

Post- Occupancy Evaluation

Salus Karen's Place
Supportive Housing
Project

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

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POST-OCCUPANCY EVALUATION (POE) OF THE SALUS SUPPORTIVE HOUSING PROJECT

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ABSTRACT

This report outlines the results of a post-occupancy evaluation (POE) of the Salus Karen's Place Supportive Housing Project completed by Dunsky Energy Consulting for Canada Mortgage and Housing Corporation (CMHC). Salus Karen's Place was completed in late 2016 and was built to high-energy efficiency standards, ultimately achieving both Passive House and LEED Platinum certification. The primary objective of the POE was to assess the building's energy, water, and thermal comfort performance now that it is fully occupied, and to compare it to both the design objectives and recognized benchmarks.

Following the initial POE, further changes were made to the building's mechanical systems to address on-going cooling issues and provide adequate thermal comfort to the occupants. Given these changes, CMHC requested that Dunsky provide an updated assessment to account for these modifications representing the final building operations. The findings of the updated assessment are included in an addendum to this report.

EXECUTIVE SUMMARY

In 2018, on behalf of CMHC, Dunsky Energy Consulting conducted a post-occupancy evaluation (POE) of the Salus Karen's Place building, which is owned and operated by the Ottawa Salus Corporation. This 42-unit supportive housing project was designed to reduce energy consumption on the site by 66% compared to Ontario Building Code requirements and has achieved both Passive House International (PHI) and LEED Platinum certifications.

The POE applied the approach outlined in the CMHC Post-Occupancy Evaluation Guide¹ to assess the degree to which the building's performance meets the design intent by evaluating six building performance areas:

- Envelope performance
- Thermal comfort
- Indoor air quality
- Water consumption
- Energy consumption
- Acoustic performance

For each performance area, on-site data was collected via metering and an occupant survey. The results were compared to relevant Canadian benchmarks for standard and high-performance multi-unit residential buildings (MURBs). As part of the process, a building energy model was also developed to support detailed analysis of energy end uses. This report outlines the findings for each area and makes recommendations for further evaluation and building operation adjustments.

Salus Karen's Place building description

Configuration: Salus Karen's Place is a four-storey (above-grade), steel-frame construction MURB. It has 2,485 m² of interior living space featuring 42 single-occupant one-bedroom apartments and 300 m² of common areas.

Envelope: A key feature of Salus Karen's Place is its high-performance building envelope construction, characterized by high airtightness performance and the avoidance of thermal bridges. The envelope has extremely high insulation values due to the use of a structurally insulated panel (SIP) system attached over the building frame and combined with integral air and vapour control. It is equipped with triple-glazed, Passive House-certified windows.

Heating: Space and water heating is provided by two 500,000-BTU/hr gas-fired condensing water heaters located in the building's basement. Each apartment is equipped with a 300-W electric baseboard resistance heater to provide supplemental heating, as needed.

Cooling: Cooling was initially provided by a single 21-kW (6-ton) chiller located on the roof. This was later supplemented by two additional 14-kW (4-ton) chillers.

Ventilation: Fresh air is provided by a make-up air unit (MAU) with an integrated energy-recovery ventilator (ERV). Central heating and cooling are delivered to the building via preconditioned make-up and recirculating airflows. The initial supply fan motor size was 1.5-hp and was replaced by a 2-hp unit when the cooling system was

¹ CMHC, 2017

upgraded. Since there is only one ventilation loop in the building, the system uses a seasonal switchover to change between cooling and heating. The supply fan motor upgrade has therefore increased the building airflow capacity for both seasons.

Findings

Overall, Salus Karen's Place demonstrated high performance in most of the POE performance areas. There were some challenges related to the building's design and **operation**, which are reflected in the POE results.

Envelope performance: Overall, the building envelope for Salus Karen's Place exceeded the Passive House standard for airtightness and insulation values, indicating that the building was constructed to high envelope performance standards. On-site air leakage, thermal imaging, visual inspection, and smoke tracer tests confirm that the envelope maintained its integrity over the initial years of the building's occupancy.

Table ES - 1: Modelled U-values by building component

Building Component	Design U-Value (W/m ² K)	Passive House Guidelines ² (W/m ² K)	Ontario Building Code ³ (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 ES - 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 ACH@50 Pa

Salus Karen's Place had significant thermal comfort challenges in 2018, and steps were taken to remedy the situation through upgrades to the cooling and ventilation system. Despite these upgrades, the building had similar overheating challenges in 2019. Overall, the following observations were made:

- **Winter thermal comfort suffered from dryness**, but showed improved temperature levels compared to 2018, with most falling within targets. Our tenant survey indicated that occupants tended to be satisfied with the conditions.
- **Summer thermal comfort suffered from 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) monitoring will be repeated in the summer of 2021.**

² Passive House Canada, 2017

³ Ontario Ministry of Municipal Affairs and Housing, 2012

Table ES - 3: Percentage of hours over 25°C over the year (2019)

Location	Percentage of hours
Passive House Standard	10%
Common Area	1%
Unit 1	4%
Unit 2	7%
Unit 3	3%
Unit 4	9%
Unit 5	12%

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 reading from one unit was 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 might have created new discomfort due to additional drafts. The survey could also provide feedback on the frequency of filter replacements measure put in place to reduce unpleasant cigarette odours.

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. It is recommended that building water consumption continue to be monitored to ensure that it stays below typical water usage. No improvement measures are suggested for the building at this stage, with the exception of an occupant water conservation awareness program, should the Salus Corporation deem this appropriate for the residents.

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

	Salus	Benchmark
Per capita consumption (m ³ /year)	65.6	91.6 ⁴
Per m ² of living space (m ³ /year)	1.11	2.0 ⁵

Energy consumption: Overall, Salus Karen's Place demonstrated an efficient use of energy over the initial years of its occupancy. It used much less energy than similar buildings but did not meet all its energy use targets.

⁴ Environment and Climate Change Canada, 2011

⁵ CMHC, 2001

Table ES - 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 ⁶
Site EUI (ekWh/m²)	-	103	115	121	-	212
Source EUI (ekWh/m²)	113	167	189	196	120	-

- Impact of building modifications:** Over the course of the POE period, modifications were made to the heating and cooling systems in response to thermal comfort and ventilation issues. Specifically, two additional 14-kW chillers were added to the central HVAC systems, and the 1.5-hp air-handling unit fan was replaced with a 2-hp fan in October 2018. During the summer of 2019, in order to improve the heat transfer, propylene glycol in the cooling loop was replaced by 35% ethylene glycol, which is a better heat transfer fluid. New control sequences were also implemented. Overall, the building modifications slightly improved thermal comfort in the apartments. However, the new equipment and heating/cooling operations resulted in an increase in the use of energy in the building.
- The tight 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, but still much lower than what the Ontario Building Code (OBC) stipulates. 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. It is important to note that, due to ongoing building modifications during the summer monitoring and the addition of temporary room air conditioners (not sub-metered), a new cooling assessment will be necessary to improve the energy model accuracy.
- There are a handful of potential improvements that could be considered by the building owner:** These include HVAC piping and controls upgrades that may be justified more from a thermal comfort perspective rather than by the utility bill savings alone.
- 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 make-up 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 2020 and 2021 summer seasons will be decisive in determining the final building operation conditions.

Acoustics: Overall, occupants appeared to be satisfied with the degree of noise transmission and vibration within their apartments. Some of the residents living on the top floor experienced vibrations in the building that are thought to be due to the building's steel structure moving as a result of passing traffic on the road in front of the building and that likely cannot be mitigated.

⁶ CMHC, 2001

Key take-aways

Based on the POE results of the Salus Karen's Place building, the following key points emerged:

- **When evaluated under full occupancy, the building met the Passive House standards in several categories and outperformed the typical Canadian MURB benchmarks for energy use and envelope performance:** The building exhibited a low energy use intensity, despite the use of supplemental air conditioning during the summer months. Water performance was around 28% better than the Canadian average, and the interior air quality was maintained at adequate levels.
- **Energy use in the building was extremely low for heating, but cooling loads were equivalent to other Canadian MURBs:** The building's high-performance envelope helped minimize heating needs to just 13% of all energy used in the building. However, the building's airtight envelope may be causing it to retain internal heating gains in the cooling season and, as a result, the cooling energy requirements are no better than a typical Canadian MURB, representing 7% of annual energy consumption.
- **Occupant thermal comfort suffered in the summer, and some challenges were also observed in the winter:** The building's extremely airtight and highly insulated envelope, along with its potentially undersized cooling and ventilation equipment, led to thermal comfort challenges in the summer of 2018, with indoor temperatures climbing well above acceptable levels. While the added chillers and the increased ventilation rates improved the occupants' thermal comfort, they did not entirely solve the issue. Moreover, in the winter, 50% of heating was delivered from the supplemental electric resistance baseboards, and humidity levels were lower than the ideal because of the lack of humidification equipment.
- **Corrective actions were taken to address thermal comfort challenges, increasing energy use in the building:** In response to the thermal comfort issues, the building's chiller and ventilation capacities were augmented. The building's energy use intensity increased by 5% compared to 2018 (8% once normalized).
- **POE data gathering will continue until October 2021, and the heating/cooling system cost-benefit analysis will be performed at that time:** Although the cooling system upgrades improved the occupants' thermal comfort in the summer months, comfort issues still occur during prolonged heat-wave conditions (i.e., consecutive days where the outdoor air temperature exceeds 30°C). By late June 2020, the portable air conditioning units had been reinstalled in the units, and the building management is considering taking further corrective actions. This has two implications for the POE. First, it necessitates doing a final cooling season evaluation in the summer of 2021 (after further building improvements have been implemented). Second, it delays the cost-benefit assessment of the integrated heating/cooling systems because there are further system costs that will need to be considered, and the systems do not yet perform to the desired standards.

En 2018, au nom de la SCHL, Dunsky Energy Consulting a mené une évaluation post-occupationnelle (EPO) de l'immeuble Karen's Place, qui appartient et exploité par la corporation Salus d'Ottawa l'entreprise Salus Ottawa. Cet ensemble de 42 logements avec services de soutien a été conçu de façon à consommer 66 % moins d'énergie que ce qu'exige le Code du bâtiment de l'Ontario, en plus d'obtenir la certification de maison passive de la International Passive House Association et la certification LEED Platine.

L'approche retenue dans le cadre de l'EPO est celle qui est décrite dans le guide d'évaluation post-occupationnelle de la SCHL⁷. Cette approche permet d'évaluer dans quelle mesure le rendement du bâtiment respecte l'intention de la conception en fonction des six domaines de rendement du bâtiment suivants:

- Rendement de l'enveloppe
- Confort thermique
- Qualité de l'air intérieur
- Consommation d'eau
- Consommation d'énergie
- Performance acoustique

Pour chaque domaine de rendement, les données ont été recueillies sur place au moyen de compteurs et d'un sondage auprès des occupants. Les résultats ont ensuite été comparés aux points de référence canadiens pertinents pour les immeubles résidentiels à logements multiples (IRLM) standards et à haut rendement. Dans le cadre du processus, un modèle énergétique du bâtiment a également été élaboré pour appuyer l'analyse détaillée des utilisations énergétiques finales. Ce rapport décrit les résultats pour chaque domaine de rendement et présente des recommandations concernant d'autres évaluations pertinentes et des ajustements à apporter en matière d'exploitation du bâtiment.

Description de l'immeuble Karen's Place de Salus

Structure : Karen's Place est un IRLM de quatre étages (au-dessus du niveau du sol) à ossature d'acier. L'immeuble compte 2 485 m² de surface habitable, comprenant 42 appartements d'une chambre pour personne seule et 300 m² d'aires communes.

Enveloppe : L'une des principales particularités de Karen's Place est son enveloppe à haut rendement, qui se caractérise par une grande étanchéité à l'air et par l'absence de ponts thermiques. L'enveloppe présente des valeurs d'isolation extrêmement élevées grâce à un système de panneaux structuraux isolés fixés à l'extérieur de l'ossature du bâtiment et à une couche continue de pare-air et de pare-vapeur. L'immeuble est équipé de fenêtres à triple vitrage certifiées maison passive.

Chauffage : Le chauffage des locaux et de l'eau est assuré par deux chauffe-eau à condensation au gaz de 500 000 BTU/h, situés dans le sous-sol de l'immeuble. Chaque appartement est équipé d'une plinthe chauffante à résistance électrique de 300 W, qui peut fournir un chauffage supplémentaire, au besoin.

⁷ SCHL, 2017

Climatisation : La climatisation a d’abord été assurée par un refroidisseur unique de 21 kW (6 tonnes), installé sur le toit. Plus tard, deux refroidisseurs supplémentaires de 14 kW (4 tonnes) ont été ajoutés.

Ventilation : L’air frais est fourni par un dispositif d’air de compensation avec ventilateur récupérateur d’énergie intégré. La climatisation et le chauffage centraux sont acheminés à l’immeuble au moyen d’un système de compensation et de recirculation d’air préconditionné. Le moteur initial du ventilateur de soufflage, d’une puissance de 1,5 HP, a été remplacé par un moteur de 2 HP lors de la mise à niveau du système de climatisation. Comme il n’y a qu’un seul circuit de ventilation dans l’immeuble, le système est doté d’une fonctionnalité de cycle inversé pour basculer de la climatisation au chauffage et vice versa lors des changements de saisons. La mise à niveau du moteur du ventilateur de soufflage augmente ainsi la capacité de débit d’air pour les deux saisons.

Constatations

Globalement, l’ensemble Karen’s Place de Salus a affiché un rendement élevé dans la plupart des domaines de rendement de l’EPO. Quelques défis liés à la conception et à l’**exploitation** de l’immeuble sont survenus se reflètent dans les résultats de l’EPO.

Rendement de l’enveloppe : Globalement, l’enveloppe du bâtiment de Karen’s Place a dépassé les valeurs cibles de la norme de la maison passive en matière d’étanchéité à l’air et d’isolation, ce qui indique que l’immeuble a été construit selon des normes de rendement élevées de performance de l’enveloppe. Les essais de détection de fuite d’air et de fumée, l’imagerie thermique et l’inspection visuelle ont confirmé que l’enveloppe avait conservé son intégrité au cours des premières années d’occupation du bâtiment.

