words, the impact of the temperature changes on occupants' thermal comfort was depended on study condition. As shown in Figure 4 below, results suggest that

[5] Results from a mixed effects model with comfort as dependent variable, accounting for repeated measures and nested data and controlling for activity level of occupant (seating, standing, slow walking, fast walking) and time of day in the building (morning, midday, afternoon, evening). The analysis was run using the statistical analysis software STATA SE16.

occupants in the widen dead band condition tended to experience greater discomfort over time, while occupants in the pre-heating condition tended to experience less discomfort over time.

Figure 4. Discomfort with air temperature, by wave and study condition[6]



Unwillingness to accept temperature

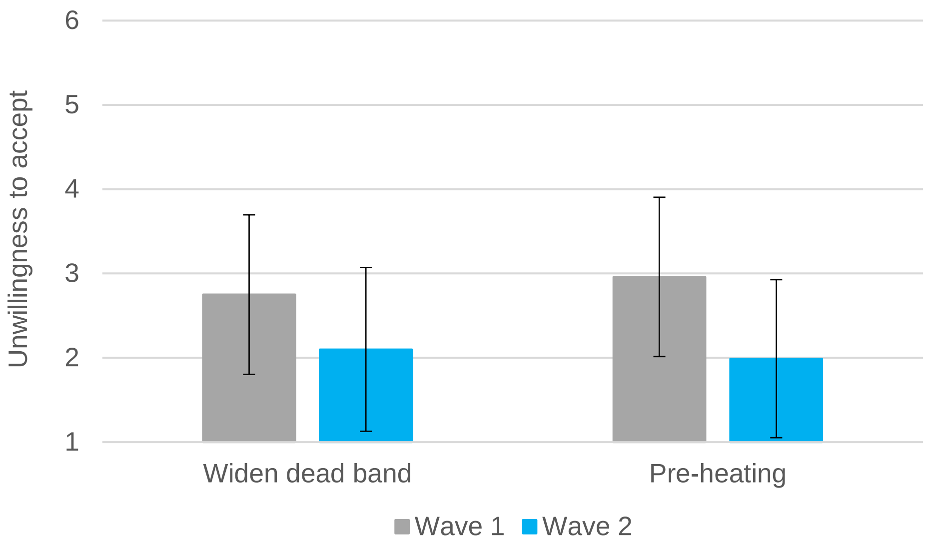
Overall, most occupants (69.4%) were willing to accept the temperature in the building moving forward, with 43% either very or extremely willing. Of the occupants who were unwilling to accept the temperature, a handful where extremely unwilling (3.8%).

There was a non-statistically significant difference in the trends of (un)willingness between the study conditions over time (b = .340, SE = 0.21, p = 0.098)[7]. As shown in Figure 5 below, although the results were non-significant, there is tentative support that occupants were more willing to accept temperatures during the trial period (than before the trial period), and this improvement appears to be somewhat more for the pre-heating condition.

[6] Greater mean score indicates greater discomfort. A scale of 2 or less indicates comfortable, while a scale of 3 or more indicates uncomfortable. Error bars represent one standard deviation.

[7] Results from a mixed effects model with unwillingness to accept as dependent variable, accounting for repeated measures and nested data and controlling for activity level of occupant and time of day in the building. The analysis was run using the statistical analysis software STATA SE16.

Figure 5. Unwillingness to accept temperature moving forward, by wave and study condition[8]



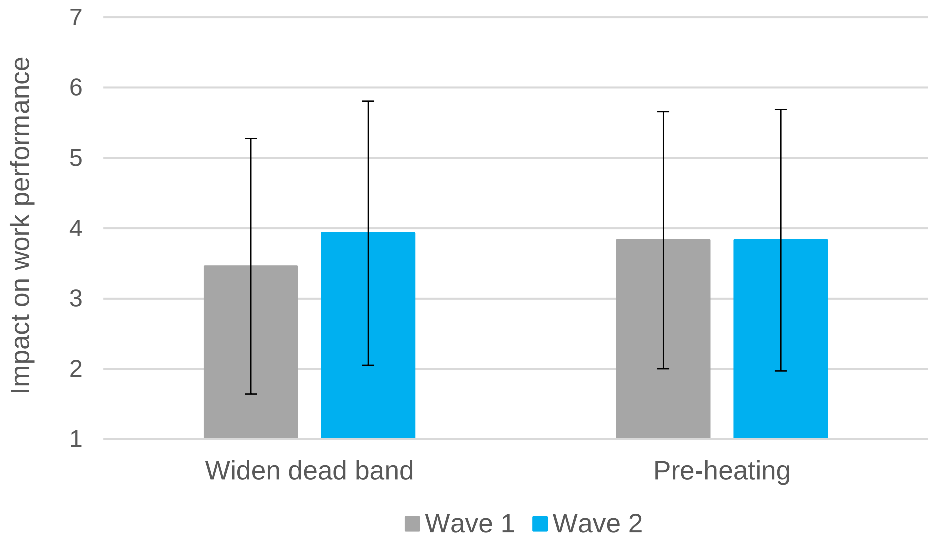
Impaired work performance

Overall, 40.1% of occupants agreed that the temperature in the building had a negative impact on their work performance, with 6.6% strongly agreeing. Most occupants (59.9%) were either neutral or disagreed that the air temperature had a negative impact on their work performance.

There was a non-statistically significant difference in the trends of impact on work performance between the study conditions over time (b = .506, SE = 0.28, p = 0.072)[9]. As shown in Figure 6 below, although the results were non-significant, there is tentative support that work performance in the widen dead band condition became more affected by the temperature during the trial period, while there was no change among occupants in the pre-heating condition.

[8] Greater mean score indicates a greater unwillingness to accept temperatures moving forward. A scale of 3 or less indicates a willingness to accept temperature, while a scale of 4 or more indicates an unwillingness to accept temperatures. Error bars represent standard deviation.
[9] Results from a mixed effects model with negative impact on work performance as dependent variable, accounting for repeated measures and nested data and controlling for activity level of occupant and time of day in the building. The analysis was run using the statistical analysis software STATA SE16.

