Demand Flexibility Case Study

SUSTAINABLE BUILDINGS RESEARCH CENTRE
UNIVERSITY OF WOLLONGONG

1. Introduction

Demand Flexibility is when energy consumption is shifted to a different time of the day (e.g. consuming electricity closer to midday – to take advantage of abundant low-cost solar power – rather than consuming electricity at peak demand times on hot summer afternoons/evenings).

Demand flexibility can reduce peak demand on the power grid, lower energy bills for customers and reduce greenhouse gas emissions.

Flexible Assets are those pieces of equipment, in a building, that can shift their energy consumption without impacting on building services. This often takes advantage of the ability of equipment to store energy. Some flexible assets available in non-residential buildings include:

- Hot water,
- Heating, Ventilation and Air-Conditioning (HVAC) systems,
- Batteries, and
- Electric vehicles.

2. Description of the case study building

The case study was carried out at the University of Wollongong (UOW) Sustainable Buildings Research Centre (SBRC) (Figure 1). It demonstrates how an HVAC system can provide demand flexibility, without impacting on occupant thermal comfort.

The SBRC building is an office building and living laboratory, designed with sustainable principles to achieve net zero energy and net zero water. It was the first building in Australia to achieve Living Building Challenge accreditation.

Figure 1 Street view of the SBRC building. Photo by Aristo Risi, University of Wollongong

3. Demand Flexibility Strategy

Demand flexibility was achieved by modulating the temperature setpoint in the SBRC. During normal cooling mode operation, the building operates with an indoor temperature set-point of 24.5°C. When called to provide demand flexibility, the cooling temperature set-point was increased to 25.5°C between 13:00 and 20:00 hrs. The 1°C increase in set-point reduces electricity demand during these hours (which also corresponds with peak time-of-use electricity tariffs for UOW). After the event is over, the set-point is returned back to 24.5°C.

The HVAC power consumption, cost savings and CO_2 emissions reduction values during the demand flexibility intervention event were then compared to those values that would have occurred without the demand flexibility intervention. The without-intervention values (i.e. 'baseline' values) are calculated based on known historical performance under the same weather conditions.

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4. Energy Emissions and Cost Savings Results

Figure 2 shows the power consumption of the HVAC system during a demand flexibility intervention event, and compares it with the expected baseline consumption. The power reduction can be seen around 13:00 when the indoor temperature set-point is increased.

Table 1 compares the HVAC power consumption, energy costs and CO_2 emissions over the test day - both for the measured demand flexibility intervention day and the calculated baseline day.

For the test day, the demand flexibility intervention achieved a cost saving of $7.44 (29%) and a CO_2 emissions reduction of 32%.

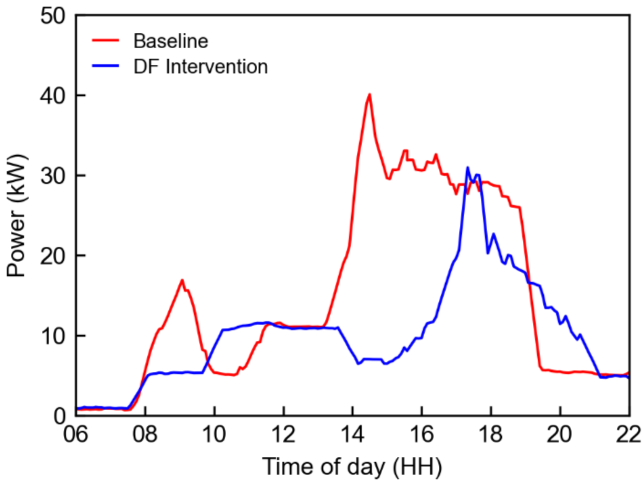

Figure 2 HVAC power consumption profile of the building during its baseline compared to an intervention event.

The energy savings presented here are specific to the test day and will vary from day to day. There is also inherent statistical uncertainty in the baseline prediction. As a result, the reduction in power consumption is not always as clear as seen in Figure 2, and the savings presented in Table 1 are not necessarily representative of average year-round savings.

However, across many test events at UOW, the demand flexibility intervention has consistently demonstrated the potential to save costs, reduce energy consumption and reduce CO_2 emissions. Ongoing UOW testing will provide more statistically conclusive expectations of savings under different weather and HVAC operational scenarios.

Table 1 The energy consumption, cost savings and CO2 emissions measured over a baseline and demand flexibility intervention event.

	Energy consumption (kWh)	**Cost ($)**	**CO_2 emissions (kg)**
Baseline	248.78	25.51	196.54
DF Intervention	168.28	18.07	132.94
Reduction Ratio	32.36%	29.17%	32.36%

As the electricity grid shifts toward increasing use of solar energy, there will be abundant low-cost, zero-emissions electricity in the middle of the day. In contrast electricity at the beginning and end of the day will likely continue to be high-cost high emissions electricity. Hence, to truly measure the CO_2 emissions, we need to compute emissions based on hourly grid carbon emissions factors (rather than average annual emissions factors).

A comparison of the hourly based CO_2 emissions between the baseline and the demand flexibility intervention event can be seen in Figure 3.