Tableau récapitulatif – 6 : Valeurs U modélisées par composante du bâtiment

Composant du bâtiment	Valeur U de la conception (W/m ² K)	Lignes directrices de la maison passive ⁸ (W/m ² K)	Code du bâtiment de l’Ontario ⁹ (W/m ² K)
Toiture	0,075	0,15	0,156
Murs au-dessus du niveau du sol	0,11	0,15	0,247
Murs sous le niveau du sol	0,12	0,15	0,247
Planchers exposés	0,11	0,15	0,183
Dalle	0,11	0,15	-
Fenêtre complète (installée)	0,8	≤ 0,8	1,9

Tableau récapitulatif – 7 : Résultats de l’essai d’étanchéité à l’air avant et après l’occupation, et comparaison avec des points de référence clés

	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 ACH@50 Pa

L’ensemble Karen’s Place de Salus a connu d’importants problèmes de confort thermique en 2018, et des mesures de modernisation du système de climatisation et de ventilation ont été prises pour remédier à la situation. Malgré

⁸ Maison passive Canada, 2017

⁹ Ministère des Affaires municipales et du Logement de l’Ontario, 2012

ces améliorations, des problèmes de surchauffe semblables sont survenus dans l'immeuble en 2019. Voici ce qui a été observé de façon générale :

- **En hiver, la sécheresse de l'air a nui au confort thermique**, mais les niveaux de température se sont améliorés par rapport à 2018, se situant pour la plupart des fourchettes cibles. Notre sondage auprès des locataires a révélé que les occupants étaient généralement satisfaits des conditions.
- **En été, l'insuffisance des systèmes de climatisation et de ventilation a nui au confort thermique.** Malgré les mesures prises au cours du deuxième semestre de 2018 pour remédier à la situation, qui ont permis une légère amélioration en 2019, il a fallu installer d'autres climatiseurs individuels pour réduire les niveaux de température dans les logements des étages supérieurs.
- Pour évaluer le rendement du bâtiment en matière de confort thermique, **la surveillance de la température et de l'humidité relative dans les logements se poursuivra à l'été 2021.**

Tableau récapitulatif – 8 : Pourcentage d'heures où la température a dépassé 25 °C au cours de l'année (2019)

Emplacement	Pourcentage d'heures
Norme de la maison passive	10 %
Aire commune	1 %
Logement 1	4 %
Logement 2	7 %
Logement 3	3 %
Logement 4	9 %
Logement 5	12 %

Qualité de l'air intérieur : Le dioxyde de carbone (CO₂) à l'intérieur a été mesuré et a été utilisé comme indicateur de l'efficacité du système de ventilation du bâtiment et de la qualité de l'air. Globalement, les niveaux de CO₂ semblent être restés dans la fourchette cible, ce qui suggère que les taux de ventilation étaient adéquats dans les logements. Les concentrations de CO₂ en été semblent nettement inférieures aux concentrations en hiver, probablement parce que les résidents ouvraient leurs fenêtres. Dans le cas d'un logement en particulier, les concentrations de CO₂ ont largement dépassé la cible au cours de la deuxième période de surveillance en hiver, car l'occupant avait obstrué manuellement l'entrée d'air. Il faudrait effectuer un autre sondage auprès des occupants pour déterminer s'il s'agit d'un comportement isolé ou si l'augmentation des taux de ventilation pourrait avoir occasionné un nouveau problème de confort thermique en raison des courants d'air supplémentaires. Un tel sondage pourrait également fournir des indications sur la fréquence des remplacements de filtres visant à réduire l'odeur désagréable de cigarette.

Consommation d'eau : Malgré une légère augmentation en 2019, la consommation d'eau a été nettement inférieure à la moyenne canadienne par habitant et nettement inférieure au point de référence de la région. Il est recommandé de continuer à surveiller la consommation d'eau de l'immeuble pour s'assurer qu'elle demeure inférieure à la consommation type. À cette étape-ci, aucune mesure d'amélioration n'est suggérée pour l'immeuble, à l'exception d'un programme de sensibilisation à la conservation de l'eau à l'intention des occupants, si Salus juge cette idée appropriée pour les résidents.

Tableau récapitulatif – 9 : Utilisation annuelle de l'eau de Karen's Place par rapport aux points de référence pertinents

	Salus	Point de référence
Consommation par habitant (m ³ /année)	65,6	91,6 ¹⁰
Consommation par m ² d'espace habitable (m ³ /année)	1,11	2,0 ¹¹

Consommation d'énergie : Globalement, on a pu démontrer que l'utilisation de l'énergie a été efficace dans l'immeuble Karen's Place de Salus au cours des premières années d'occupation. Karen's Place a utilisé beaucoup moins d'énergie que des immeubles semblables, mais n'a pas atteint toutes ses cibles de consommation d'énergie.

Tableau récapitulatif – 10 : Comparaison de l'intensité énergétique (IE) de Karen's Place avec des points de référence clés

Karen's Place de Salus	Modélisation de la conception	Rendement réel en 2017	Rendement réel en 2018	Rendement réel en 2019	Norme de la maison passive	IRLM standard : SCHL ¹²
IE du site (kWh/m ²)	-	103	115	121	-	212
IE à la source (kWh/m ²)	113	167	189	196	120	-

- Incidence des modifications apportées au bâtiment :** Au cours de la période de l'EPO, des modifications ont été apportées aux systèmes de chauffage et de climatisation en raison de problèmes de confort thermique et de ventilation. Plus précisément, deux refroidisseurs de 14 kW ont été ajoutés aux systèmes centraux de chauffage, de ventilation et de climatisation (CVC), et le ventilateur de l'appareil de traitement d'air de 1,5 HP a été remplacé par un ventilateur de 2 HP en octobre 2018. Au cours de l'été 2019, afin d'améliorer le transfert thermique, le propylèneglycol du circuit de climatisation a été remplacé par de l'éthylèneglycol à 35 %, un fluide plus efficace. De nouvelles séquences de contrôle ont également été mises en œuvre. Globalement, les modifications apportées au bâtiment ont légèrement amélioré le confort thermique dans les appartements. Cependant, le nouvel équipement et les opérations de chauffage/climatisation connexes ont entraîné une augmentation de la consommation d'énergie dans l'immeuble.
- L'étanchéité de l'enveloppe de l'immeuble a contribué à maintenir à un bas niveau la consommation d'énergie pour le chauffage, mais a aussi entraîné une augmentation des besoins en matière de climatisation :** La charge de chauffage était de 6 % supérieure à la norme de la maison passive, mais tout de même nettement inférieure à ce qu'exige le Code du bâtiment de l'Ontario. Par contre, les besoins de climatisation représentaient 7 % de la consommation totale d'énergie en 2019, ce qui situe Karen's Place dans la même fourchette que les autres IRLM exposés au climat d'Ottawa. Il est important de noter qu'en

¹⁰ Environnement et Changement climatique Canada, 2011

¹¹ SCHL, 2001

¹² SCHL, 2001

raison des modifications continues apportées à l'immeuble pendant la période de surveillance estivale et de l'ajout de climatiseurs individuels temporaires (sans compteur divisionnaire), une nouvelle évaluation de la climatisation sera nécessaire afin d'améliorer l'exactitude du modèle énergétique.

- **Le propriétaire de l'immeuble pourrait envisager d'apporter certaines améliorations :** Il pourrait notamment moderniser la tuyauterie et les commandes du système de CVC, une amélioration davantage motivée par le maintien du confort thermique que par les économies potentielles sur la facture de services publics.
- **Il faut poursuivre les activités de surveillance de l'immeuble pour évaluer son rendement énergétique dans des conditions d'exploitation normales qui maintiennent des seuils acceptables de confort thermique en été :** La surveillance continue de la température de l'air de compensation est importante pour s'assurer que les dernières mesures mises en place règlent les problèmes de surchauffe. Puisque l'augmentation de la capacité des refroidisseurs n'a pas entièrement atténué les préoccupations relatives aux problèmes de surchauffe, les saisons estivales 2020 et 2021 seront déterminantes pour établir les conditions d'exploitation définitives de l'immeuble.

Acoustique : Globalement, les occupants semblaient satisfaits du degré de transmission du bruit et de vibration dans leur appartement. Certains résidents vivant au dernier étage ont ressenti des vibrations que l'on croit attribuables à la circulation automobile devant l'immeuble, qui ferait bouger la structure d'acier du bâtiment. Il est donc peu probable que ces vibrations puissent être atténuées.

Principaux points à retenir

À la lumière des résultats de l'EPO de l'immeuble Karen's Place, voici les principaux points à retenir :

- **Évalué dans le cadre d'une occupation complète, l'immeuble a satisfait à la norme de la maison passive dans plusieurs catégories et a obtenu un rendement supérieur aux points de référence d'IRLM types au Canada en ce qui a trait à la consommation d'énergie et au rendement de l'enveloppe :** L'immeuble affichait un faible IE malgré l'utilisation de climatiseurs supplémentaires pendant les mois d'été. L'utilisation rationnelle de l'eau a été d'environ 28 % supérieure à la moyenne canadienne, et la qualité de l'air intérieur a été maintenue à des niveaux adéquats.
- **La consommation d'énergie dans l'immeuble était extrêmement faible pour le chauffage, mais les charges de climatisation étaient équivalentes à celles d'autres IRLM au Canada :** L'enveloppe à haut rendement de l'immeuble a contribué à réduire les besoins de chauffage de telle façon qu'ils représentaient seulement 13 % de toute l'énergie utilisée dans l'immeuble. Cependant, l'étanchéité à l'air de l'enveloppe a peut-être contribué à ce que l'immeuble conserve ses gains de chauffage interne pendant la saison chaude. Résultat : le pourcentage d'énergie requise pour la climatisation n'était pas meilleur que celui d'un IRLM type au Canada, s'élevant à 7 % de la consommation d'énergie annuelle.
- **Le confort thermique des occupants a diminué en été, en plus de connaître quelques problèmes en hiver :** L'enveloppe extrêmement étanche à l'air et très isolée de l'immeuble, combinée à l'équipement de climatisation et de ventilation potentiellement insuffisant, a entraîné des problèmes de confort thermique à l'été 2018, la température intérieure ayant grimpé bien au-dessus des niveaux acceptables. Bien que les refroidisseurs supplémentaires et l'augmentation des taux de ventilation aient amélioré le confort thermique des occupants, cela n'a pas entièrement résolu le problème. De plus, en hiver, 50 % de

la chaleur provenait des plinthes électriques d'appoint, et les taux d'humidité étaient inférieurs au pourcentage idéal en raison du manque d'humidificateurs.

- **Des mesures correctives ont été prises pour régler les problèmes de confort thermique, ce qui s'est traduit par une augmentation de la consommation d'énergie dans l'immeuble :** En réponse aux problèmes de confort thermique, la capacité des refroidisseurs et de la ventilation a été augmentée. L'IE de l'immeuble a augmenté de 5 % par rapport à 2018 (et même de 8 % une fois normalisée).
- **La collecte de données dans le cadre de l'EPO se poursuivra jusqu'en octobre 2021, et l'analyse coûts-avantages des systèmes de chauffage et de climatisation sera effectuée à ce moment-là :** Bien que les améliorations apportées au système de climatisation aient amélioré le confort thermique des occupants pendant les mois d'été, des problèmes de confort persistent lorsqu'il y a des vagues de chaleur prolongées (c'est-à-dire lorsque la température de l'air extérieur dépasse les 30 °C pendant plusieurs jours consécutifs). À la fin du mois de juin 2020, les climatiseurs portatifs ont été réinstallés dans les logements, et la gestion immobilière envisage aujourd'hui de prendre d'autres mesures correctives. Cela aura deux répercussions sur l'EPO. Premièrement, il faudra effectuer une évaluation finale de la saison estivale à l'été 2021 (après la mise en œuvre d'autres améliorations dans l'immeuble). Deuxièmement, cela retardera l'analyse coûts-avantages des systèmes intégrés de chauffage et de climatisation, d'une part parce que d'autres coûts liés aux systèmes devront être pris en compte, d'autre part parce que les systèmes n'ont pas encore le rendement souhaité.

Acknowledgments

Dunsky Energy Consulting gratefully acknowledges the assistance and cooperation of Christa McIntosh Senior Manager Property & Administration, Salus Corporation, in the development of this POE report, as well as Shannon Walker, Property Manager, who hosted the facility walk-throughs and provided tremendous help throughout the whole study period.

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1 INTRODUCTION

This report outlines the results of a Post-Occupancy Evaluation (POE) of the Salus Karen's Place Supportive Housing Project completed by Dunskey Energy Consulting for Canada Mortgage and Housing Corporation (CMHC). Salus Karen's Place was completed in late 2016 and was built to high-energy efficiency standards, ultimately achieving both Passive House International (PHI) and LEED Platinum certification. The primary objective of the POE is to assess the building's energy, water, and thermal comfort performance now that it is fully occupied and compare it to both the design objectives and recognized benchmarks.

The first POE monitoring period took place in 2018. A second POE monitoring period was performed in 2019 to assess building conditions after an upgrade of the central systems to address cooling challenges. As part of this second phase, a detailed and calibrated energy model of the building was developed. A third phase will be completed in 2021, once the on-going cooling issues have been fully addressed, at which time the building EUI and thermal comfort assessments will be updated, and a cost-benefit analysis of the integrated heating/cooling systems will be performed.

The structure of the report is as follows:

- **Methodology:** This section describes the development of the POE plan, data collection activities and building energy modelling, analysis, and reporting.
- **Findings:** This section presents the POE results by performance area, which are divided into energy performance, water performance, indoor air quality, thermal comfort, and occupant experience.
- **Conclusion and Next Steps:** This section provides an overall summary of the study and next steps.