Figure 6. Negative impact on work performance due to temperature, by wave and study condition[10]

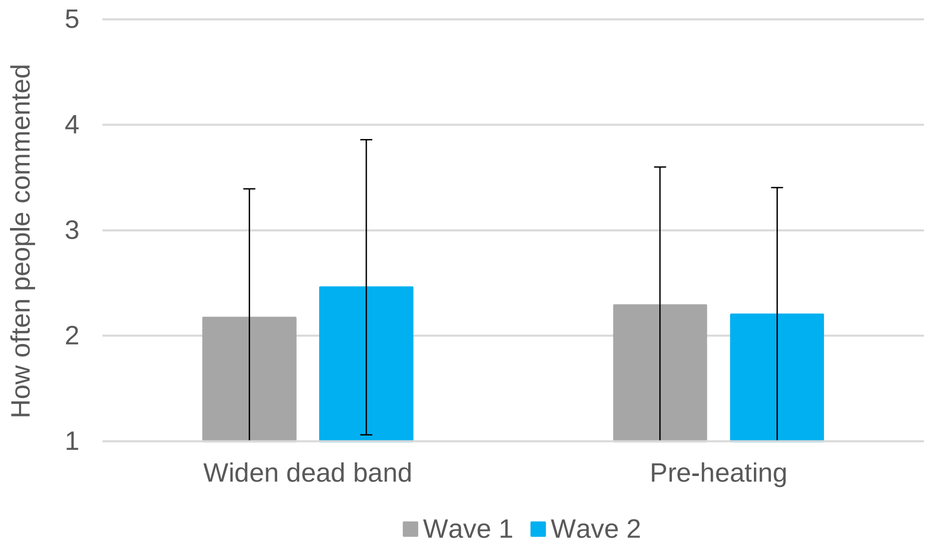


People commenting

Overall, most people (68%) either never, or only sometimes, heard people around them commenting on the temperature being too cold or too hot.

There was no statistically significant difference in the trends of people commenting on temperature between the study conditions over time (b = -.108, SE = 1.32, p = 0.935)[11].

Figure 7. People commenting on the air temperature being too cold/hot, by time and study condition[12]



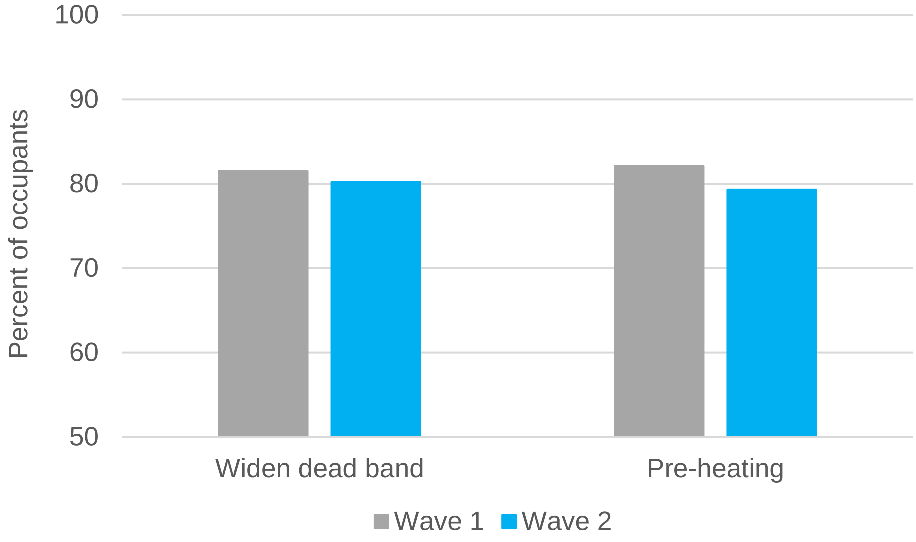
[10] Greater mean score indicates a greater negative impact on work performance. A scale score of 3 or less indicates a disagreement with the statement "the temperature had a negative impact on my work performance", while a scale score of 5 or more indicates an agreement. Error bars represent standard deviation.
[11] Results from a mixed effects model with people commenting as dependent variable, accounting for repeated measures and nested data; controlling for activity level of occupant and time of day in the office. The analysis was run using the statistical analysis software STATA SE16.
[12] Greater mean score indicates more frequently hearing nearby occupants commenting that the temperature is too cold/hot. Error bars represent standard deviation.

Self-regulating thermal comfort

Overall, most occupants (80.8%) engaged in a behavior to help manage their thermal comfort. Among these occupants, most wore an extra layer of clothing to keep warm (75.6%), some wore lighter clothing to keep cool (29.8%), and a small handful used a powered heating device (2.6%) or a powered cooling device (2%). A small proportion (9.3%) engaged in an alternative behavior to manage their thermal comfort (e.g., used a blanket or drank a warm beverage to keep warm).

There was no statistically significant difference in the trends of people adopting a behavior to manage their thermal comfort between the study conditions over time (b = -.086, SE = 0.38, p = 0.822).

Figure 8. Occupant performed behavior to manage their thermal comfort, by time and study condition



RESULTS STUDY 2: EFFECTIVENESS OF COMMUNICATION

Drawing on the occupant survey we investigate the impact of the communication intervention.

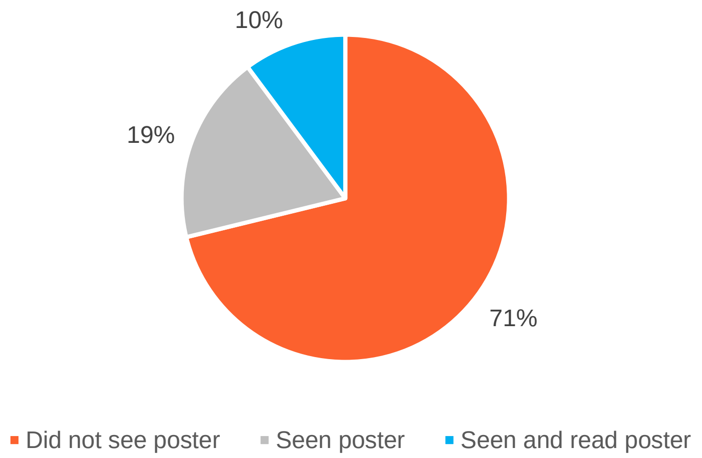
OCCUPANT SURVEY

Sample characteristics

Across the study, 59 participants reported being in building 24, 25, 26 or 32 during the trial period (i.e., in buildings where the posters were displayed). Just over half were students (55.9%), identified as female (52.5%) and most were aged 18-39 years (91.5%).

Awareness of posters and poster content

Of the participants who were in buildings where posters were displayed, most did not see the poster (71.18%). Some occupants did see the poser, but did not read it (18.64%), and only a handful read the poster (10.17%).



CONCLUSION & RECOMMENDATIONS

Our key findings across the general study and the two sub-study components suggest four approaches for the Monash Net Zero Initiative team and BPD in managing building energy demand and engaging with occupants with regards to potential impacts of changes to HVAC control.

General findings

With regards to the average building occupant experience of changes to HVAC settings and behavioural response across the eight buildings included in this trial we found:

- **No notable difference in average self-reported thermal comfort levels before and during the trial period**, with around 2/3 of occupants' indicating that they felt "comfortable" or "comfortably cold/warm",
- **No substantial difference in how willing occupants are to accept temperatures** that they experienced under the tested alterations to HVAC settings in comparison to the current standard,
- **No noticeable behavioural response** (with the exception of a slight increase in lodging requests/complaints). Behaviours aimed at self-regulating comfort levels were equally common before and during the trial period.

These findings align with the perception of Faculty Service managers, most of whom observed little or no changes in occupants' comfort levels and consider the trialed temperature changes as appropriate at selected times in future HVAC operation.

