

Post-Occupancy Evaluation of the Salus Karen's Place Supportive Housing Project

Introduction

Public, not-for-profit, co-operative and private rental housing that serves populations experiencing vulnerabilities is typically least able to afford the incremental costs of energy efficiency measures. Yet these types of housing can be most susceptible to energy poverty and the impacts of climate change. Further, the organizations that provide for the units do not typically have the R&D capacity to support the research needed to identify cost-effective strategies to reduce energy consumption and emissions. Understanding how well Passive House approaches work to achieve energy cost savings and durability goals and to determine whether the design targets were achieved, whether the innovative equipment operated as intended, whether the occupants were comfortable, and whether management were satisfied with the building operation and performance are important to know. This type of data informs housing providers on improvement opportunities and course correction pathways to optimize the performance of their buildings and to fully realize energy and cost savings. Documenting successful practices and challenges also helps CMHC to develop a better understanding of opportunities and barriers to increasing housing affordability and environmental sustainability. Further, this work provides the building industry with lessons learned and potential strategies of how to facilitate resilient building design, occupant comfort and efficient building operation.

Karen's Place, owned and operated by Ottawa Salus Corporation, is a four-storey, 42-unit apartment building that provides supportive housing to adults living with mental illness and concurrent challenges. Ottawa Salus Corporation is a recognized provider of assisted housing, including both rental housing and social supports. In keeping with the focus on community and life skills, Salus Karen's Place provides communal amenity spaces on the ground floor, including common room, kitchen, laundry, exterior yard and sunporch to foster a supportive environment for residents. A deep commitment to energy efficiency and durability was identified in the development of Salus Karen's Place, as annual energy and operational cost savings can be directly reinvested into supportive programs for the clients it serves.

Given the commitment to energy efficiency, the building was designed to Passive House standards, which prioritize an exceptionally well-performing building envelope with high levels of insulation, avoidance of thermal bridges, high-performing windows and very high overall airtightness. The design incorporates hot water heating with supplemental electric baseboards, cooling through a rooftop chiller and carefully designed ventilation and energy recovery systems. The Passive House design approach implemented at Salus Karen's Place is applicable to many similar multi-unit residential buildings to significantly reduce annual energy use and operating costs, which in turn increase the long-term affordability of the housing units and the level of social support programs that can be offered to residents.

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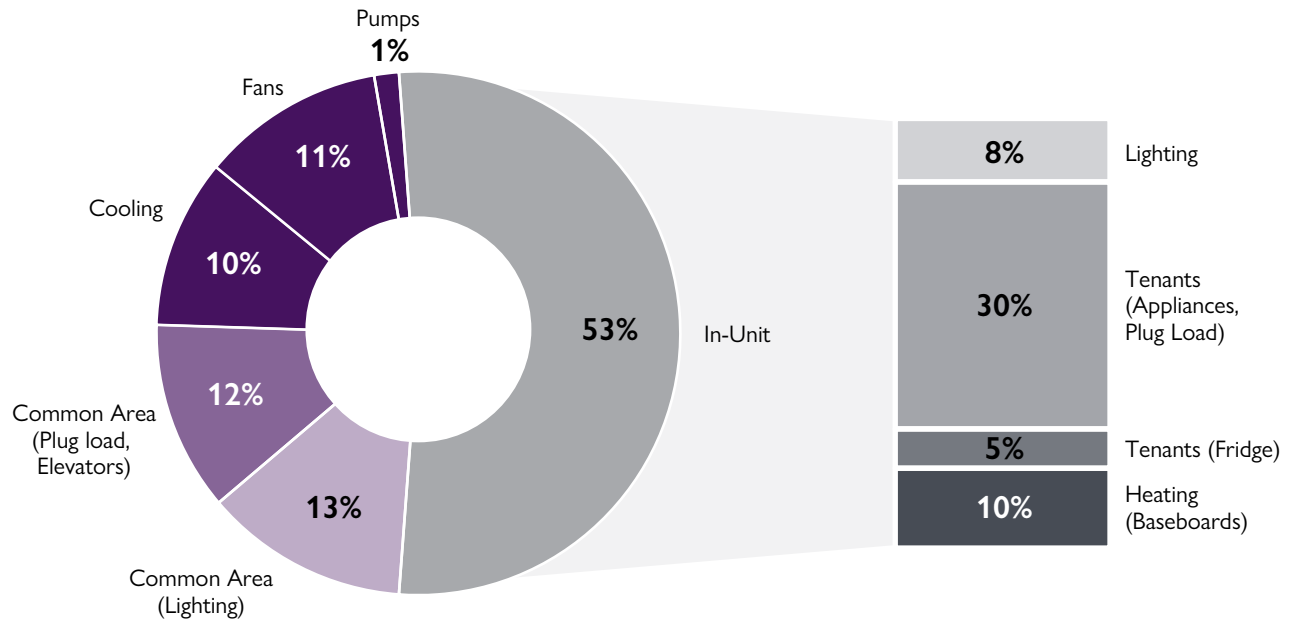
Project Overview