The Passive House International Standard

Passive House is an internationally recognized standard for energy efficient building design and construction. It applies a performance-based approach that leaves building designers free to choose how best to meet the certification standards. Typically, Passive House certified buildings have the following features:

1. Exceptionally high levels of insulation
2. Well-insulated window frames and glazing
3. Thermal bridge free design and construction
4. An airtight building envelope
5. Ventilation with highly efficient heat or energy recovery and high air quality

According to Passive House Canada, research has shown the energy consumption for heating and cooling in Passive House buildings to be roughly 80 percent lower than in conventional buildings. To be certified to the Passive House International (PHI) standard, the building must achieve the following benchmarks:

- **Primary Energy Demand:** Less than 120 kWh / m²/yr
- **Space Heating Demand:** 15kWh/m²/yr or 10W/m²
- **Space Cooling Demand:** Similar to heating but with an allowance for dehumidification.
- **Airtightness:** < 0.6 ACH@50Pa
- **Thermal comfort:** must be met for all living areas year-round with not more than 10% of the hours in any given year over 25°C

Salus Karen's Place Passive House Certification

PHI is considered to be among the most stringent building efficiency certification standards. To date, only four multi-unit residential buildings (including Salus Karen's Place) have successfully been certified by Passive House Canada. At the time of its construction, Salus Karen's Place was North America's largest project built to the International Passive House standard.

For simplicity purposes, Passive House Canada is referred as Passive House through the report.

1.1 Salus Karen's Place: Building Concept and Description

The Salus Karen's Place building (*Figure 1*) is a 42-unit supportive housing project located in Ottawa, Ontario that has achieved both Passive House International (PHI) and LEED Platinum certifications. It is the first multi-unit residential Passive House project in Canada, and the first affordable housing project to achieve the Passive House standard in North America. The building design sought to reduce energy consumption on the site by 66% compared to the Ontario Building Code requirements. The heating demand is designed to be reduced by up to 85% compared to the current Ontario Building Code.

Construction on the building was completed in late 2016, and the building achieved full occupancy in March 2017. The building is owned and operated by the Ottawa Salus Corporation, which provides supportive housing and services to adults living with mental illness.



Figure 1. Salus Karen's Place Building

1.1.1 Building Configuration

Salus Karen's Place is a four-storey (above-grade), steel-frame construction, multi-unit residential building (MURB). The building has 2,485 m² of interior living space, which includes 42 single-occupant one-bedroom apartments and 300 m² of common areas. The common areas include a large common room, a kitchen area (equipped with fridge, stove, dishwasher and freezer), a laundry room with 2 washers and 2 driers, and a small office that is used by the Salus staff team. Each apartment has a small kitchen, which includes a stove and a fridge.

1.1.2 High-Performance Building Envelope

A key feature of Salus Karen's Place is its high-performance building envelope. It achieves extremely high insulation values through a combination of structurally insulated panel (SIP) systems installed outboard of the steel structure (for most above-grade walls), batt insulation, insulated concrete foams (for lower walls and foundation walls), and thermally broken cladding support to achieve insulation values that exceed PHI standards. It is equipped with triple glazed, Passive House certified windows. The design and construction paid specific attention to maintaining high airtightness performance and avoiding thermal bridges in order to minimize heating requirements.

1.1.3 Central Heating, Cooling, and Ventilation

The heating and cooling needs of Salus Karen's Place are primarily met through a centralized ventilation system with delivery of heating and cooling through the ventilation system. The heating and cooling systems are made up of two hot water heaters, a make-up air unit with an integrated ERV and an air-cooled chiller. Figure 2 shows an overview of the HVAC system.

Key heating, ventilation, and air conditioning (HVAC) features include:

- **Heating:** Space and water heating is provided by two 500,000-BTU/hr gas fired condensing water heaters located in the building basement. Each apartment is equipped with a 300-W electric baseboard resistance heater to provide supplemental heating as needed.
- **Cooling:** Cooling was initially provided by a single 21-kW (6-ton) chiller located on the roof. This was eventually supplemented by two additional 14-kW (4-ton) chillers.
- **Ventilation:** Fresh air is provided by a make-up air unit (MAU) with an integrated energy recovery ventilator (ERV). Central heating and cooling are delivered to the building by preconditioning the make-up and recirculating airflows. The initial supply fan motor size was 1.5-hp which was replaced by a 2-hp when the cooling system was upgrading. Since there is only one ventilation loop in the building, the system uses a seasonal switch-over to change between cooling and heating. The supply fan motor update has therefore increased the building airflow capacity for both seasons. In the building, the air is supplied directly in the suite living rooms and exhausted from rooms where moisture and odours build up (in-unit kitchens and bathrooms). There is not a separated ventilation loop for corridors.
- **In-apartment conditioning:** For each common area and apartment, the make-up air flow is controlled by a variable air volume (VAV) box. This allows for an accurate temperature control and provides passive dehumidification in summer (longer contact with the cooling coil causes moisture content in the airflow to condense).

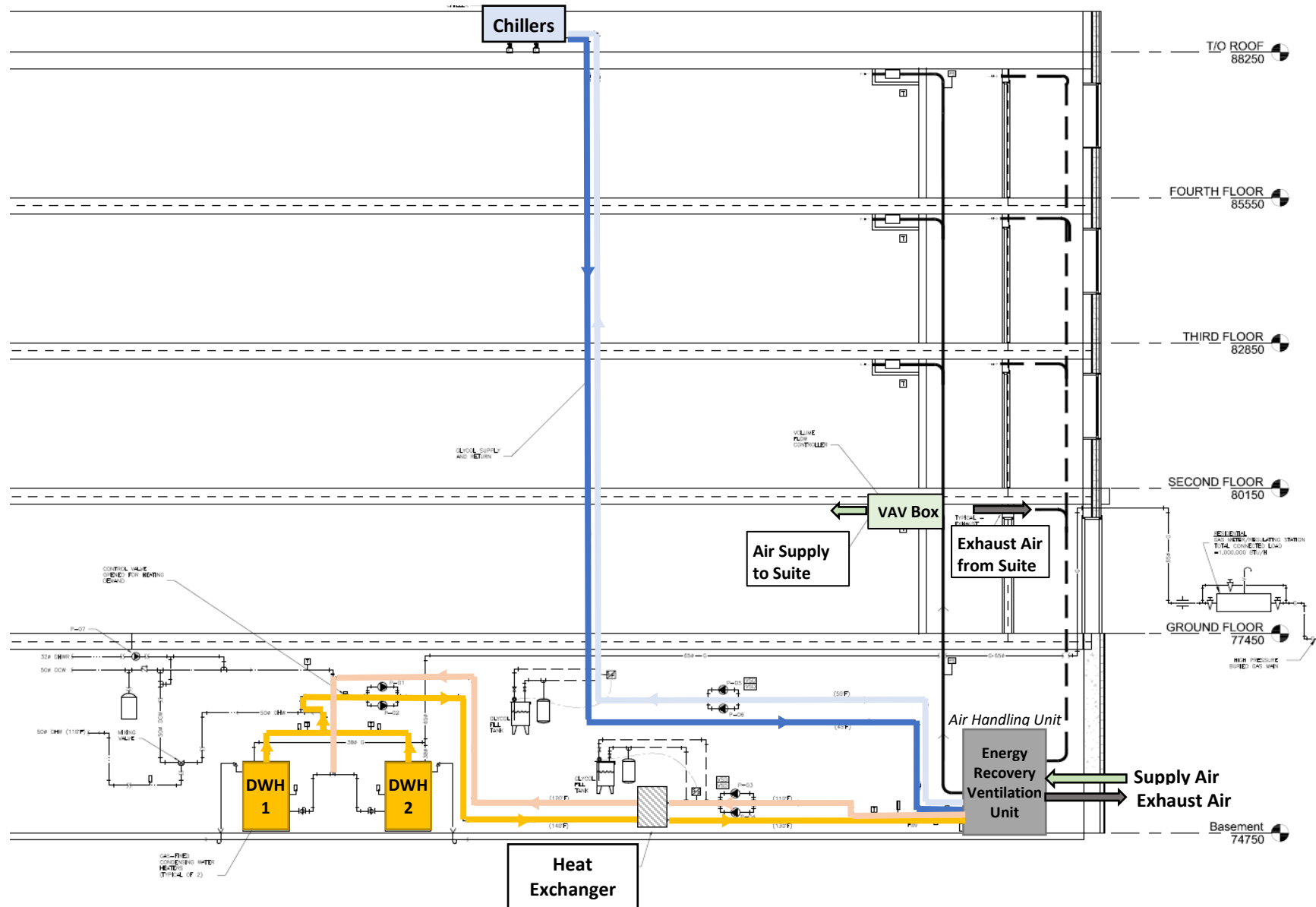


Figure 2: Centralized HVAC System



2 METHODOLOGY

The study was completed in four primary steps:

1. POE Plan Development
2. Data Collection
3. Building Energy Modelling
4. Analysis and Reporting

2.1 POE Plan Development

To inform the POE plan in the first phase of this study, we began by collecting key information related to the building design, operation, and occupant perceptions. Using historical billing data and available equipment specifications, we identified unexpected trends and highlighted areas requiring further investigation. We also held a meeting with the building design and operation teams and reviewed project design documents to identify key building features and operational protocols. Concurrently, we administered a 20-question survey to occupants, which included questions related to thermal comfort, indoor air quality, noise and more. The survey response rate was 43%, and the results helped to further highlight areas requiring focused attention during the POE. The occupant survey responses are included in Appendix B: Occupant Survey Results.

Using the information gathered through the above activities, a detailed POE plan was developed that outlined our approach to measuring the following areas of the buildings' performance:

- **Envelope performance:** Air leakage rates
- **Energy performance:** Whole building, apartments, common areas, major end uses (heating, cooling, ventilation, domestic hot water, plug loads, etc.)
- **Water consumption:** Whole project, buildings and specific end uses
- **Indoor air quality:** CO₂ (logged in three apartments)
- **Thermal comfort:** Temperature and relative humidity (logged in three apartments)
- **Occupant experience:** Survey through building manager

The plan identified key equipment and systems for monitoring and outlined a schedule for data collection activities.

2.2 Data Collection

Data collection activities were performed two times. The first monitoring period was performed from January to December 2018 corresponding to the first phase of the study. Activities included an initial meeting with the building design and management teams, a walk-through audit (which included the installation of key equipment sub-meters), site visits during full heating (winter) and full cooling (summer) modes (which included an assessment of the building's operation and key equipment performance), and collection of the building's electricity, natural gas, and water bulk meter data.

After the upgrade of central building systems, a second phase was added to the POE study covering January 2019 to January 2020. Data collection activities were identical to the previous phase, including an additional meeting with the property manager and the company responsible for the building modifications.

A full summary of data collection activities is included in Appendix C: Data Collection.

2.3 Building Energy Modelling

A building simulation model was developed to support detailed analysis of energy end uses. It was developed in eQuest (version 3.65) and was based on 15-minute interval electricity utility data along with other utility, on-site meter, and climate data. The calibrated model provided an accurate overview of the building energy performance including the end-use breakdowns presented in the section 3.5.5 of this report. It can be used to assess energy and demand impact of a large portfolio of measures. It can also predict parameters for the current building conditions as well as for other weather and occupancy patterns. In this role, the model becomes a powerful tool in a Measurement & Verification approach.

The architectural model of the building is based on a floor-by-floor representation, with each individual suite defined as a thermal zone. The resulting model is therefore very extensive with 82 thermal zones (*Figure 3*).

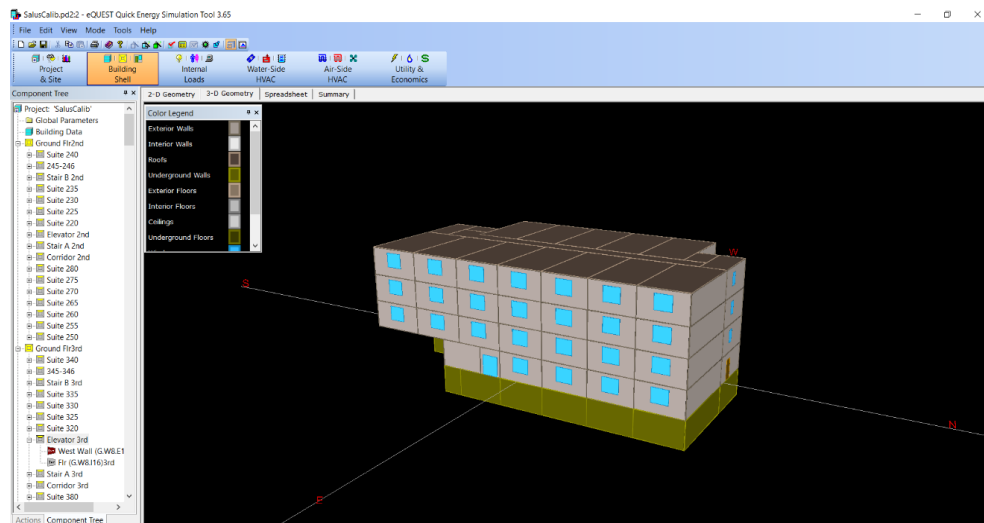


Figure 3: eQuest Architectural Model of Salus Karen's Place

The calibration of the eQuest model was performed using hourly weather data over the selected baseline year (December 2018 to November 2019). The data used in the calibration process included: monthly data from the bulk meters, interval meter data, BAS trend data and sub-metering data. The calibration process requirements met the ASHRAE 14 Standard¹³. Full details are included in Appendix F: Building Energy Modelling.

2.4 Analysis

Over the course of the study, quarterly progress reports were provided to CMHC that outlined the data collected, observations made, and any site visits or tests performed. In this report, building performance is assessed, energy and water consumption is analyzed for both POE monitoring periods, findings from the occupant survey and qualitative observations are presented, and potential operational issues are identified alongside low to no-cost improvement recommendations.

¹³Coefficient of Variation of the Root Mean Square Error (CV(RMSE)) of +/- 15% with a Normalized Mean Bias Error (NMBE) of +/- 5% for monthly data and a CV(RMSE) of +/- 30% with a NMBE of +/- 10% for hourly data.