However, the lodged complaints/requests data and Faculty Service Managers survey highlighted some notable exceptions with some occupants experiencing periods of 'extremely warm' or 'extremely cold' temperatures in some buildings or areas. Some of the mentioned temperature were 27°C, temperatures that were above or below the allowed temperature fluctuations which suggests irregularities in the implementation of the HVAC strategies.

In the present trials, we allowed temperatures to fluctuate to a higher magnitude and for longer periods of time as to be expected or planned during microgrid operation. The intent was to be able to understand occupants experience of temperatures and behavioural response under more 'extreme' circumstances and get a sense of the boundaries of comfort. The fact that these more intense temperature fluctuations did not result in a substantial increase in discomfort, unwillingness to accept temperatures going forward or impaired work performance, demonstrates that these HVAC control strategies are appropriate.

Recommendation 1: The tested HVAC control strategies can be applied across Monash campus as an appropriate strategy for dynamic control during peak times to allow for greater flexibility and maximize the benefits of the microgrid.

Implementation of a broader scheme, however, should best be accompanied by close monitoring of temperatures and/or lodged requests at least in early stages. This will allow to quickly detect unforeseen irregularities or differences between buildings (or areas within buildings) and a pro-actively response to ensure appropriate engagement with occupants. We recommend this particularly given the fairly high proportion of occupants indicating that they were experiencing discomfort before (as well as during) the intervention and qualitative insights that suggested variability between and within buildings.

While we recommend close monitoring and pro-active management of **lodged requests/or complaints** during a broader program roll-out, it is important to note that these **should not be relied on as an indicator of general occupant comfort**. Based on the experience from this research trial, the number of lodged complaints does not correlate with average levels of discomfort.

For any evaluation of the impact of a broader roll-out of the tested strategies, we would recommend surveying occupants *before* implementation of any changes to capture baseline levels of discomfort or conducting repeated/regular surveys (e.g. twice a year) rather than completing a single data collection after changes have been implemented. This is because there is expected to be variability in comfort between individuals and buildings, and existing levels of discomfort.

Impacts of different HVAC strategies

With regards to differences between the two difference intervention treatments – i.e. widening of temperature dead bands vs. pre-heating/pre-cooling of buildings – study 1 found the following:

- A significant difference in the trends of comfort between the different treatments (HVAC strategies) over time. Results suggest that occupants in the widen dead band condition tended to experience greater discomfort over time, while occupants in the pre-heating condition tended to experience less discomfort over time.

- No significant difference between both treatments in terms of their impact on occupants' self-reported willingness to accept these temperatures going forward, negative impact on work performance, and behavioural response.

Recommendation 2: While both tested HVAC strategies are appropriate, a strategy using pre-heating or pre-cooling buildings may be slightly more appropriate than widening of dead bands and is worth investigating further.

However, due to the small number of buildings in each treatment condition and that fact that buildings vary on a large number of parameters (e.g. building age, thermal mass and insulation properties) which can influence building temperatures and perceptions of comfort, we recommend further investigation for a more robust understanding of the differences between both strategies, which could be done alongside a broader roll-out.

Effectiveness of using communication to building occupants

- Our results showed that only a small number of occupants had seen the poster, with only 10% reporting to have seen and read the poster.

We therefore conclude that communication of changes to HVAC control via poster or notices, which tends to be a common element of a communication strategy especially where more direct forms of communication are not possible or practical, is limited in terms of effectively increasing awareness. However, considering that we found no notable differences in the average experience of comfort, willingness to accept temperatures or impaired work performance, upfront communication of HVAC changes to occupants does not appear necessary.

Recommendation 3: Based on the experiences of the buildings included in this trial, active engagement with building occupants in the lead up to HVAC control changes is not necessary.

If communication was planned, based on this study we recommend a multi-channel approach which alongside posters/notices displayed on-site includes more direct forms of communication where practicable. However, communication strategies that actively engage with request or complaints, explaining reasons behind changes and reassuring that the concern will be attended to, may be more appropriate.

Recommendation 4: The insights developed here are specifically intended to provide guidance for the Net Zero Initiative team for developing the Monash microgrid and maximizing its benefits through ensuring optimal functioning. More broadly though, our findings on the staff and students experience when using Monash University buildings can also provide useful insights for the Buildings and Property Division and the general operation of heating and cooling systems.

Limitations and key considerations

While this report provides valuable insights, it is important to treat the results reported here with some caution due to a number of limitations. Firstly, while the wave 1 (baseline) and wave 2 (post-intervention) surveys were distributed to the same study population of staff and students using the buildings selected in this research trial, most of the respondents filling in the surveys were different individuals. In other words, only a small proportion filled in the survey twice, prior to and after the intervention. As thermal comfort and the other occupant perceptions investigated in this study are likely to vary between individuals, we expect that this limitation has resulted in a greater variety in responses or ‘noise’ in the data than if we had surveyed the same individuals twice.

Secondly, the Covid 19 pandemic and the related density limits in building usage and the fairly high number of staff and students working or studying remotely (on some days of the week) is likely to have created a unique context for this research trial. Future studies should confirm the present findings in other settings.

Thirdly, while we observed an increase in lodged requests/complaints, due to the small number of complaints received during the trial period, these findings need to be treated with caution. It is possible the findings occurred simply by chance alone. In addition, there is a risk that the dissemination of the baseline survey which asked staff and students about their comfort levels may have made them more likely to report any discomfort or complaints they experience during the trial (i.e., they are more likely to consider reporting it now that they see Monash is listening).

Lastly, some results in the Faculty Service Manager survey indicate that there may have been dysfunctional equipment which may have influenced the temperatures to deviate from the planned intervention treatments. In particular affected was possibly the building in the widening of dead bands study condition. This may have influence discomfort in the affected buildings, likely creating greater discomfort than to be expected under microgrid operation.

REFERENCES

Aghniaey, S., & Lawrence, T. M. (2018). The impact of increased cooling setpoint temperature during demand response events on occupant thermal comfort in commercial buildings: A review. *Energy & Buildings*, *173*, 19–27. https://doi.org/10.1016/j.enbuild.2018.04.068

Arens, E., Humphreys, M. A., de Dear, R., & Zhang, H. (2010). Are 'class A' temperature requirements realistic or desirable? Building and Environment, 45(1), 4–10.

Buratti, C., Palladino, D., & Ricciardi, P. (2016). Application of a new 13-value thermal comfort scale to moderate environments. *Applied Energy*, *180*, 859–866.

Fulhu, M., Mohamed, M., & Krumdieck, S. (2019). Voluntary demand participation (VDP) for security of essential energy activities in remote communities with case study in Maldives. *Energy for Sustainable Development, 49*, 27-38. doi:10.1016/j.esd.2019.01.002

Gyamfi, S., & Krumdieck, S. (2011). Price, environment and security: Exploring multi-modal motivation in voluntary residential peak demand response. *Energy Policy, 39*(5), 2993-3004.