The owner and design team for Salus Karen's Place set out to achieve ambitious energy consumption reduction targets by seeking, and attaining, Passive House certification. To understand the extent to which performance targets were achieved, CMHC commissioned a post-occupancy evaluation (POE) project to characterize energy, water, acoustic and indoor air quality performance, to benchmark performance relative to recognized standards, to assess overall occupant satisfaction, and to identify opportunities for performance improvements. The building was completed and fully occupied in late 2016 and March 2017, respectively. In 2018–2020, for two, one-year monitoring periods (January–December 2018 and January 2019–January 2020), CMHC funded a POE study of the project.

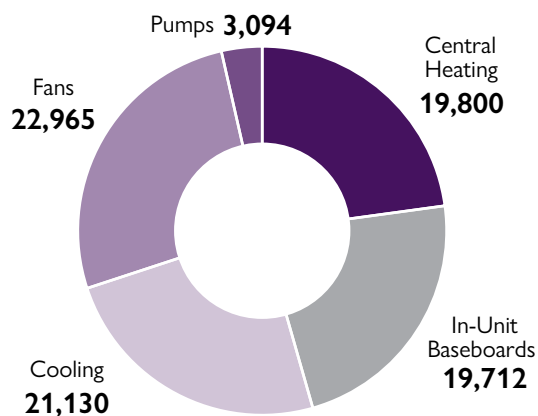
Key Findings

Salus Karen's Place demonstrated high performance in most of the POE performance areas; however, there were challenges maintaining thermal comfort during the cooling season.

To determine the end-use breakdown of electricity consumption in the building, lighting and key electrical equipment and appliances were inventoried during the building walk through. The results were used to calibrate the building energy model used to determine the end-use profiles (figure 1). HVAC systems (heating, cooling, pumps, fans, air-conditioning units) represented 33% of total 2019 electricity use. In-suite appliances were the next largest sources of consumption. In-apartment electricity use represented 53% of all electricity consumption in the building (excluding room air-conditioners).

Figure 1: Salus Karen's Place Electricity Consumption by End-Use

Supplemental heating provided by the electric baseboards represented 10% of electricity use in the building. The calibrated building energy model identified that approximately 50% of the building's heating needs were provided by the in-unit baseboard supplemental heating (figure 2).

Figure 2: Calibrated Energy Model Results
Energy Use (Measured in ekWh) by HVAC Equipment

Sources: xxxxxxxx

Envelope performance: The building envelope exceeded the Passive House standard for insulation values ([table 1](#)) and airtightness ([table 2](#)). Insulation values were depicted by U-values—the ability of an element to transmit heat from a warm space to a cold space and vice versa. The lower the U-value, the better insulated the building element. Airtightness was measured using the air change rate unit. The air change rate is a measure of the air volume added to or removed from a space in one hour, at a given indoor-outdoor air pressure difference, divided by the volume of the space. On-site air leakage, thermal imaging, visual inspection, and smoke tracer tests verified that the envelope maintained its integrity over the initial years of building occupancy.