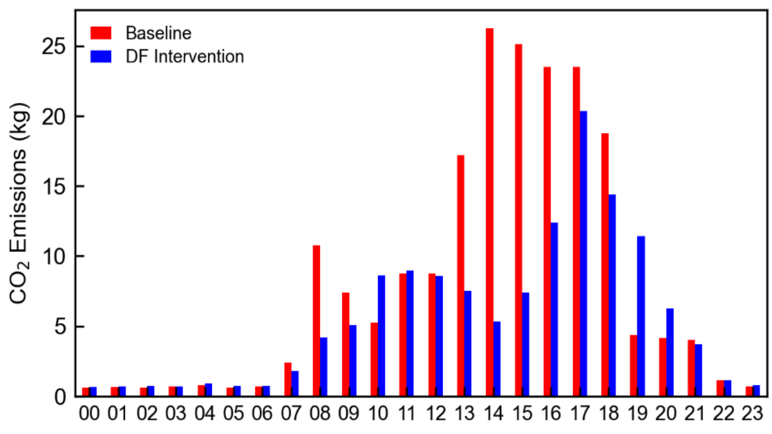

Figure 3 Hour by hour CO2 emissions from the building for the baseline and during the demand flexibility intervention event.

5. Occupant Comfort Findings

Figure 4 illustrates variations in indoor air temperatures, in different thermal zones of the building during the demand flexibility event. It shows that there is significant variability in the temperatures experienced across the SBRC, with the first floor generally being hotter than the ground floor. It also shows that the temperatures in the zones respond somewhat coarsely to the setpoint change, and rarely reach the exact global temperature set-point.

Surveys were conducted during both demand flexbility intervention and non-intervention (baseline) periods of operation. The aim was to see if there are any differences in the building occupants' thermal comfort experience. The thermal comfort surveys were obtained in the morning (before the event) and afternoon (after the event). An average of 12 occupants responded in each survey.

Figure 5 presents the occupant survey results on a 7-point scale. It shows that similar comfort results were observed in the morning and afternoon, and during an event. The survey found no evidence of occupants feeling any obvious change in indoor thermal comfort, due to the increase in the temperature set-point by 1°C. These findings are consistent with PMV calculations done using ASHRAE Standard 55-2023.

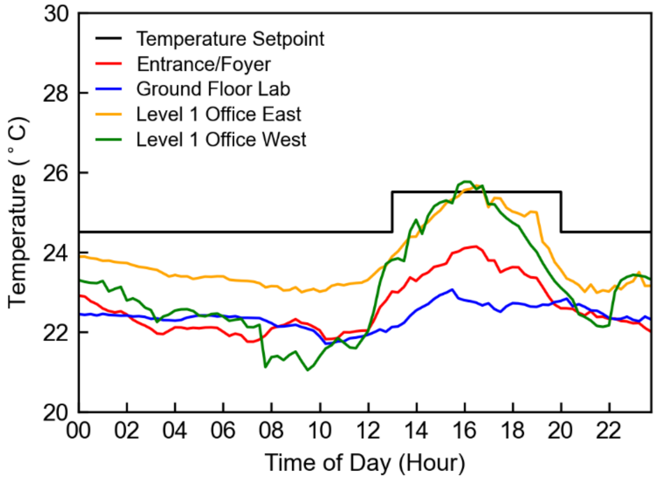

Figure 4 Average indoor temperature of various zones and the temperature set-point during the demand flexibility intervention.

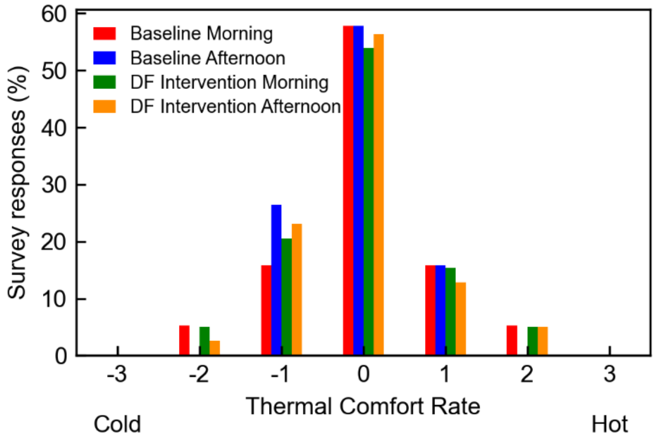

Figure 5 Survey responses for each thermal comfort rating collected during demand flexibility intervention and non-intervention periods. -3 represents cold and 3 represents hot. Responses collected in the "Intervention Morning" do not involve any change in conditions as the intervention was only performed in the afternoon.

Acknowledgements

This case study is conducted by the University of Wollongong in collaboration with CSIRO, as part of the NSW Digital Infrastructure for Energy Flexibility (DIEF) project.

Supported by

NSW GOVERNMENT

This project is funded by the NSW Government in association with CSIRO, under the Net Zero Plan Stage 1: 2020-2030.

Project partners

CSIRO, amber, DNA Energy, EVSE, NUBE iO, RACE for 2030, UNSW Sydney, University of Wollongong Australia, wattwatchers