Hoyt, T., Lee, K., Zhang, H., Arens, E., & Webster, T. (2005). Energy savings from extended air temperature setpoints and reductions in room air mixing. *UC Berkeley: Center for the Built Environment*. Retrieved from https://escholarship.org/uc/item/28x9d7xj

Klemm, C, Tull, F, & Smith, L, Identifying and targeting human behaviour in Microgrids. Literature and Practice Review. Melbourne, Australia: BehaviourWorks Australia, Monash Sustainable Development Institute, Monash University, December, 2020.

Kohlhepp, P., Harb, H., Wolisz, H., Waczowicz, S., Muller, D., & Hagenmeyer, V. (2019). Large-scale grid integration of residential thermal energy storages as demand-side flexibility resource: A review of international field studies. *Renewable & Sustainable Energy Reviews, 101*, 527-547. doi:10.1016/j.rser.2018.09.045

Kuhnel, M., Ravanbach, B., Hanke, B., Weigel, O., Stuermer, I. W., McMaster, A., . . . von Maydell, K. (2020). Load predictions: vulnerability of micro-grids based on renewable energies due to increasing population and individual demand. *Iet Renewable Power Generation, 14*(8), 1312-1320. doi:10.1049/iet-rpg.2019.0705

Martin, R. (2020). Making sense of renewable energy: Practical knowledge, sensory feedback and household understandings in a Scottish island microgrid. *Energy Research & Social Science, 66*. doi:10.1016/j.erss.2020.101501

Numminen, S., & Lund, P. D. (2019). Evaluation of the reliability of solar micro-grids in emerging markets - Issues and solutions. *Energy for Sustainable Development, 48*, 34-42. doi:10.1016/j.esd.2018.10.006

Shakya, B., Bruce, A., & MacGill, I. (2019). Survey based characterisation of energy services for improved design and operation of standalone microgrids. *Renewable & Sustainable Energy Reviews, 101*, 493-503. doi:10.1016/j.rser.2018.11.016

APPENDIX A

COMMUNICATION / POSTERS

MONASH University

60 YEARS OF MAKING CHANGE

REDUCE MONASH'S ENERGY CONSUMPTION DURING HIGH DEMAND PERIODS

WE'RE EXPLORING WAYS TO REDUCE MONASH'S ENERGY CONSUMPTION DURING HIGH DEMAND PERIODS

WHAT IS HAPPENING?

Between 17 - 30 May, we are testing different air temperatures in this building. You may notice slightly higher or lower ambient air temperatures than normal.

WHY IS THIS HAPPENING?

At certain hotter or colder times of the year, we use significantly more energy to heat and cool our buildings on campus. This increase in demand places strain on our local energy network, increasing the chance of power outages that can affect vital services at the University.

By temporarily changing building air temperatures (1-2 degrees), we can reduce the strains and help Monash reach its goal of achieving net zero greenhouse gas emissions by 2030.

WHAT YOU NEED TO DO?

Nothing much. Just be prepared that there may be changes in building air temperatures during this testing phase (e.g., through different clothing choices) and recognise the Monash community's ambition to achieve net zero emissions by 2030.

Contact Us

E: netzero@monash.edu

CRICOS provider: Monash University 00008C
Produced by: Monash Campus Community Division, May 2021

APPENDIX B

EXAMPLE OF BUILDING OCCUPANT SURVEY

A series of surveys were disseminated in wave 1 and 2. Each survey was tailored to the different buildings included in the trial as well as to the specific target audience – i.e. staff or students. Wave 1 and 2 surveys were largely identical.

Student Survey for Building 92 (Wave 2)

Q1.1 Welcome and thanks for your interest to participate in this survey!

Please ensure you have read the Explanatory Statement attached (If you haven't read it yet, click here). By completing this survey, you are giving your consent to participate in this study.

Q1.2 Monash's Buildings and Property Division are interested in your experience of the air temperature in the general use, office and teaching area of the **Learning and Teaching Building**.

Q1.3 We are interested in your experiences in the past 2 weeks. Specifically, during weeks 11 and 12 of the semester (i.e., Monday 17th May - Sunday 30th May).

Have you spent any time in this area of the building during that time period?

○ Yes

○ No

Q2.1 What time of day were you in this area? Select ALL that apply.

- ☐ Morning (before 11am)
- ☐ Midday (between 11am and 2pm)
- ☐ Afternoon (between 2pm and 5pm)
- ☐ Evening (after 5pm)

Q2.2 What was your **usual** type of activity? Select ALL that apply.

- ☐ Seating (e.g., typing)
- ☐ Standing (e.g., filing)
- ☐ Walking (slow-paced)
- ☐ Walking (fast-paced)/high physical activity

Q2.3 How would you describe your comfort levels in regards to the air temperature?

- ○ Much too cold
- ○ Too cold
- ○ Comfortably cold
- ○ Comfortable
- ○ Comfortably warm
- ○ Too warm
- ○ Much too warm

Q2.4 How much are you willing to accept these air temperatures moving forward?

- ○ Extremely willing
- ○ Very willing
- ○ Somewhat willing
- ○ Somewhat unwilling
- ○ Very unwilling
- ○ Extremely unwilling

Q2.5 Did you engage in any of the following behaviours? Select ANY that apply.

- ☐ Wore an extra layer of clothing to keep warm
- ☐ Wore lighter clothing to keep cool
- ☐ Used a powered heating device to keep warm
- ☐ Used a powered cooling device to keep cool
- ☐ Other behaviour to achieve thermal comfort.
  Please specify: ____

Q2.6 Please indicate your response to the following two statements.
The air temperature had a negative impact on my work performance.

- ○ Strongly agree
- ○ Agree
- ○ Somewhat agree
- ○ Neither agree nor disagree
- ○ Somewhat disagree
- ○ Disagree
- ○ Strongly disagree

Q2.7 The people around me commented on the air temperature being too hot or too cold.

- ○ Always
- ○ Most of the time
- ○ About half the time
- ○ Sometimes
- ○ Never

Q2.8 Some basic information about you.

How old are you?

- ○ Less than 18
- ○ 18 - 39
- ○ 40 - 59
- ○ 60 - 79
- ○ 80+

Q2.9 Your gender

- ○ Male
- ○ Female
- ○ Non-binary / gender diverse
- ○ Prefer not to say

Q2.10 We distributed a similar survey 2 weeks ago. Did you also complete that survey?

- ○ Yes
- ○ No
- ○ Not sure

Q3.1 It would be great if we could link your responses across surveys. To help us do this, while safeguarding your anonymity, please answer the following questions.

What is the first letter of the street you live on?

▼ A (1) ... Z (26)

Q3.2 What are the **LAST two** numbers of your postcode?

____

Q3.3 Day of birth

▼ 1 (1) ... 31 (31)

Q4.1 Have you been in ANY of the following buildings over the past 2 weeks?