Table 1: Modelled U-values by building component

Building Component	Design U-Value (W/m ² K)	Passive House Guidelines ¹ (W/m ² K)	Ontario Building Code ² (W/m ² K)
Roof	0.075	0.15	0.156
Above-grade walls	0.11	0.15	0.247
Below-grade walls	0.12	0.15	0.247
Exposed floors	0.11	0.15	0.183
Slab	0.11	0.15	-
Whole window (installed)	0.8	≤ 0.8	1.9

Table 2: Airtightness results before and after occupancy and comparison to key benchmarks

	Salus Karen's Place (before occupancy)	Salus Karen's Place (after occupancy)	Passive House Standard	Net-Zero Energy
Air changes per hour*	0.4 ACH@50 Pa	0.44 ACH@50 Pa	≤ 0.6 ACH@50 Pa	1.0 ACH@50 Pa

* The test was not conducted using standard blower door testing procedures. Instead, these results were generated by pressurizing the building using the ventilation system. The building pressurization test procedure was based on ASTM Standard E-779-99. For full methodology and results, refer to appendix G of the full post-occupancy evaluation report by following the link under 'For Further Reading' on page 9.

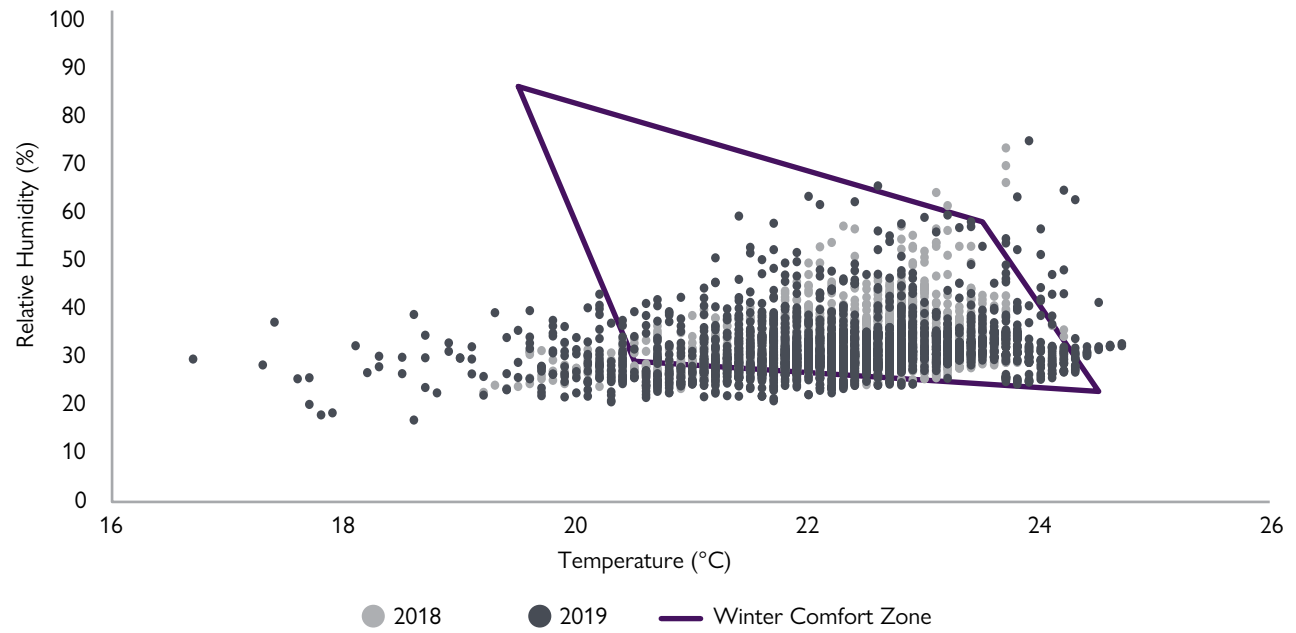
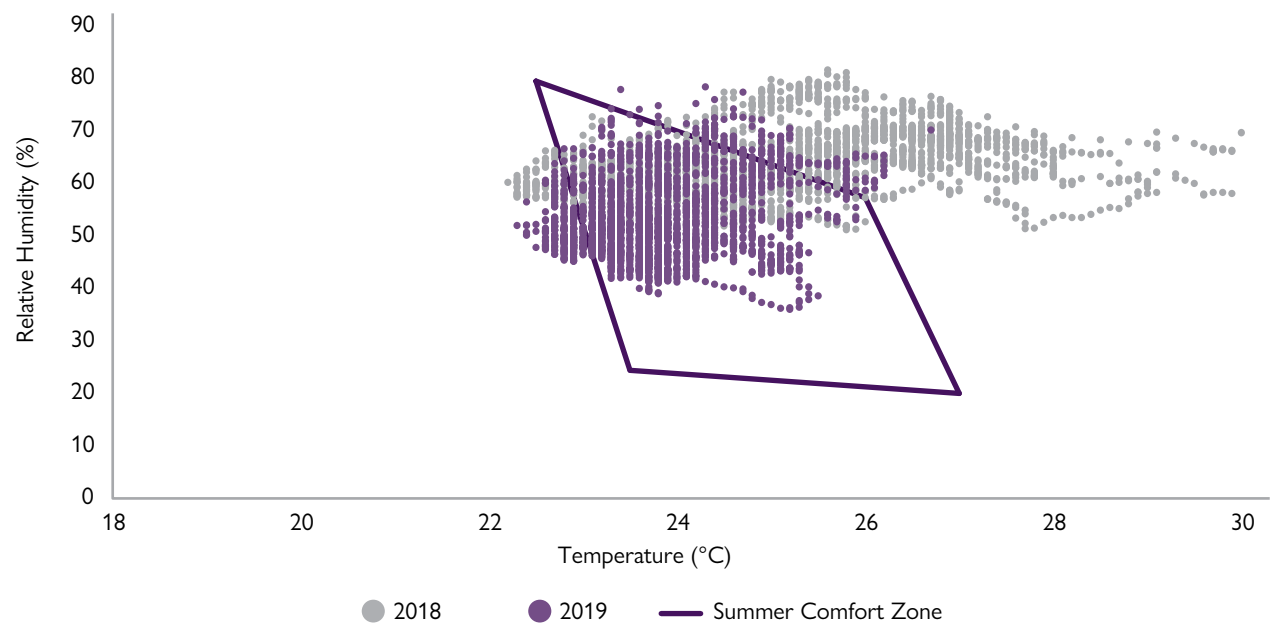
It is important to note that the test used to generate the results in the above table is not as accurate as the standard blower door test. The above test should not be considered equal to the blower door test, but rather aims to provide a high-level estimate of the exfiltration rate. The major limitation of the above test was that the HVAC equipment in place was not able to generate sufficient outdoor air flows and static pressure for a proper pressurization or depressurization to perform an accurate testing.

Thermal comfort: Salus Karen's Place experienced overheating challenges in summer 2018 and steps were taken to remedy the situation through upgrades to the cooling and ventilation systems. Despite these upgrades, the building

experienced similar overheating challenges in 2019. It should be noted, however, that temperature, relative humidity and CO₂ were measured during limited periods in three apartments on the middle and top floors. These measurements were further bolstered by the temperature data collected from each apartment using the building automation system. Winter measurements were taken from January 24 to February 7, 2018, and from January 17 to February 1, 2020. Summer measurements were taken from July 24 to August 24, 2018, and from August 8 to September 8, 2019. The following demonstrates both winter and summer temperature and relative humidity measurements for the same unit. For full results, please consult the [full report](#).

¹ Passive House Canada. (2017). *Developer's Guide to Passive House Buildings*. Retrieved from: <https://www.passivehousecanada.com/passive-house-resources/>

² Ontario Ministry of Municipal Affairs and Housing. (2016). *Ontario Building Code SB10-2017, Div.3, Chapter 3, Zone 6*.