3 FINDINGS

The report findings are organized into the following performance areas:

1. Envelope Performance
2. Thermal Comfort
3. Indoor Air Quality
4. Water Consumption
5. Energy Consumption
6. Acoustics

Below, each performance area is further broken down to allow for a more detailed presentation of study findings and targeted recommendations.

Post-Occupancy Building Modifications

Several changes were made to the Salus Karen's Place building systems and operation prior to and during the POE period (*Figure 4*). These improvements were made in response to challenges with maintaining thermal comfort in the building and had immediate effects on performance, which are documented wherever possible. However, because many of these changes were made mid-way through the POE period, their impact on energy consumption and other POE performance areas may not be fully captured in this report.

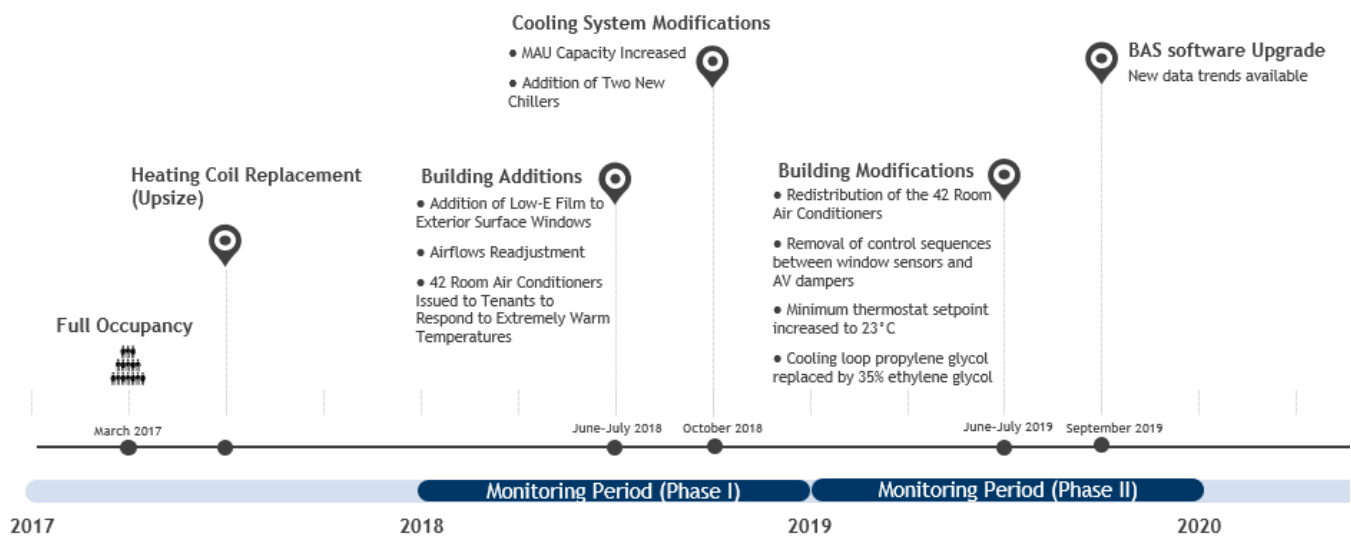


Figure 4. Study and Changes Timeline

3.1 Envelope Performance

Achieving industry-leading airtightness and insulation values are among the most important factors in meeting the Passive House certification. Certified Passive House buildings must achieve an airtightness of no more than 0.6 air changes per hour at 50 Pascals of pressurization, and the envelope and HVAC systems must be designed to ensure that energy consumption does not exceed 15 kWh per square meter of living space. In the following section, we provide an assessment of the building envelope based on a review of the design specification, on-site testing, and visual inspection.

3.1.1 Insulation Values

The building envelope employs a combination of structural insulated panels (for most above-grade walls), batt insulation, insulated concrete forms (for lower walls and foundation walls), and thermally broken cladding support to achieve insulation values that exceed Passive House standards. The wall section U-values calculated from the installed materials are provided below¹⁴ (*Table 1*).

Table 1. Modelled U-Values by Building Component.

Building Component	Design U-Value (W/m ² K)	Passive House Guidelines ¹⁵ (W/m ² K)	Ontario Building Code (2017) ¹⁶ (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

3.1.2 Airtightness

A pressurization test was performed on November 19th, 2018 to test the building's airtightness. The results are included below (*Table 2*). The test¹⁷ entails using the building's ventilation to achieve maximal pressurization, then correlating the pressure level achieved to the air changes per hour value - expressed in cubic feet per minute at 50 Pa of pressure (CFM50). This method was used as an approximation, given that a full building blower door test was not possible under the study scope.

¹⁴ Sonia Zouari, 2015

¹⁵ Passive House Canada, 2017

¹⁶ Ontario Ministry of Municipal Affairs and Housing, 2016.

¹⁷ Details are included in Appendix F.

Table 2. Pressurization Test results and Comparison to Key Benchmarks

	Salus Karen's Place	International Green Construction Code (IGCC) ¹⁸	Current PH Guidelines ¹⁹	Canadian Average ²⁰	Energy Star MF high rise ²¹
CFM50/ft²	0.2 (corrected to 50Pa)	0.20	0.24	0.5	0.29

When converted to air changes per hour (ACH), the air leakage is assessed to be 0.44 ACH@50 (*Table 3*).

Table 3. 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 ²²
Air changes per hour	0.4 ACH@50	0.44 ACH@50	≤ 0.6 ACH@50	1.5 ACH@50

Overall, the building envelope exhibits insulation and airtightness performance that exceeds the Ontario Building Code and the Passive House standard.

3.1.3 Thermal Imaging and Visual Inspection

During our winter site visit, we used thermal imaging²³ to perform a qualitative assessment of heat loss through the building envelope to verify that there were no construction or degradation anomalies. One of the images is displayed below (*Figure 5*). As a result of the thermal imaging settings and the cladding emissivity, yellow and red shading tones represents surfaces with cooler temperatures associated with minimal heat loss, while blue tones indicate higher surface temperatures associated with greater heat loss from the building.

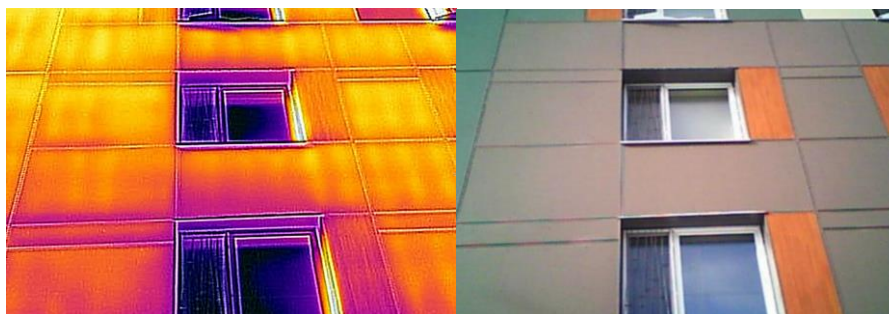


Figure 5. West-Facing Wall of the Building

¹⁸ RDH. 2016. Note: Adjusted to cfm/ft² at 50 Pa (flow exponent of 0.5).

¹⁹ Passive House Canada, 2017. Converted to CFM50/ft².

²⁰ RDH. 2016. Note: Adjusted to cfm/ft² at 50 Pa (flow exponent of 0.5).

²¹ Ontario Ministry of Municipal Affairs and Housing, 2012

²² NRCAN, 2019. Net Zero Energy and Net Zero Energy Ready Housing.

²³ The thermal camera used is a FLIR One model with a temperature resolution of 0.1°C. Due to complications in obtaining these measurements associated with the building cladding reflectivity, the results are considered to provide just a qualitative assessment of building heat loss variations, rather than an accurate measurement of the surface temperatures.

Our results revealed that the heat losses through the envelope were most pronounced at the windows. This is to be expected based on the relative U values of the windows compared to the walls. No evidence of thermal bridging on the wall surfaces was apparent from the images.

During the occupant survey, one tenant mentioned the presence of drafts from the window. In order to verify if this signalled a problem with the window, we performed a smoke leak test (*Figure 6*). The window seemed perfectly airtight and no anomalies were detected.

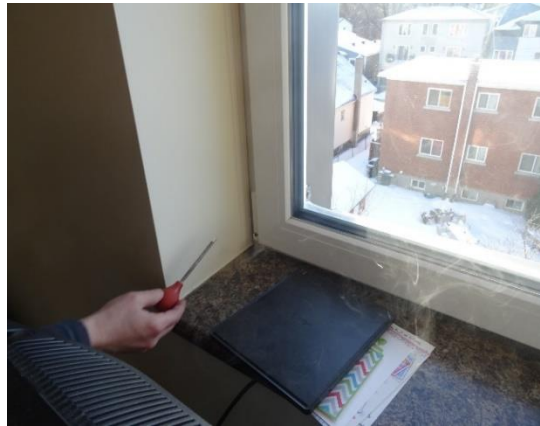


Figure 6. Smoke Leak Test (January 24th, 2018)

3.1.4 Envelope Performance Key Findings

Overall, the building envelope for Salus Karen's Place exceeded the PHI Standard for airtightness and insulation values indicating that the building was constructed to high envelope performance standards. On-site air leakage, thermal imaging, visual inspection, and smoke tracer tests verified that the envelope maintained its integrity over the initial years of its occupancy. The envelope is not expected to show further signs of deterioration in the upcoming years given that the building has passed the critical two years after construction, a period where building envelope failures and anomalies from inadequacies in the design or construction usually occur.

3.2 Thermal Comfort

We evaluated the building's ability to maintain occupant thermal comfort based on the American Society of Heating, Refrigerating, and Air-Conditioning Engineers (ASHRAE) target ranges for temperature and relative humidity (RH). Beyond occupant comfort, temperature and humidity are also important metrics to track for human health reasons, and should they fall outside the recommended range may result in adverse impacts such as over-heating or growth of mold and fungus in the building.

To limit disturbances to the residents, temperature and RH data were collected during limited time periods in a few apartments. Temporary sensors were installed in three apartments to collect temperature and RH results on 15-minute intervals over two-week periods in the summer and the winter 2018 and 2019²⁴. The apartment units were selected for monitoring to account for locational variations within the building:

- **Unit 1:** South-West corner, middle floor
- **Unit 2:** East facing, middle floor
- **Unit 3:** West-facing, top floor

The results are presented relative to the thermal comfort target zones indicated in the ASHRAE 55-1992 guidelines. To augment these results, temperature data for each apartment and for the common areas was also collected via the Building Automation System (BAS) on five-minute intervals spanning the study period.

3.2.1 In-Unit Thermal Comfort

As part of the POE data collection, we monitored the temperature and RH profiles in three units (15-minute interval data). For comparative purposes, the same units were used for all monitoring periods. They were selected to represent varying unit positions and orientations in the building.

The winter monitoring period occurred from January 24th to February 7th, 2018, and from January 17th to February 1st, 2020. During the first winter assessment, daily exterior minimums²⁵ ranged from -21.1°C to -7.3°C with an average HDD@18°C of 28°C. The second winter monitoring period was slightly cooler with temperatures ranging from -26°C to -10.6°C with an average HDD of 33°C. The Temperature vs RH plots presenting 15-minute interval spot measurements are presented for each unit over the heating seasons (winter) in both 2018 and 2020 winters (*Figure 7, Figure 8, Figure 9*). In-unit temperatures and RH values can be compared relative to the winter ASHRAE comfort zone targets.

²⁴ Precision of the equipment used to collect temperature and RH data is included in Appendix C: Data Collection along with the pictures of installed sensors.

²⁵ Environment Canada weather data for the Ottawa International Airport.

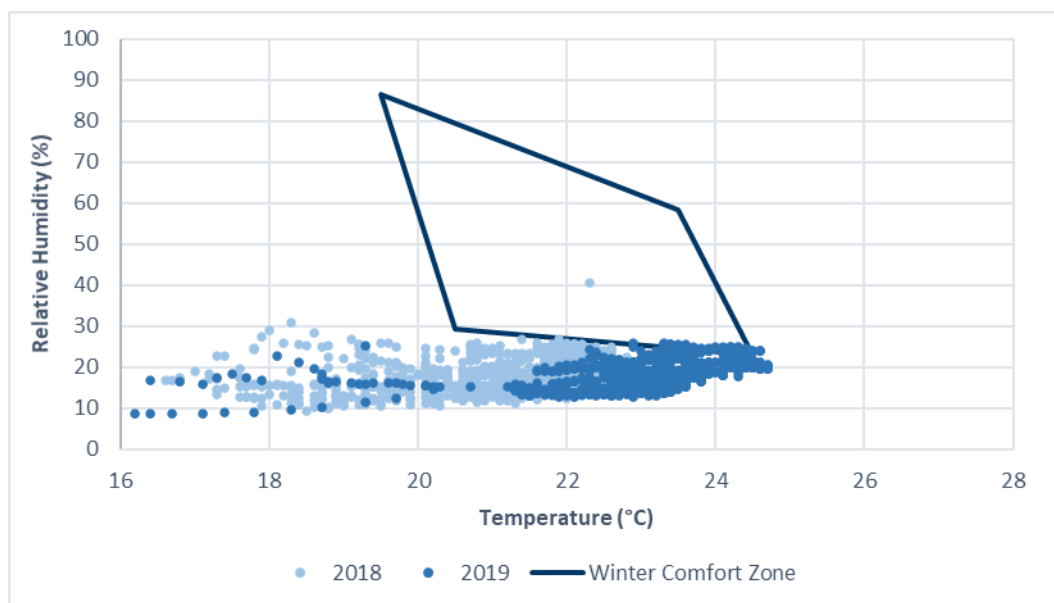


Figure 7. Winter Thermal Comfort Performance for Unit 1 (Southwest Corner Unit)