14 Rainforest walk

15 Rainforest walk

16 Rainforest walk

21 College walk (and adjacent lecture theatres)

- Yes
- No

Q4.2 Did you see this poster displayed while in this building(s)?

- Yes, I have seen AND read this poster
- Yes, BUT I did not read it
- No, or I don't remember

Q5 That's the end of the survey. Please use the space below to add any comments you may have and press the arrow button to submit your responses.

____

____

____

____

____

APPENDIX C

EXAMPLE OF FACULTY SERVICE MANAGER SURVEY

Net Zero Initiative Trials

Please ensure you have read the Explanatory Statement attached to the email. By completing this survey, you are giving your consent to participate in this study.

Thank you for taking the time to fill out this survey. Your responses will help us monitor the effect and appropriateness of the trials and will be treated as confidential.

Q1 Before we begin, please select the building(s) you manage.

- ☐ Western Science Lecture Theatres Building (Bldg 24), 15 Rainforest Walk
- ☐ Eastern Science Lecture Theatres Building (Bldg 25), 16 Rainforest Walk
- ☐ Technology & Faculty of Science Building (Bldg 26), 14 Rainforest walk
- ☐ Engineering Lecture Theatre Building (Bldg 32), 21 College Walk
- ☐ New Horizons Building (Bldg 82), 20 Research Way
- ☐ Learning and Teaching Building (Bldg 92), 19 Ancora Imparo Way
- ☐ Biomedical Learning and Teaching Building (Bldg 93), 7 Ancora Imparo Way
- ☐ The Woodside Building for Technology and Design (TED; Bldg 94), 20 Exhibition Walk

>>> Dependent on the answer above, respondents were displayed tailored survey questions about occupants in the respective building. Below is the example survey for Western Science Lecture Theatres Building (Bldg 24), 15 Rainforest Walk <<<

Q2 The Net Zero Initiative Trials involved making changes to the heating and cooling in the Western Science Lecture Theatres Building (Bldg 24), 15 Rainforest Walk. Information posters, outlining the trial, were also displayed for occupants in this building. These changes were in place for two weeks from **Monday 17th to Sunday 30th May**.

Q3 Please indicate your level of agreement with the following statements:

BEFORE the trial period, in general occupants seem to have been comfortable with the temperature in the building.

- Strongly agree
- Agree
- Somewhat agree
- Neither agree nor disagree
- Somewhat disagree
- Disagree
- Strongly disagree

Q4 **DURING** the trial period, in general occupants seem to have been comfortable with the temperature in the building.

- Strongly agree
- Agree
- Somewhat agree
- Neither agree nor disagree
- Somewhat disagree
- Disagree
- Strongly disagree

Q5 The following questions are about any changes you may have noticed from the weeks before the trial period to the weeks during the trial period.
To what degree do you feel occupants' comfort levels **changed** from before the trial period to during the trial period?

- Became much more comfortable
- Became somewhat more comfortable
- About the same amount of comfort
- Became somewhat less comfortable
- Became much less comfortable

Q6 To what degree have the number of complaints or requests (regarding the temperature) **changed** from before the trial period to during the trial period?

- ○ Much more complaints or requests
- ○ Somewhat more complaints or requests
- ○ About the same amount of complaints or requests
- ○ Somewhat less complaints or requests
- ○ Much less complaints or requests

Q7 Please indicate your level of agreement with the following statements:

The tested changes in temperature and display of posters would be appropriate in this building at selected times moving forward.

- ○ Strongly agree
- ○ Somewhat agree
- ○ Neither agree nor disagree
- ○ Somewhat disagree
- ○ Strongly disagree

Q8 The approach of changing temperatures and displaying posters would be appropriate across **other** campus buildings at selected times.

- ○ Strongly agree
- ○ Somewhat agree
- ○ Neither agree nor disagree
- ○ Somewhat disagree
- ○ Strongly disagree

Q9 Do you have any comments to explain your responses above or want to mention anything else that we should know?

____

____

____

____

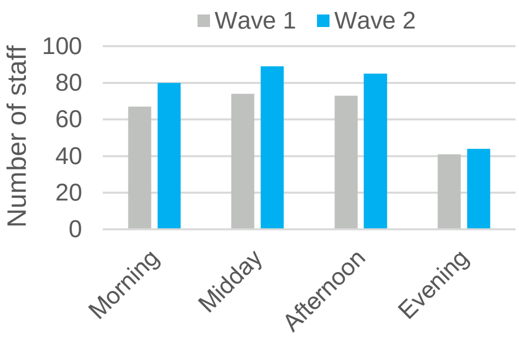
APPENDIX D

BUILDING 82: NEW HORIZONS BUILDING

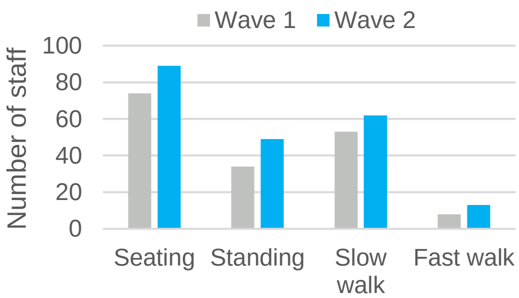
Intervention: Pre-heating

Number of included surveys: 176
Staff wave one: 77
Staff wave two: 99
Student wave one: 0
Student wave two: 0

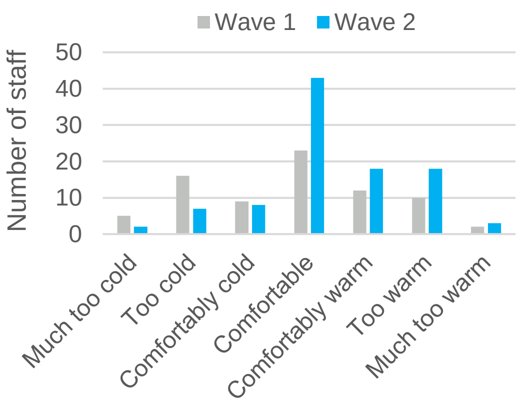
When are occupants in this building?



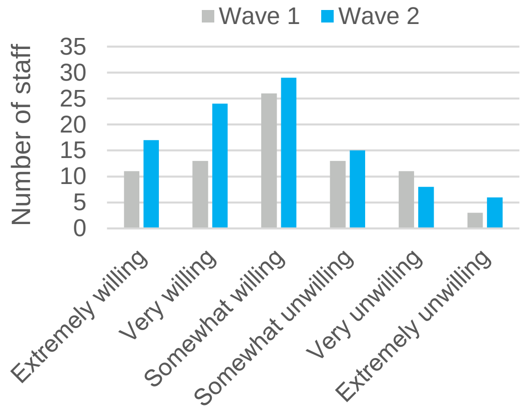
What are occupants doing in this building?