Figure 3: Winter Thermal Comfort Performance for East-Facing Unit**Figure 4: Summer Thermal Comfort Performance for East-Facing Unit**

Overall, the following observations were made:

- *Winter 2019 thermal comfort was impacted by dryness* but showed improved temperature levels compared to 2018, with most falling within targets. The tenant survey indicated that occupants tended to be satisfied with the conditions.
- *Summer 2019 thermal comfort was impacted by the limited cooling and ventilation systems.* Despite the steps taken in the latter half of 2018 to remedy the situation, which resulted in a slight improvement in 2019, additional room air-conditioners were required once more to reduce temperature levels in the upper units.
- To evaluate the building's thermal comfort performance, the summer in-unit temperature and relative humidity (RH) measurements were repeated during Phase 2 in summer 2022.

Indoor air quality: Indoor carbon dioxide (CO₂) was measured as an indicator of building ventilation system effectiveness and air quality. Overall, CO₂ levels appeared to stay mostly within the targeted range, suggesting that ventilation rates were adequate within the units. Summer CO₂ concentrations appeared to be notably lower than winter concentrations, likely due to residents opening their windows. The readings from one unit were significantly over target during the second winter monitoring period because the occupant had manually obstructed the air supply inlet. Another occupant survey would have to be conducted to reveal if this was an isolated behaviour or if the increased ventilation rates put in place to address overheating might have created new discomfort due to additional drafts. The survey could also provide feedback on the frequency of air filter replacements put in place to reduce unpleasant cigarette odours. The following table (table 3) demonstrates an average of summer and winter values, along with the standard deviation associated with each. For full results and graphs pertaining to each unit, please consult the [final report](#) in the link on page 9.

Table 3: Average summer and winter measured CO₂ concentrations

		CO ₂ Concentration (ppm) – 2018	CO ₂ Concentration (ppm) – 2019
Summer	Average	529	565
	Standard deviation	89	149
Winter	Average	685	802
	Standard deviation	123	200

Water consumption: Water consumption was found to be significantly lower than the Canadian average on a per capita basis, and significantly lower than the benchmark on an area basis, despite a slight increase in water consumption in 2019 (table 4). Given the single occupancy of each unit in the building, the low water consumption relative to the benchmark was to be expected.

Table 4: Salus Karen's Place annual water use relative to relevant benchmarks

	Salus	Benchmark
Per capita consumption (m ³ /year)	65.6	91.6 ³
Per m ² of living space (m ³ /year)	1.11	2.0 ⁴

Energy consumption: Overall, Salus Karen's Place demonstrated an efficient use of energy over the initial years of its occupancy. It generally came close to meeting its energy use targets and used much less energy than many of the key benchmarks (table 5).

Table 5: Comparison of Salus Karen's Place energy use intensity (EUI) to key benchmarks

Salus Karen's Place	Design Modelling	2017 Actual Performance	2018 Actual Performance	2019 Actual Performance	Passive House Standard	Standard MURB: CMHC ⁵
Site EUI (ekWh/m ²)	-	103	115	121	-	212
Source EUI (ekWh/m ²)	113	167	189	196	120	-

Table 6: Comparison of Salus Karen's Place energy use intensity (EUI) to key benchmarks

	Salus Karen's Place Design Modelling ⁶	Salus Karen's Place Actual Performance	Passive House Standard*	OBC (NECB 2015 part 8)
Heating EUI (ekWh/m ² /yr)	14	16	15	41

* Heating or cooling demand is the annual heating or cooling energy demand for space conditioning within the Passive House boundary per square metre of treated floor area (kWh/m²_{TFA}/yr). This is the amount of heating or cooling energy output from all types of heating or cooling equipment.