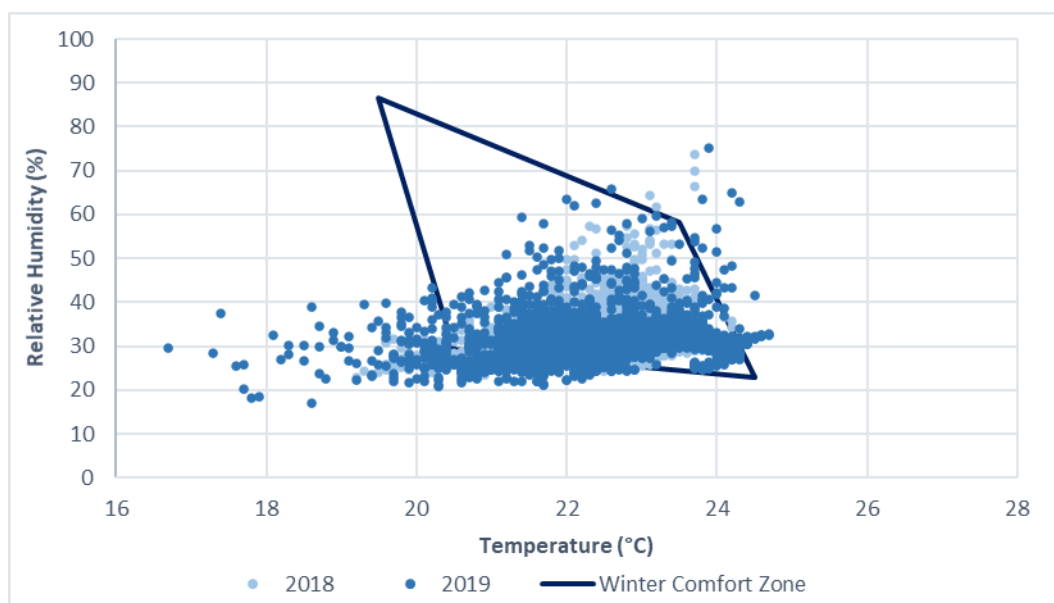


Figure 8. Winter Thermal Comfort Performance for Unit 2 (East-facing unit)

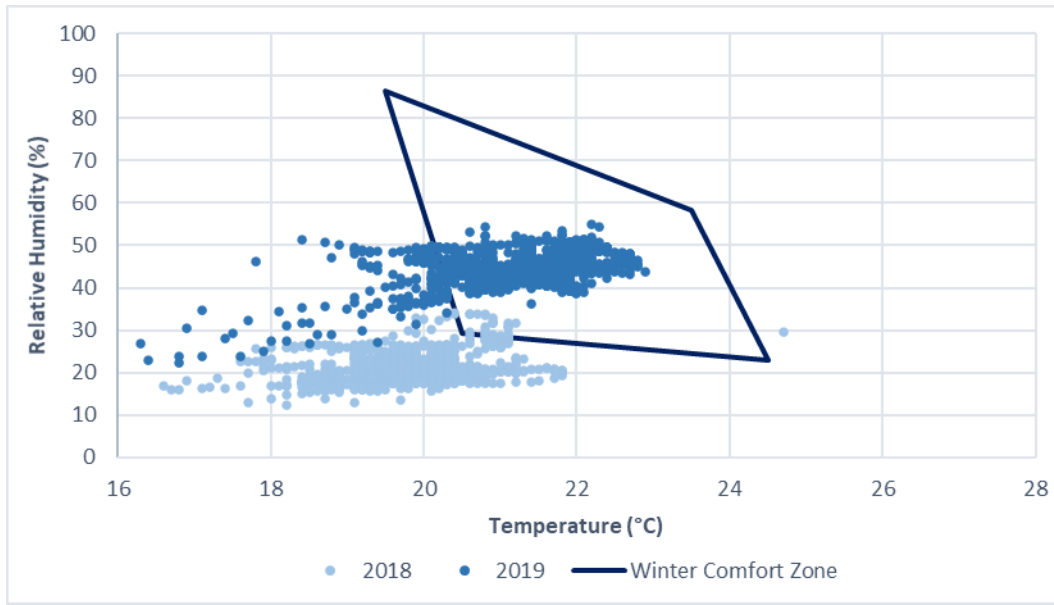


Figure 9. Winter Thermal Comfort Performance for Unit 3 (West-facing Top Floor Unit)

By analyzing both winters readings, two distinctive patterns were observed:

- Greater comfort levels were achieved in the winter 2020:** While both winter thermal profiles show similar trends, a slightly better performance is visible during the second monitoring (i.e. the data points are more often clustered within the ASHRAE Winter Comfort Zone or closer as indicated by the blue lines while the winter was slightly cooler). The top floor unit shows a less dry and warmer environment which may indicate that the supply fan motor replacement improved upper unit conditions. A similar pattern was perceived on another monitored unit on the top floor. This observation is supported through the BAS data, where the ERV unit was running at close to full capacity at all times for the first monitoring period, potentially limiting the humidity control in the building.
- Winter thermal profiles appear to be slightly drier than the ASHRAE targets:** For most of the 2020 readings, temperatures are mostly within ASHRAE targets. The low temperatures that can be seen in Units 1 and 2 are likely the result of the occupants opening the window. However, RH levels tends to remain low throughout the winter season, which can be expected for a MURB that does not have central humidification.

The summer monitoring period occurred from July 24th to August 24th, 2018 and from August 8th to September 8th, 2019. Both summer monitoring periods occurred after the Low-E film had been added to the windows, and the second summer monitoring period took place after the increase of the supply fan motor and the cooling capacity. All three units had room AC units during both test periods, and it is unclear whether there were being used during the test. During the summer 2018 measurements, daily exterior maximums²⁶ ranged from 20.8°C to 32.8°C with an average CDD@18°C of 4°C while the 2019 temperatures ranged from 16.7°C to 30.4°C with an average CDD of 1°C. The Temperature vs RH plots presenting 15-minute interval spot measurements are presented for each unit over the cooling season (Summer) data from both 2018 and 2019 (*Figure 10, Figure 11, Figure 12*). In-unit temperatures and RH values can be compared relative to the summer ASHRAE comfort zone targets.

²⁶ Environment Canada weather data for the Ottawa International Airport.

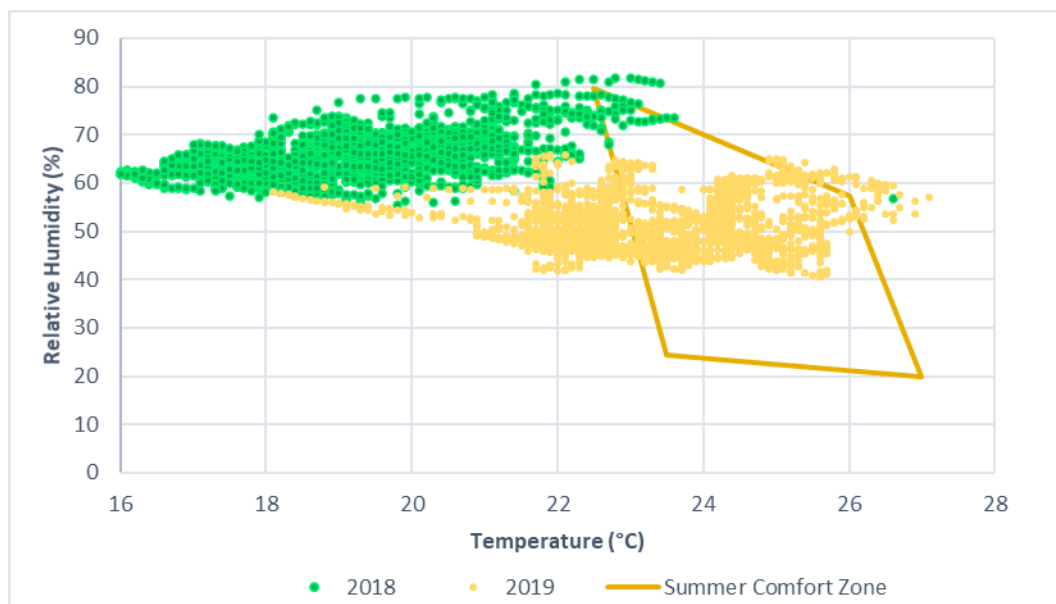


Figure 10: Summer Thermal Comfort Performance for Unit 1 (Southwest Corner Unit)

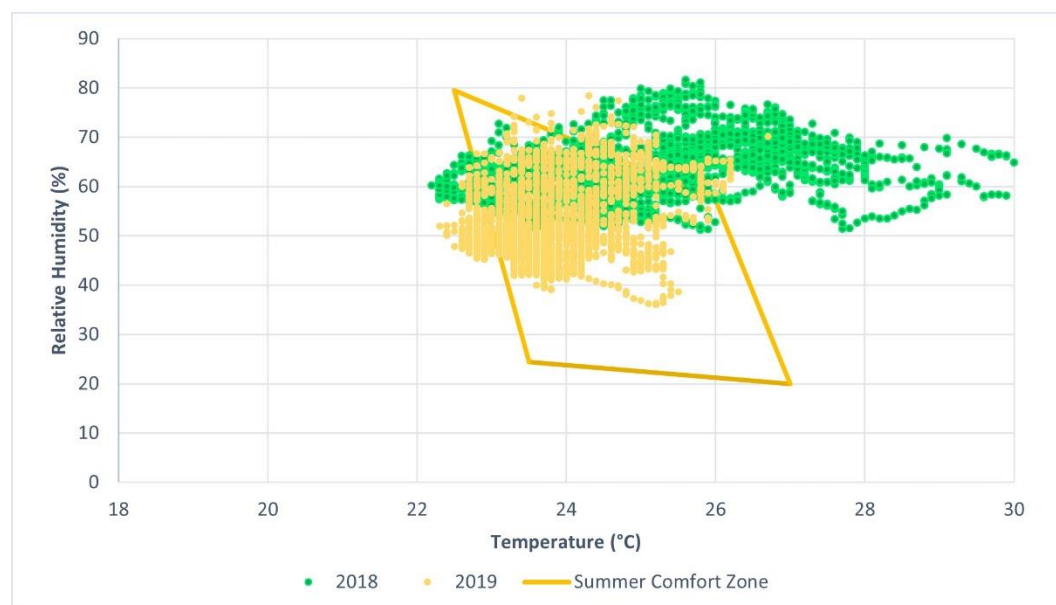


Figure 11: Summer Thermal Comfort Performance for Unit 2 (East-facing unit)

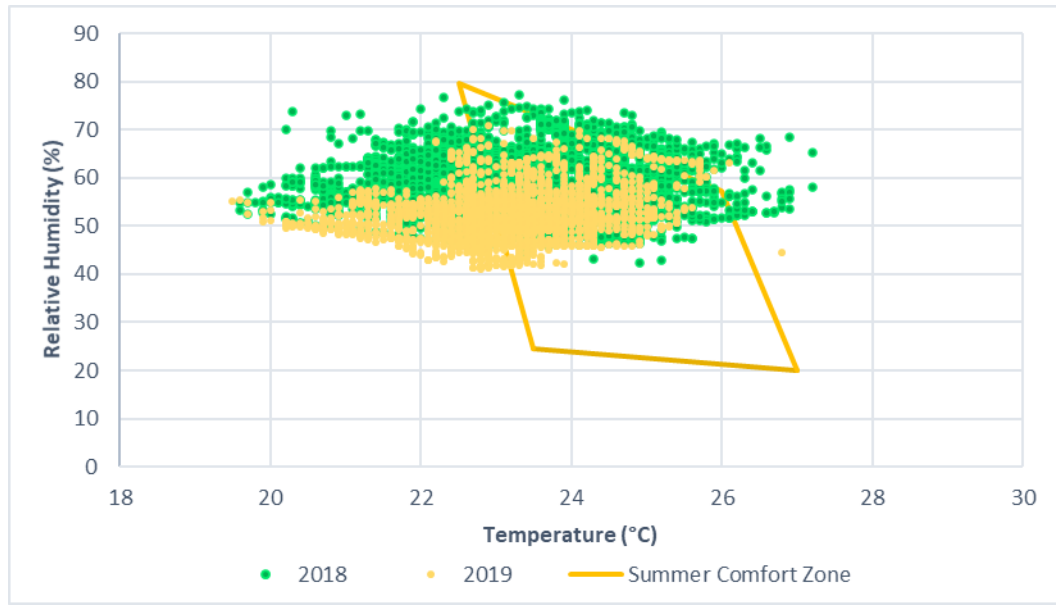


Figure 12: Summer Thermal Comfort Performance for Unit 3 (West-facing Top Floor Unit)

A portion of the readings fall outside the target comfort zones in all units across the summer season, which might illustrate the building's HVAC system challenges.

- **Summer thermal comfort shows significant variation:** During both summer monitoring periods, room AC units were installed in each apartment due to challenges maintaining the temperatures levels within the ASHRAE target zones. All units maintained RH levels in the high range of ASHRAE targets at all times, however, each unit has a different temperature profile:
 - **Unit 1** typically had summer temperatures lower than the ASHRAE targets, especially during the first monitoring period. Given that this is a southwest corner, it suggests that the AC unit was likely used extensively, which was the case during both summer site visits.
 - **Unit 2** had the widest variation in temperatures during the first monitoring period. The resident in this unit reported opening their window very frequently, which may have caused the temperature variations. This was validated by unit 2 consistently having the lowest CO₂ reading (see IAQ section). The 2019 summer readings showed less variation, which is likely the result of a milder summer temperatures and less extensive periods with opened windows (resulting from a reduced amount of smoke smells in the building).
 - **Unit 3** exhibited more tightly grouped summer temperatures and a relatively good fit with the summer ASHRAE comfort zone. Observation of the CO₂ monitoring results suggest that this the resident kept the window closed for most of the summer monitoring period. These observations are consistent during both summer periods with no noticeable improvements except fewer high temperatures which can be explained by milder temperatures or the use of the provided AC unit.
- **Summer profiles are not likely representative of the current building systems and operations:** As previously mentioned, the summer monitoring periods occurred while temporary room AC units were being used in each apartment both before and after the central cooling system was upgraded. In order to assess the building's current thermal comfort performance, the summer monitoring period temperature and RH logging will be repeating after commissioning of the cooling system and when the building is operating with a more permanent cooling system.