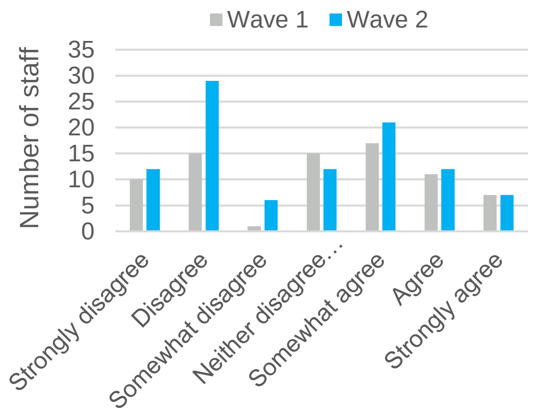
How comfortable are occupants in this building?



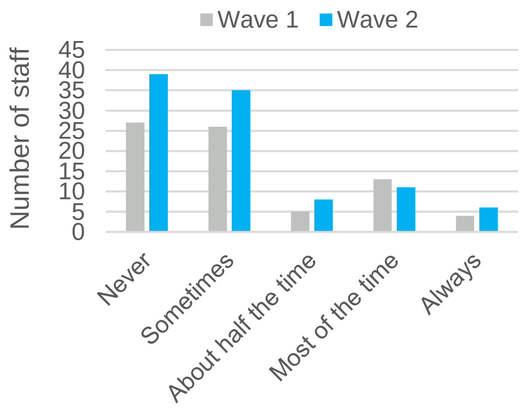
How much are occupants willing to accept these temperatures moving forward?



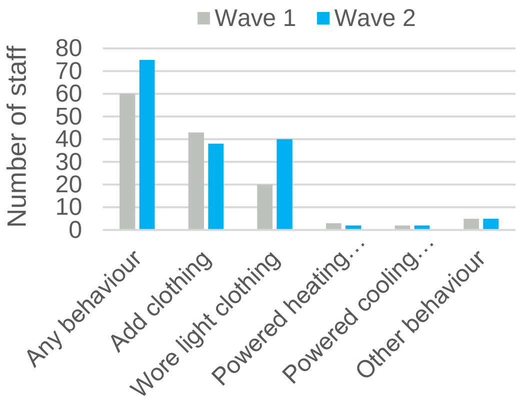
The air temperature had a negative impact on my work performance . . .



The people around me commented on the air temperature being too hot or too cold . . .



What behaviours did occupants adopt to manage thermal comfort?

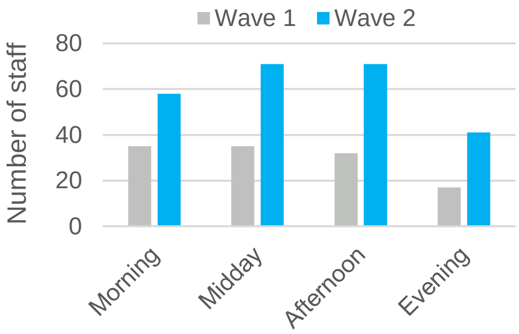


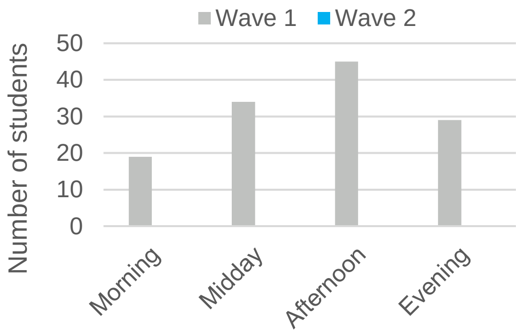
BUILDING 94: WOODSIDE BUILDING

Intervention: Pre-heating

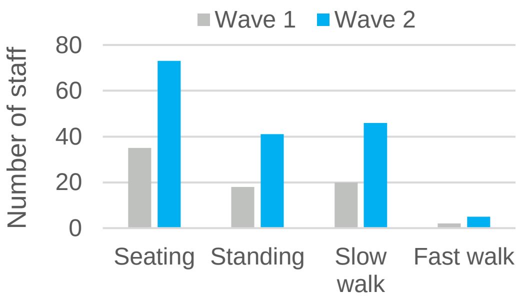
Number of included surveys: 160
Staff wave one: 36
Staff wave two: 75
Student wave one: 49
Student wave two: 0

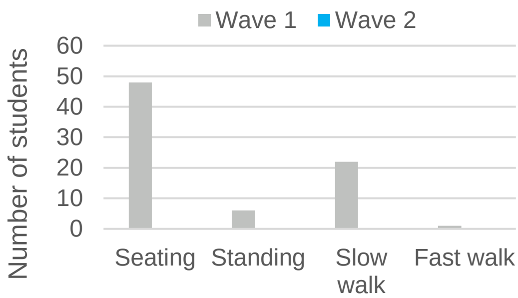
When are occupants in this building?



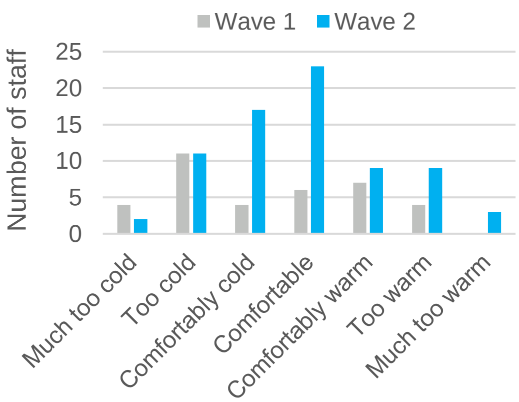


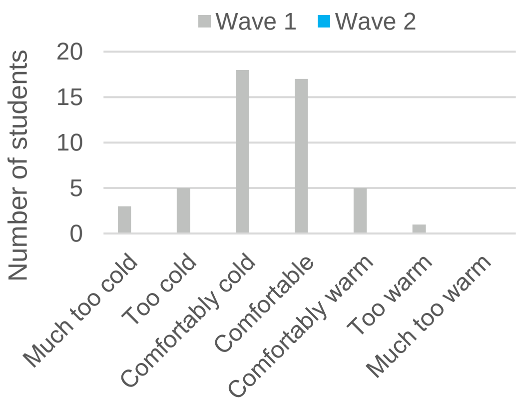
What are occupants doing in this building?