³ Environment and Climate Change Canada. (2011). *Residential Water Use*. Retrieved from: <https://www.canada.ca/en/environment-climate-change/services/environmental-indicators/residential-water-use.html>

⁴ CMHC. (2001). *Research Highlight: Analysis of the Annual Energy and Water Consumption of Apartment Buildings in the CMHC HiSTAR Database*. Ottawa, ON: CMHC.

⁵ *Ibid.*

⁶ Performance path results as calculated by CSV Architects for the Salus Building.

- The tight, well-insulated, building envelope helped to keep heating energy use low, but also led to increased cooling needs: The heating load is 6% higher than the Passive House standard. On the other hand, cooling needs represented 7% of total energy consumption in 2019, which is in the same range as other multi-residential buildings in Ottawa's climate.
- Further monitoring of the building is needed to evaluate its energy performance under normal operations that maintain acceptable summer thermal comfort thresholds: Ongoing monitoring of the makeup air temperature is important to ensure that the most recent measures solve the overheating issues. Since the increased chiller capacity did not entirely alleviate all overheating concerns, the 2022 summer season will be decisive in determining the final building operation conditions in Phase 2 of the project.

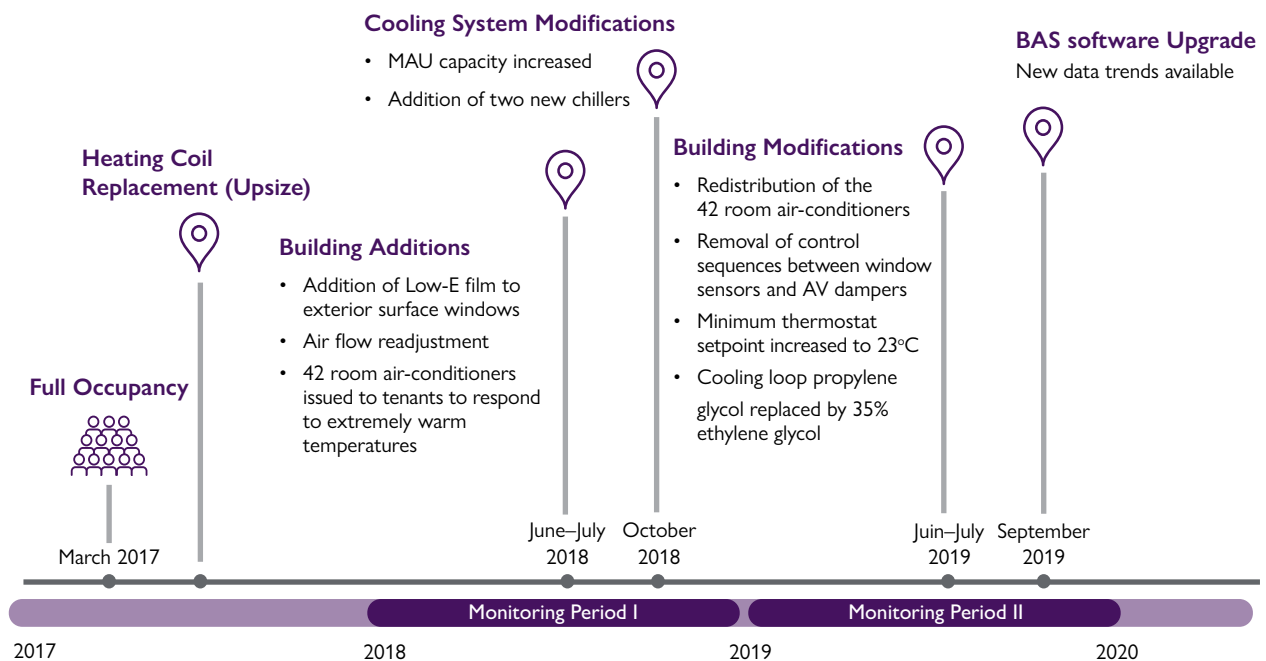
The study consists of two monitoring periods resulting from several changes made to the building systems midway through the POE period (figure 5).