3.2.2 Cooling Challenges

The Salus Karen's Place building experienced significant thermal comfort challenges in 2018 due to a number of extremely hot maximum daily temperatures in Ottawa during the months from June to September.²⁷ The combination of the building's extremely airtight envelope (which makes it susceptible to internal heat gains in summer) along with limited chiller capacity and low ventilation rates to deliver the cooled air to the apartments, resulted in interior temperatures exceeding 30°C in some apartments when a heat wave struck Ottawa in June 2018.

In order to illustrate this issue, we present the interior temperature readings from the BAS over the summer period for the Unit 4, an East-facing unit on the top floor of the building (*Figure 13*).

To respond to this challenge, Salus Ottawa took immediate actions to improve the thermal comfort of residents. First, low-emissivity films were added to the building's exterior windows. Next, in late June, portable room air conditioners were distributed to each apartment. The impact of these measures can be seen in the temperature trends logs from various units in the building. In particular, it can be seen that in-unit maximum temperatures were reduced after July 1, 2018 (*Figure 13*).

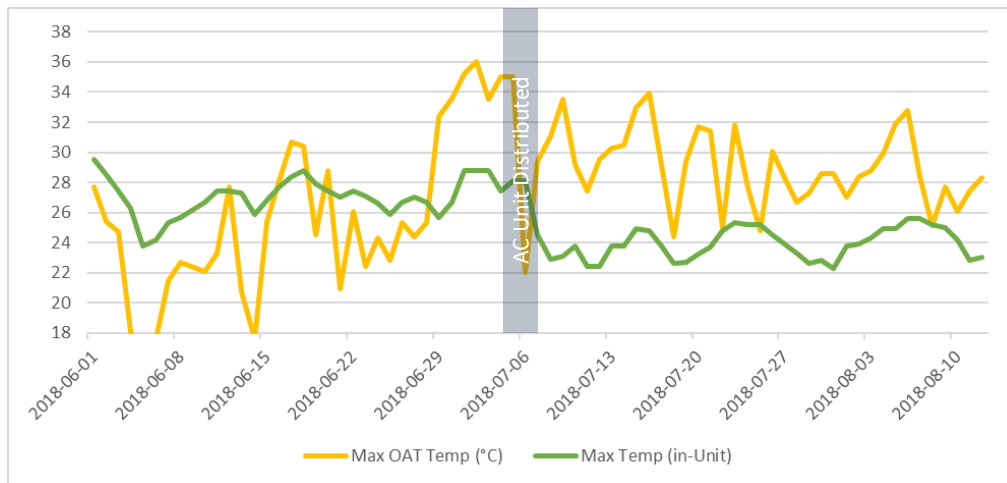


Figure 13. Daily Maximum Temperature in Unit 4 and Maximum Outdoor Air Temperature (OAT) - 2018

In October 2018, the central chiller capacity was increased from 21kW to 49kW (133% increase) and the MAU fan was increased from 1.1 kW to 1.5kW (33% increase).

Despite the improvements made in 2018, thermal comfort challenges were also experienced in 2019. At the end of June, when outside temperatures shot up for a few consecutive days, in-unit temperatures in the upper units of the building reached up to 30.3°C. As a result, room air conditioners were redistributed upon resident request. The cooling challenges experienced by the building are clearly demonstrated by the interior temperatures of a top-floor unit (*Figure 14*). Several additional measures were implemented in July in response:

- The minimum thermostat setpoint of each unit was increased to 23°C during the cooling season.

²⁷ According to Environment Canada weather data for the Ottawa International Airport. Ottawa can typically expect to have just 12 days where the maximum temperature exceeds 30°C, and only one day over 35°C every three years. In 2018 there were 24 days when the temperature exceeded 30°C and two in which it exceeded 35°C (with a maximum of 36°C).

- Any control sequences between window sensors and VAV dampers were removed (except sequences for building pressurization in suites that have temporary cooling units installed).
- The propylene glycol refrigerant was replaced by a 35% ethylene glycol refrigerant in the cooling loop, as ethylene glycol offers better freeze protection and is more effective heat transfer fluid²⁸.

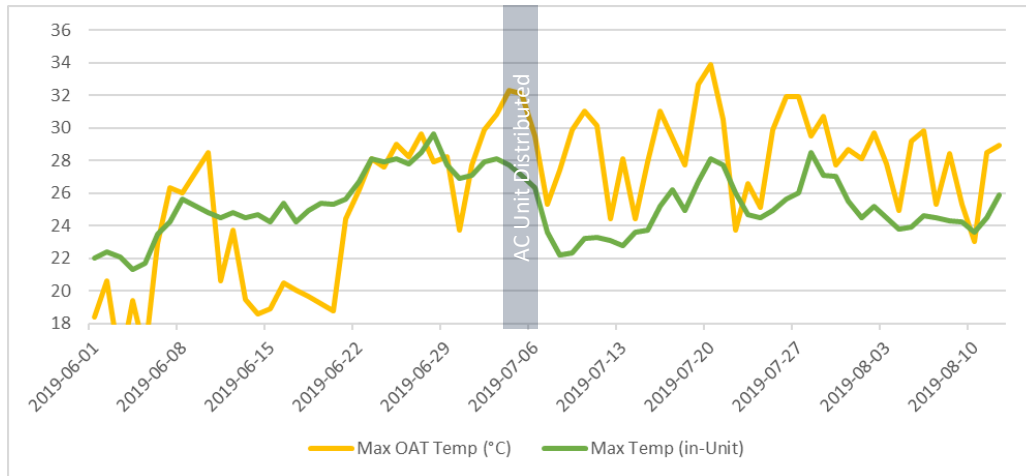


Figure 14: Sample In-Unit Daily Maximum Temperature and Maximum Outdoor Air Temperature (OAT) – 2019

Passive House Standards state that “thermal comfort must be met for all living areas year-round with not more than 10% of the hours in any given year over 25°C.” Analysis of in-unit temperature data from the BAS in a handful of units²⁹ shows that in 2019 this was achieved in almost all cases. The table below (*Table 4*) includes the results for Unit 1 to 4 as well as Unit 5, the warmest unit, a west-facing unit in the top floor. This represents an improvement from 2018 when there were a few more exceptions. These improvements can be attributed to two main factors. The first one is directly linked to the building modifications, more specifically, the MAU fan upgrade and added chiller capacity. The second one is the quick turnaround by Salus to provide added cooling capacity with the installation of the room air conditioners.

Table 4. Portion of Hours Over 25°C Over the Year

Location	Portion of hours (2018)	Portion of hours (2019)	Max Temperature (2018)	Max Temperature (2019)
Passive House Standard	10%	10%	-	-
Common Area	10%	1%	28.7°C	26.7°C
Unit 1	3%	4%	26.7°C	27.3°C
Unit 2	16%	7%	27.7°C	29.7°C
Unit 3	2%	3%	26.6°C	29.0°C
Unit 4	20%	9%	31.1°C	29.6°C
Unit 5	19%	12%	32.5°C	30.3°C

²⁸ For an equivalent volume %, ethylene glycol is 2% more conductive than propylene glycol on average (Ref. Veolia, retrieved in 08-2020. *Glycol Heat-Transfer Fluids Ethylene Glycol versus Propylene Glycol*)

²⁹ Analysis based on data retrieved from the BAS for the entire years of monitoring (Jan 2018-Dec 2019).

3.2.3 Occupant Feedback

The occupant survey was conducted in November 2017, and therefore does not reflect the tenant perspective after the cooling challenges and corrections in 2018. Due to study limitations, and the sensitive nature of the building tenant population, it was not possible to conduct a second occupant survey to detect changes in perception vis-à-vis the thermal comfort.

The 2017 summer period was notably milder than 2018. For example, in 2017 there were only 8 days in June-September where the maximum outdoor temperature exceeded 30°C, while in the same period in 2018 there were 24. Moreover, June to September 2018 experienced over 350 cooling degree days, compared to just 211 in 2017.

- **Even in 2017, many occupants felt that the summer temperatures were too hot:** Less than half of the respondents found summer temperatures to be just right in 2017, with another 47% feeling that the temperatures were warmer than ideal, and full 29% feeling that the summer temperatures were too hot. This may be a good predictor of the reaction to the over-heating issues that arose in the summer of 2018, when outdoor daily maximums far exceeded those in 2017.
- **Occupants felt that winter temperatures were generally adequate, if not slightly too warm for some:** The residents' perception of the temperature in their apartments are displayed below (*Figure 15*). The majority of residents found winter temperatures to be appropriate, with a notable portion feeling that the winter temperatures may be a little hotter than their preference. This fits with expectations for an extremely airtight and well-insulated building such as Salus Karen's Place. However, this is somewhat inconsistent with the in-unit measurements, which tend to trend somewhat below the target ASHRAE temperatures during the winter months (*Figure 7 to Figure 9 above*).

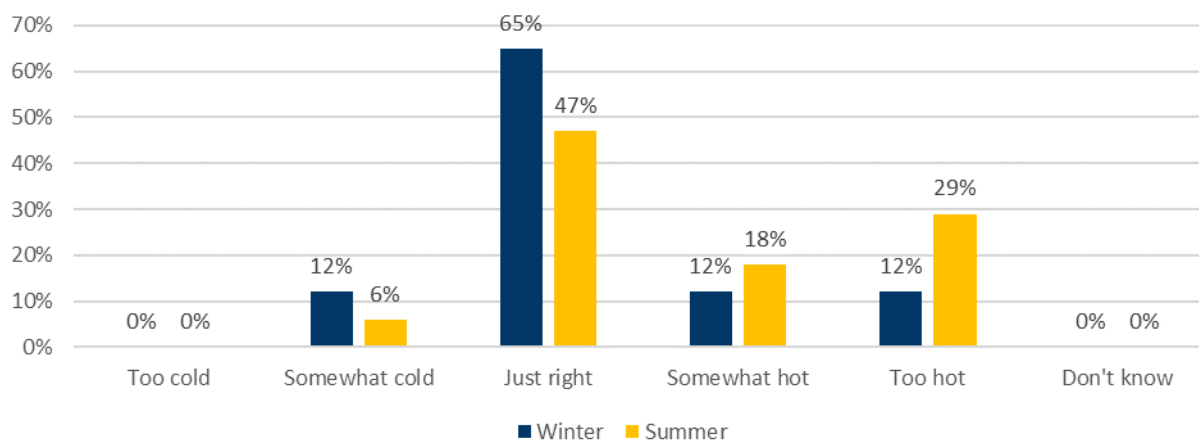


Figure 15. Occupant Survey Results: Winter and Summer Temperature

The occupant survey results for humidity in the building are presented below (*Figure 16*). The following observations are made:

- **Many occupants found the building more humid than desirable in the summer:** 30% of the occupants found the building to be either somewhat humid or too humid in the summer, but interestingly 35% found the building drier than desirable. Given that the cooling and ventilation systems have been upgraded, these results are not likely representative of the current building conditions.

- **Occupants found the building drier than desirable in the winter:** 41% of occupants found that the building was either somewhat dry or too dry in the winter. This is consistent with the in-unit RH monitoring results above and is to be expected in a building that does not have humidification.

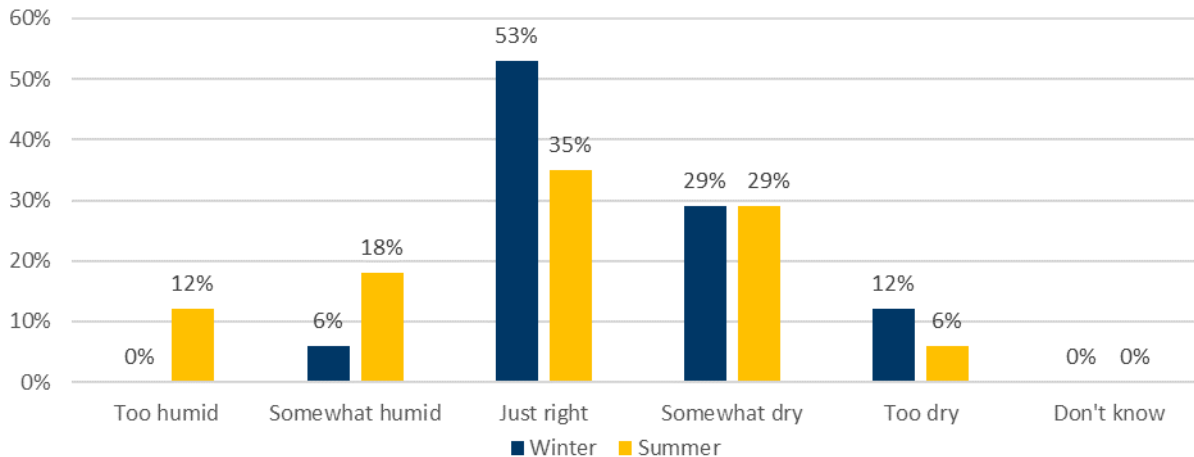


Figure 16. Occupant Survey Results: Winter and Summer Humidity

Occupant comfort can also be impacted by uneven distributions of in-unit temperatures as well as drafts. Neither variations in temperatures nor drafts are reflected in the logger results, which collected data in a single location in the units, and therefore occupants were asked to report on these factors in the survey. A third of those occupants surveyed reported uneven temperature distributions in their apartments, and one quarter reported draftiness.