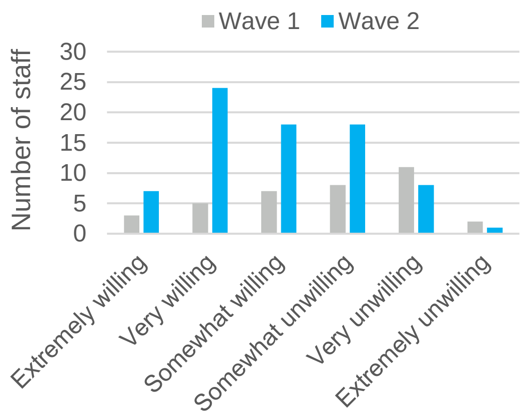


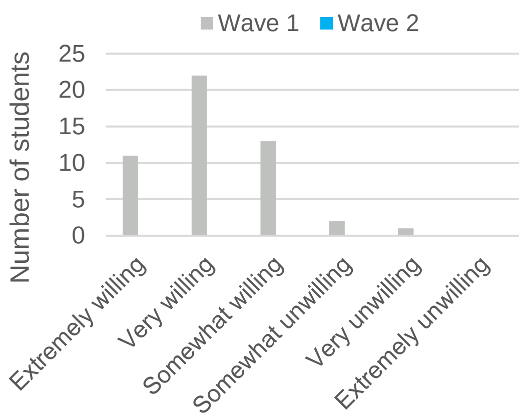
How comfortable are occupants in this building?



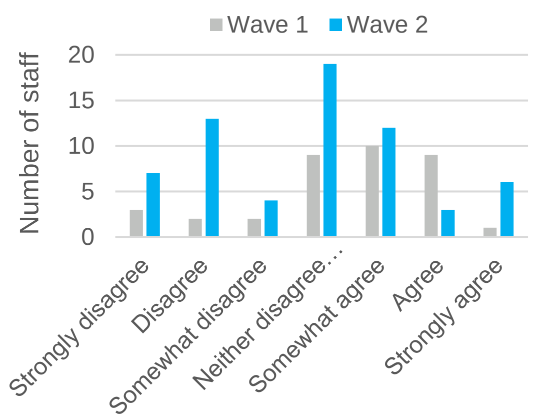


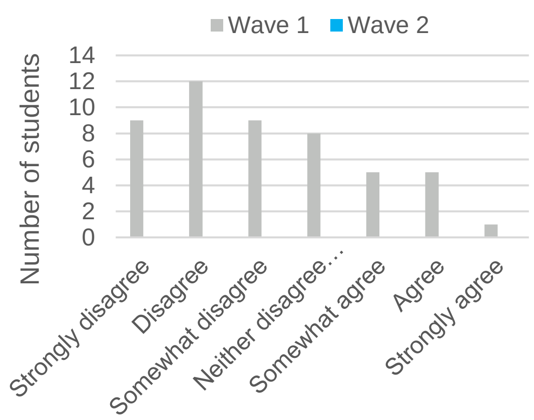
How much are occupants willing to accept these temperatures moving forward?



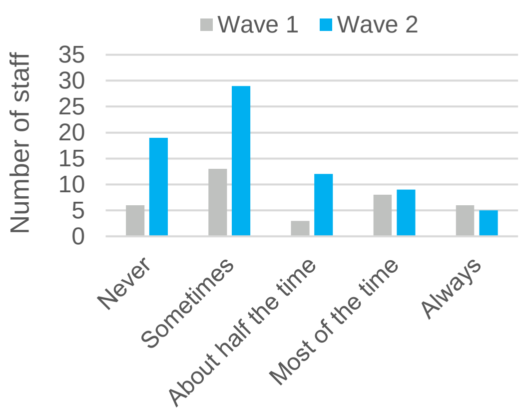


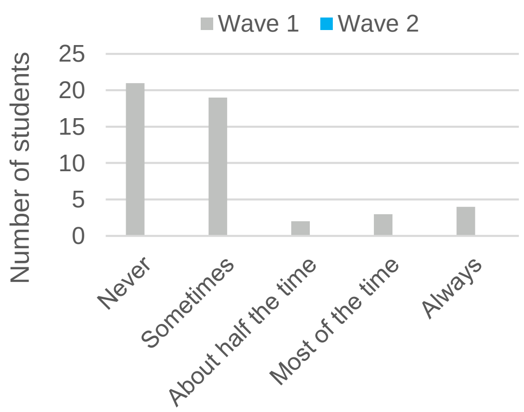
The air temperature had a negative impact on my work performance . . .



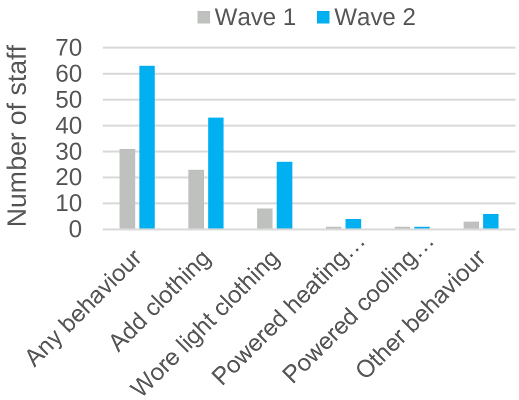


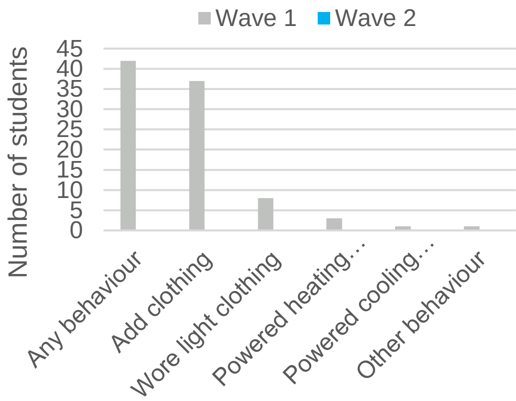
The people around me commented on the air temperature being too hot or too cold . . .





What behaviours did occupants adopt to manage thermal comfort?



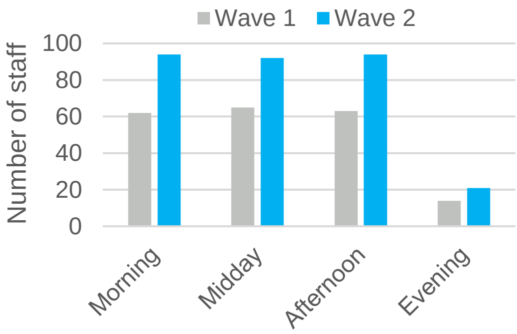


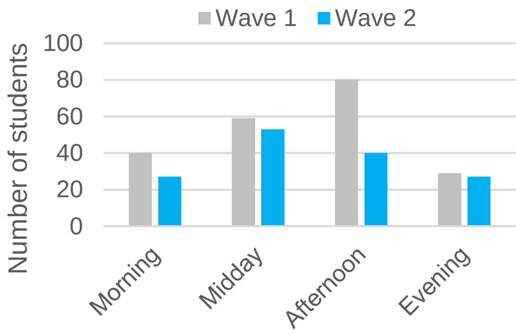
BUILDING 92: LEARNING & TEACHING BUILDING

Intervention: Widen dead band

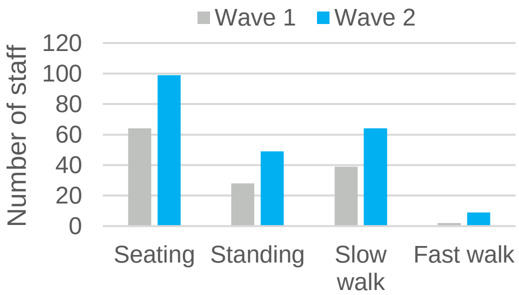
Number of included surveys: 329
Staff wave one: 66
Staff wave two: 102
Student wave one: 91
Student wave two: 70

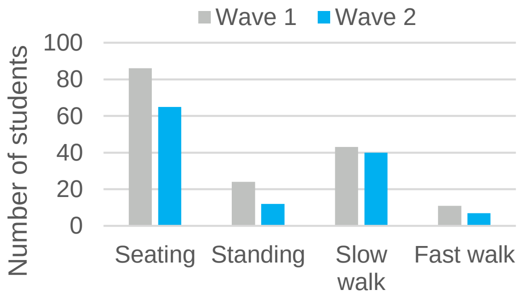
When are occupants in this building?