Fast Facts

- This project is the first multi-unit residential Passive House project in Canada.
- It is one of the few* multi-unit residential buildings certified by Passive House Canada.
- It was North America's largest* project built to the International Passive House standard.
- It is the first affordable housing project to achieve the Passive House standard in North America.

*at the time of construction.

Figure 5: Timeline of Modifications to Address Overheating in Phase 1 of the Study



Implications for the Housing Industry

The research demonstrates that achieving low energy and/or low emissions is very possible in a larger building, such as this one, even on an affordable housing budget. This POE also showed that well-insulated, airtight envelopes and low window-to-wall ratios may not be sufficient to prevent overheating and additional cooling may be needed along with passive cooling strategies. Further commissioning of the building's cooling system at the outset may have mitigated the challenges that were encountered later. As well, the ventilation strategy worked and maintained good indoor air quality and comfort conditions to balance the airtightness of the building.

Overall, this POE provided an opportunity to assess performance against targets and to find out how performance (and costs) could be improved. It helped identify potential corrective measures, such as the undersized cooling system in this case, to achieve higher performance and ultimately support the reduction of operating costs, thereby generating affordability both for providers and tenants alike. By regularly conducting POEs, affordable housing providers get options to find innovative solutions to long-term planning and affordability.

Project Managers



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Full Report

Post-Occupancy Evaluation of the Salus Karen's Place Supportive Housing Project, August 2020

https://eppdscrmssa01.blob.core.windows.net/cmhcprodcontainer/sf/project/archive/research_6/salus-poe-final-report_final.pdf

Further Reading

Low-Energy Buildings — Karen's Place

<https://assets.cmhc-schl.gc.ca/sites/cmhc/professional/housing-markets-data-and-research/housing-research/research-reports/housing-needs/low-energy-buildings-karens-place/low-energy-buildings-karens-place-69140-en.pdf?rev=9b2c630d-7e01-41b7-9118-a05fb74a3325>

Housing Research Report — Salus Karen's Place (formerly known as Salus Clementine) Building Profile

https://eppdscrmssa01.blob.core.windows.net/cmhcprodcontainer/sf/project/archive/research_6/salus-karens-place-formerly-known-as-salus-clementine-building-profile.pdf

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Alternative text and data for figures

Figure 1: Salus Karen's Place Electricity Consumption by End-Use

End-use	Total (ekWh)
Common Area (Lighting)	25,543
Common Area (Plug load, Elevators)	23,716
Cooling	21,130
Fans	22,965
Pumps	3,094
Lighting	15,667
Tenants (Appliances, Plug Load)	60,984
Tenants (Fridge)	9,704
Heating (Baseboards)	19,712

Figure 2: Calibrated Energy Model Results: Energy Use (Measured in ekWh)
by HVAC Equipment

End-Use Equipment	Consumption (ekWh)
Central Heating	19,800
In-Unit Baseboards	19,712
Cooling	21,130
Fans	22,965
Pumps	3,094

Figure 5: Timeline of Modifications to Address Overheating in Phase 1 of the Study

Time	Period	Modifications
March 2017		Full Occupancy
June 2017		Heating Coil Replacement (Upsize)
January 2018		Start of the Monitoring Period 1
June–July 2018	Monitoring Period 1	Building Additions <ul style="list-style-type: none"> • Addition of Low-E film to exterior surface windows • Air flow readjustment • 42 room air-conditioners issued to tenants to respond to extremely warm temperatures
October 2018		Cooling System Modifications <ul style="list-style-type: none"> • MAU capacity increased • Addition of two new chillers
December 2018		End of Monitoring Period 1
January 2019		Start of the Monitoring Period 2
June–July 2019	Monitoring Period 2	Building Modifications <ul style="list-style-type: none"> • Redistribution of the 42 room air-conditioners • Removal of control sequences between window sensors and AV dampers • Minimum thermostat setpoint increased to 23°C • Cooling loop propylene glycol replaced by 35% ethylene glycol
September 2019		BAS software Upgrade <ul style="list-style-type: none"> • New data trends available
December 2019		End of Monitoring Period 2