3.2.4 Thermal Comfort Key Findings

Salus Karen's Place experienced significant thermal comfort challenges in 2018 and steps were taken to remedy the situation through upgrades to the cooling and ventilation system. Despite these upgrades, the building experienced similar overheating challenges in 2019. Overall, the following observations are made:

- **Winter thermal comfort suffered from dryness** but showed improved temperature levels compared to 2018, with most now falling within targets. Our tenant survey indicated that occupants tended to be satisfied with the conditions.
- **Summer thermal comfort suffered from the limited cooling and ventilation systems.** Despite the steps taken in the latter half of 2018 to remedy the situation and the slight improvement observed in 2019, additional room air conditioners were required once more to lower temperature levels in the upper units.
- To evaluate the building's current thermal comfort performance, **the summer in-unit temperature and RH monitoring will be repeated in 2021.**

3.3 Indoor Air Quality

Indoor carbon dioxide (CO₂) concentrations provide a measure of building ventilation, with high CO₂ concentrations pointing to inadequate in-unit ventilation and consequently poor air quality. Inadequate ventilation is a concern in indoor environments, as it may result in the build up of indoor pollutants (including volatile organic compounds, carbon monoxide, particulate matter, and others) as well as unpleasant smells or stuffiness. ASHRAE provides guidance related to ventilation and indoor air quality and advises that CO₂ concentrations are kept at 700 ppm above outdoor conditions, resulting in recommended indoor CO₂ concentrations of 1000-1100 ppm or less³⁰. As a point of comparison, CO₂ concentrations in outdoor air typically range from 300 ppm to 400 ppm³¹.

3.3.1 In-Unit Monitoring of CO₂ Levels

Carbon dioxide concentrations were recorded using data loggers in three of the building's apartment units during two two-week periods (one in the summer and one in the winter) for both POE monitoring periods. For comparison purposes, the same units were used for each reported year.

- **Unit 1:** Southwest corner, middle floor
- **Unit 2:** East-facing, middle floor
- **Unit 3:** West-facing, top floor

The in-unit CO₂ concentrations collected during the four monitoring periods are presented below (*Figure 18, Figure 19, Figure 20, and Figure 21*). Variations in concentrations over time and among the units can be seen and are likely a result of differing ventilation rates, occupancy patterns, and open windows. Overall, CO₂ levels were maintained below the ASHRAE guideline for all measurements, with a few peaks exceeding 1100 ppm during the second winter monitoring. This statement is true for all periods and all units with the exception of the measurements taken in the top floor unit (Unit 3) during the 2019/2020 winter season (*Figure 20*). During the site visit on January 17, 2020, it was reported that the tenant in Unit 3 blocked the air supply inlet with aluminium foil which hindered the fresh air coming in, resulting in higher CO₂ concentration levels (*Figure 17*).



Figure 17: Unit 3 - Air Supply Inlet

³⁰ ASHRAE, 2013

³¹ USDA Food Safety and Inspection Service.

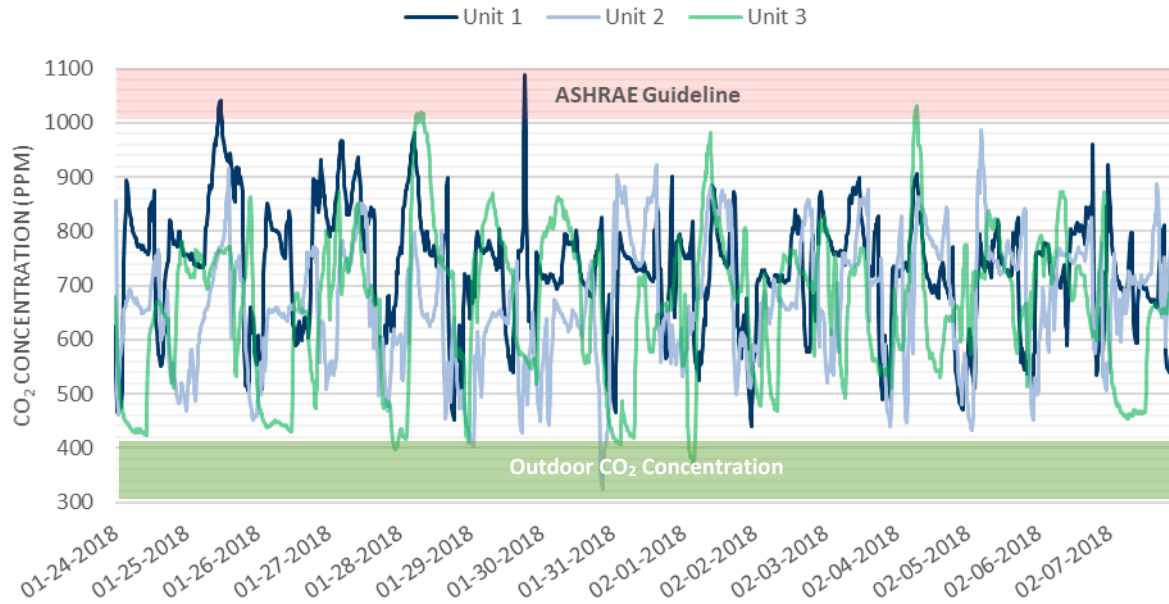


Figure 18. Measured CO₂ Concentrations in Apartments, Winter 2018

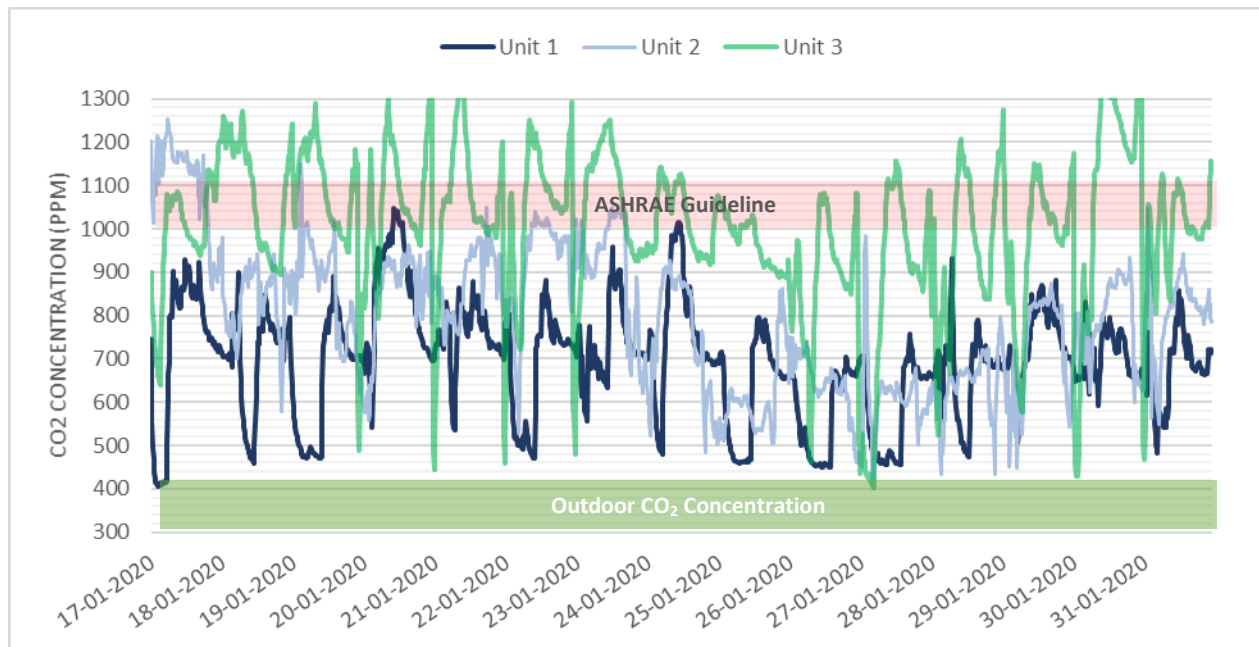


Figure 19: Measured CO₂ Concentrations in Apartments, Winter 2020

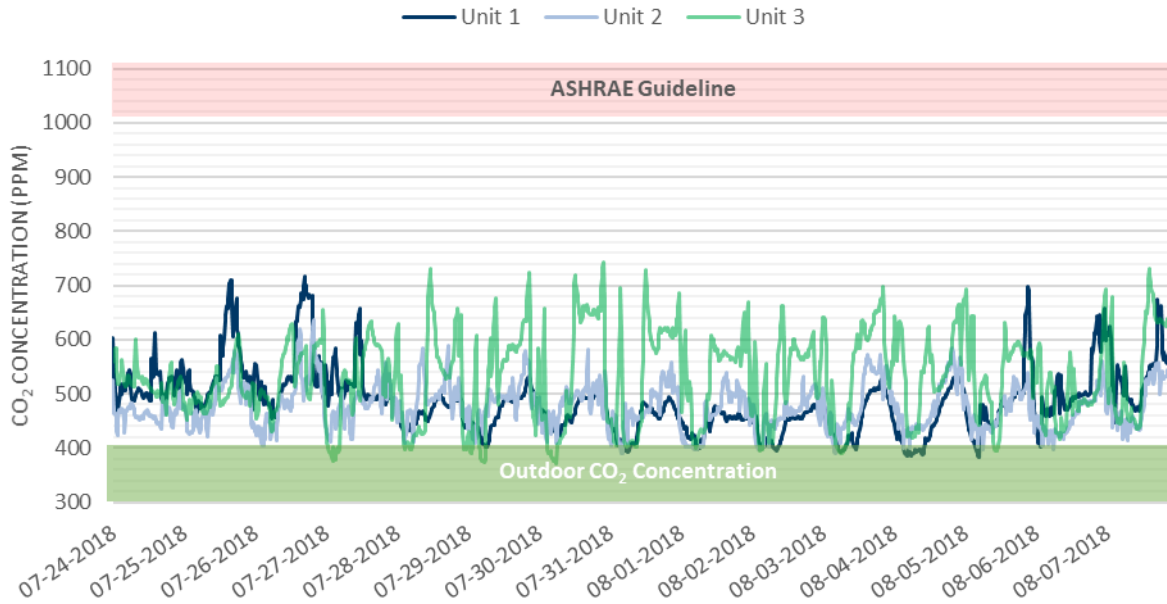


Figure 20. Measured CO₂ Concentrations in Apartments, Summer 2018

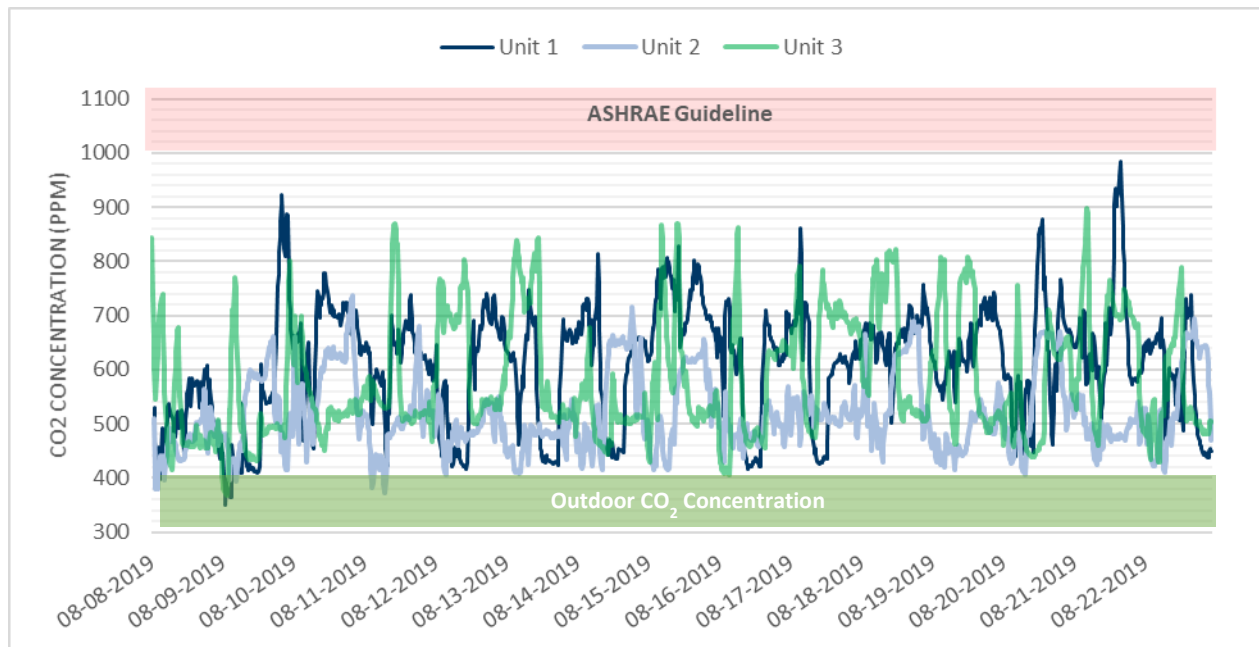


Figure 21: Measured CO₂ Concentrations in Apartments, Summer 2019

An average of summer and winter values, along with the standard deviation associated with each, are presented below (Table 5).

Table 5. Average Summer and Winter Measured CO₂ Concentrations

		CO ₂ Concentration (ppm) – 2018	CO ₂ Concentration (ppm) – 2020
Summer	Average	529	565
	Standard deviation	89	149
Winter	Average	685	802
	Standard deviation	123	200

3.3.2 Occupant Survey Results

Occupant behaviours can impact CO₂ concentrations, including opening windows and use of in-unit range hoods. When asked how often they kept windows open, 50% of occupants reported opening windows often during the summer compared to 17% who reported often opening windows often during the winter. This aligns with the patterns of increased CO₂ concentrations observed during the winter in the logged data.

High CO₂ levels can be an indicator of low ventilation rates. Inadequate ventilation can also lead to build up of unpleasant smells in apartment units. In the occupant survey, 39% of the residents who participated reported unpleasant smells, specifically citing cigarette smoke. Mid-way through the first study period, the maintenance team began to change the ERV filter once every two weeks, instead of once every month, and clean the ERV once per month. Despite these challenges, the majority of occupants report satisfaction with building air quality as ranging from neutral to high satisfaction (*Figure 22*).