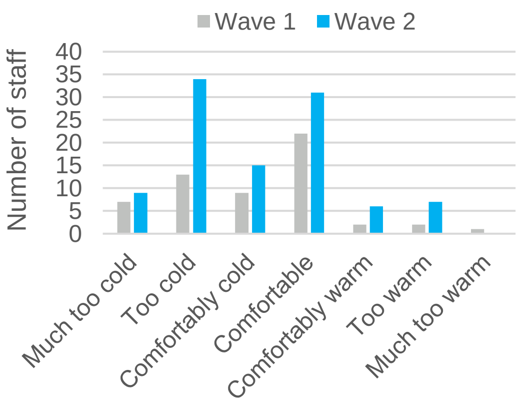


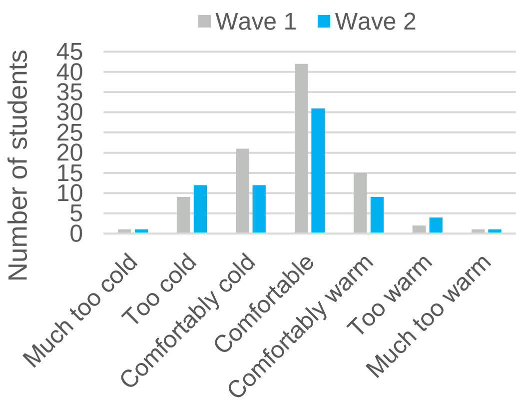
What are occupants doing in this building?



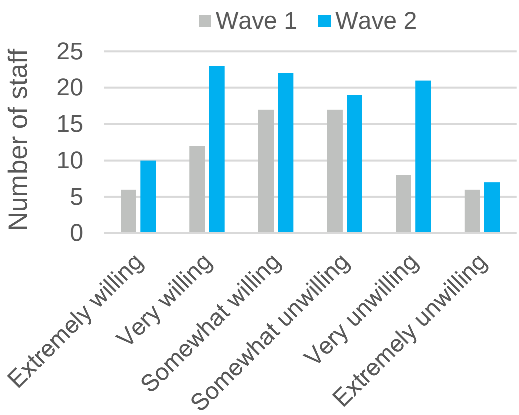


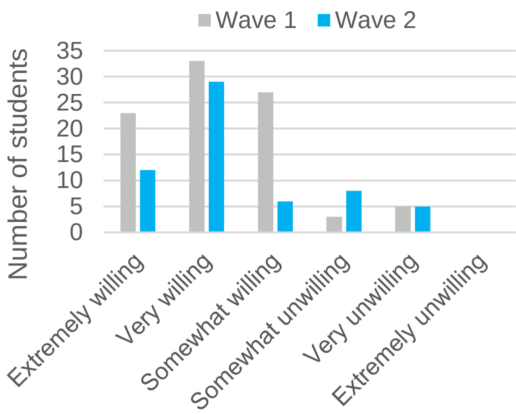
How comfortable are occupants in this building?



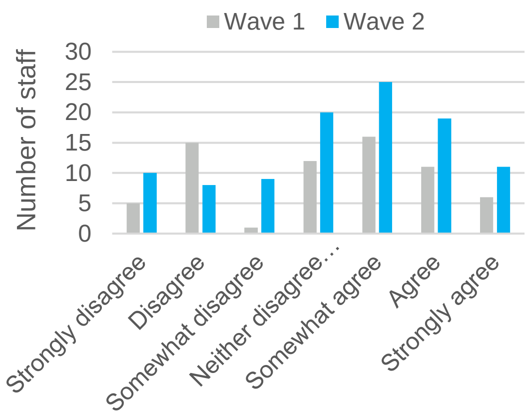


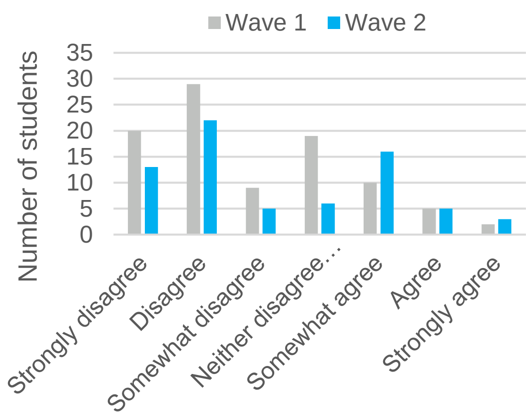
How much are occupants willing to accept these temperatures moving forward?



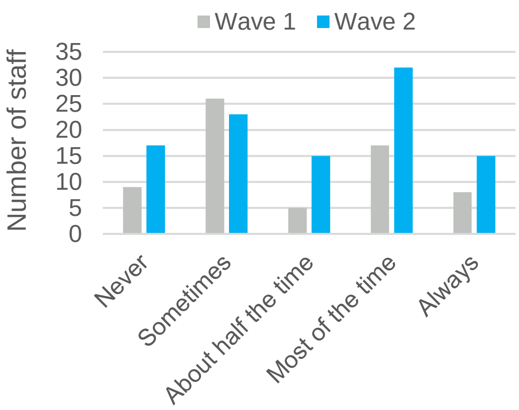


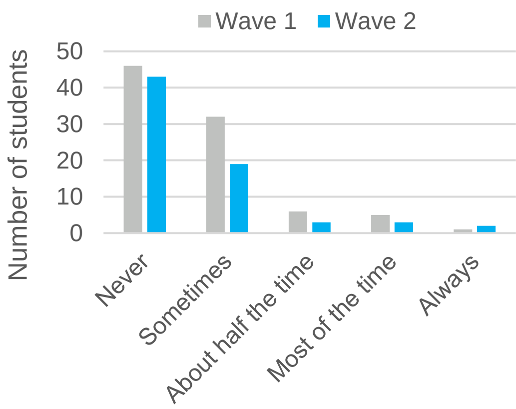
The air temperature had a negative impact on my work performance . . .





The people around me commented on the air temperature being too hot or too cold . . .





What behaviours did occupants adopt to manage thermal comfort?