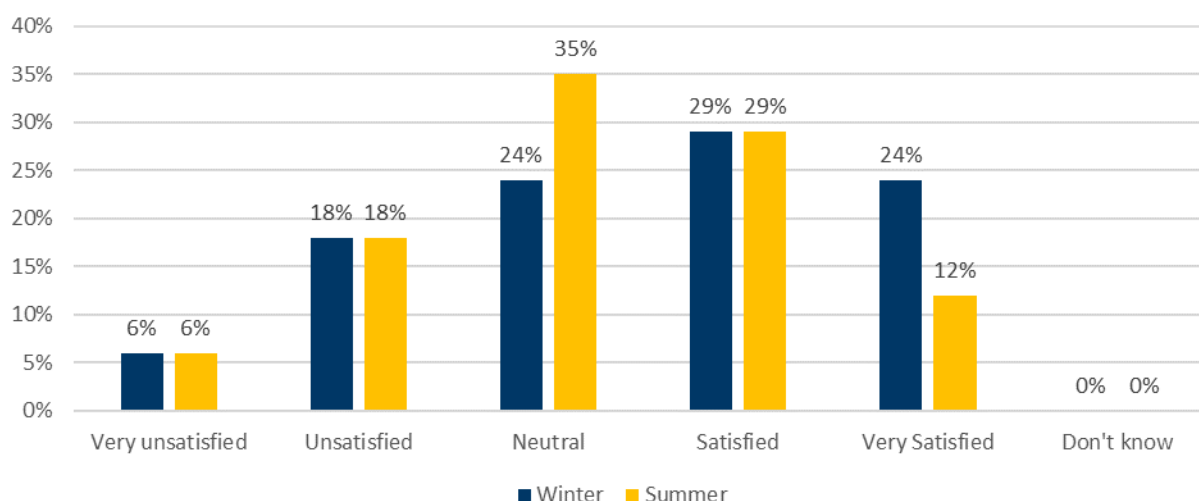


Figure 22. Occupant Survey Results: Air Quality Satisfaction Survey

3.3.3 Indoor Air Quality Key Findings

Overall, CO₂ levels appeared to stay mostly within the targeted range, suggesting that ventilation rates were adequate within the units. Summer CO₂ concentrations were notably lower than winter concentrations, likely due to residents opening their windows.

However, one-unit's readings were significantly over target during the second winter monitoring period as the result of the manual obstruction of the air intake by the occupant. A final occupant survey will be conducted to reveal if this was an isolated behavior or if the increased ventilation rates might have created new discomfort due to additional drafts. The survey will also provide feedback on the effectiveness of the new filter replacement frequency put in place to reduce unpleasant cigarette odors.

3.4 Water Consumption

Water use was tracked via the building's bulk water meter, as well as submetering on laundry equipment³². Monthly water consumption remained consistent throughout the year, with annual consumption totalling 2,463m³ in 2018 and 2,756m³ in 2019 (Figure 23).

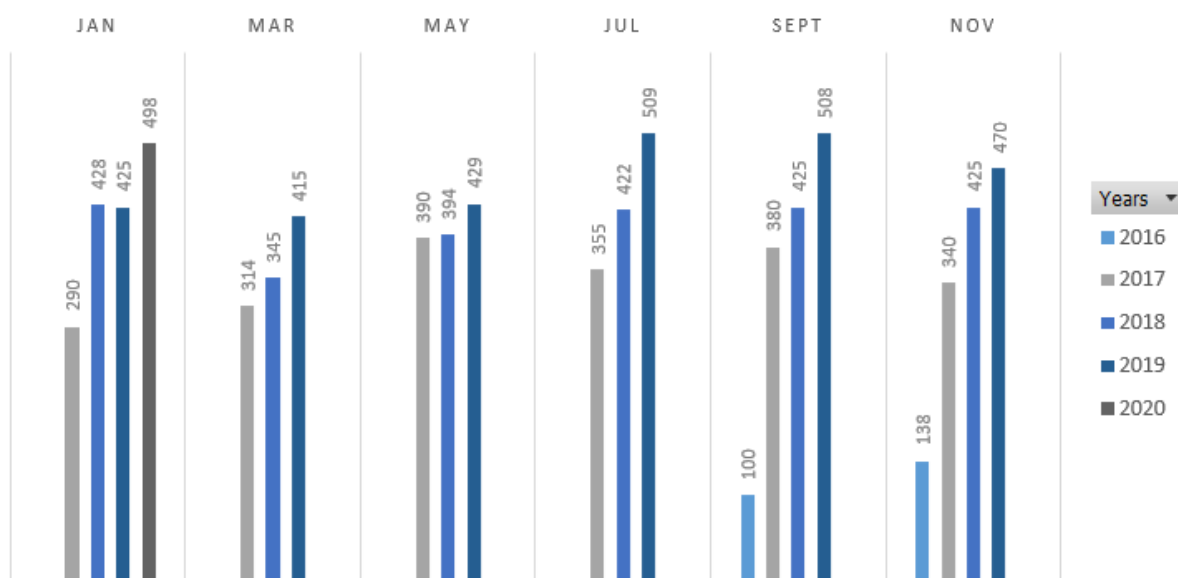


Figure 23. Salus Karen's Place Water Use (m³)

In January 2017, daily average water consumption reached 80% of current levels, suggesting that the building was nearly fully occupied by that time. (See Appendix D: Additional Study Data for more details). Water consumption in the building slowly increased between 2018 and 2019, exhibiting a year-over-year increase of 13% in the annual water consumption. This trend seemed to continue in 2020 and should be closely monitored. The increase may be caused by different water usage from current or new tenants. Despite this trend, total water use in 2019 compared well to normalized per capita and living space benchmarks (Table 6).

Table 6. Salus Karen's Place Annual Water Use Relative to Relevant Benchmarks

	Salus Karen's Place (2018)	Salus Karen's Place (2019)	Benchmark
Per capita consumption (m ³ /year)	58.6	65.6	91.6 ³³
Per m ² of living space (m ³ /year)	0.99	1.11	2.0 ³⁴

³² Submeters on the laundry equipment was installed for the first POE monitoring period (Jan-Dec 2018)

³³ Environment and Climate Change Canada, 2011

³⁴ CMHC, 2001

A breakdown of hot and cold water use in the building was determined using the bulk water meter data and the portion of monthly gas consumption associated with water heating. Further detail was obtained from sub-meters installed on two of the building's laundry machines. The results show that laundry represented less than 4% of total water consumption, and only a small fraction of that was hot water, indicating that tenants primarily use cold water wash cycles (*Figure 24*).

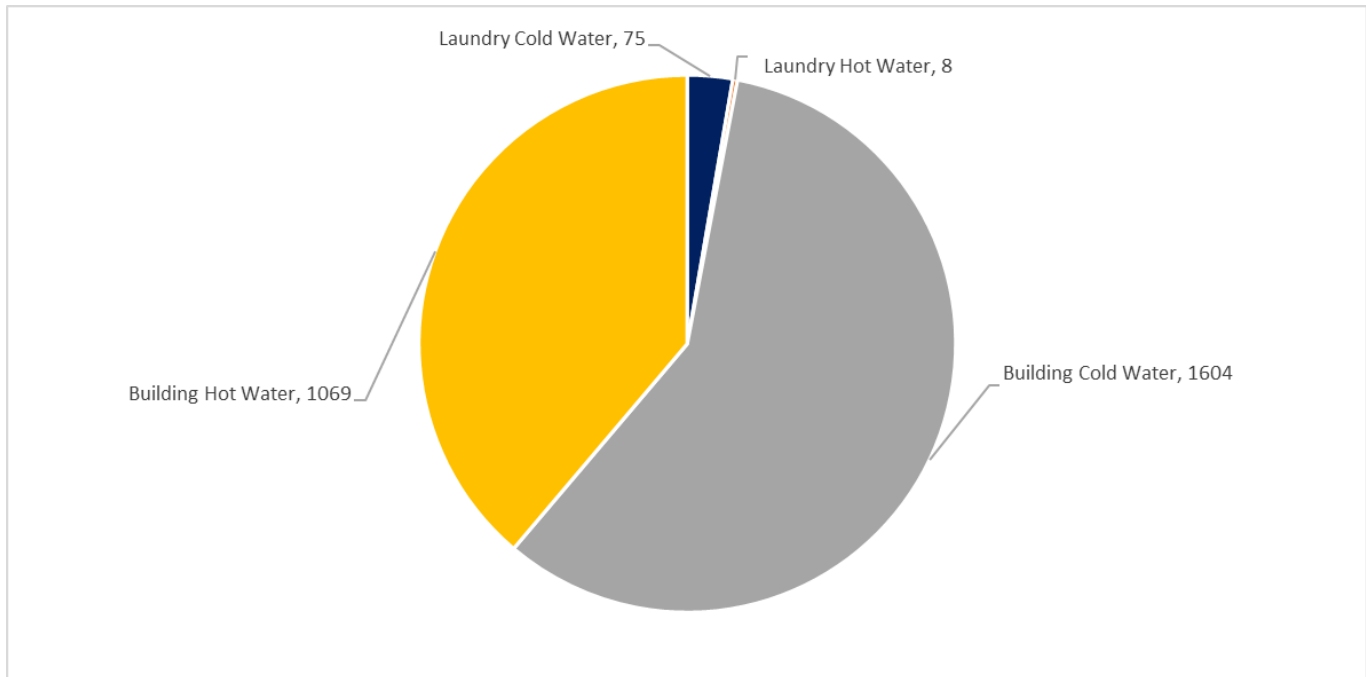


Figure 24. 2019 Water Consumption by End Use Breakdown (average m³/yr)

3.4.1 Water Consumption Key Findings

Despite a slight increase in water consumption in 2018 and 2019, 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. It is recommended that building water consumption continue to be monitored to ensure that it stays below typical water usage. No improvement measures are suggested for the building at this stage, with the exception of an occupant water conservation awareness program, should the Salus Corporation deem this appropriate for the residents.

3.5 Energy Consumption

The previous performance area discussions have shown that Salus Karen's Place achieved high performance in a few key areas (envelope, water consumption, IAQ), but experienced challenges with thermal comfort. This impacted the building's energy performance and is discussed in the following sections.

Energy performance was evaluated based on electricity and natural gas billing bulk meter data, as well as sub-meters and equipment schedule tracking from the BAS data over the study period. A building energy model was also developed and calibrated to 2019 building data (more details are provided in Appendix F: Building Energy Modelling) and was used to provide more accurate energy consumption breakdown.

In this section, we first provide an overview and breakdown of total energy consumption. This is followed by overall electricity use, electricity demand, and natural gas use. Next, more detailed analysis is presented for the building HVAC systems, hot water, and remaining electricity-consuming equipment including appliances, plug loads, and lighting. Finally, we describe the impact that building HVAC system improvements, implemented just prior to or during both POE periods, have had on energy consumption.

3.5.1 Energy Use Intensity

To assess the energy use intensity (EUI), gas consumption is converted to equivalent kWh (ekWh) to allow for comparison of the overall energy consumption among facilities with differing shares of electricity and gas use. The total electricity consumption was 191,175 kWh in 2018 and 192,809 kWh in 2019 (calendar year) and the total natural gas consumption was 93,659 ekWh in 2018 and 107,443 ekWh in 2019, which results in an overall annual consumption of 283,834 ekWh in 2018 and 300,252 ekWh in 2019 for all end uses (*Figure 25*).

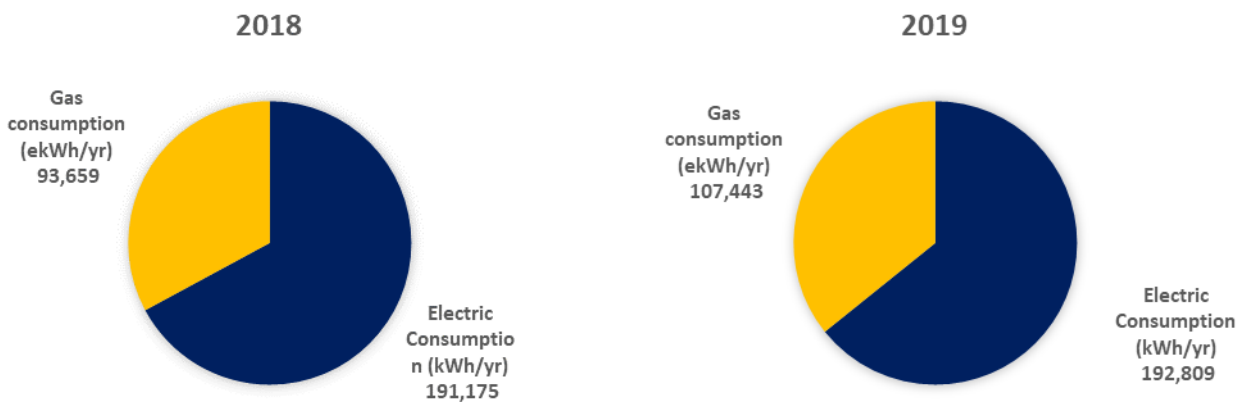


Figure 25. Salus Karen's Place Annual Energy Consumption (ekWh/yr) by Fuel Type for 2018 and 2019

This translates to an **EUI of 115 ekWh/m²/yr** in 2018, which out-performs the stringent Passive House Standard by about 4% but is 9% higher than the initial Salus Karen's Place design estimate. In 2019, the EUI was 5% higher than in 2018, with a total **EUI of 121 ekWh/m²/yr**, which is 1% higher than Passive House Standard. The EUI in 2018 and 2019 was 12% and 18% higher than in 2017, which is primarily the result of additional cooling demand

during the summer of 2018 and 2019³⁵. By normalizing the 2019 consumption based on the previous year, it is noticeable that the 2019 increase is mainly the result of the supply fan motor replacement in October 2018. More details are provided in the next sections.

When converted to primary energy consumption³⁶ (or source energy), in 2019, the **source EUI is 196 ekWh/m²/yr**, which is 63% higher than Passive House Standard (52% once normalized) and 73% higher than the initial Salus Karen's Place design estimate (62% once normalized). However, compared to other buildings, Salus Karen's Place still performs well with respect to overall energy use (*Table 7*).

Table 7. Comparison of Salus Karen's Place 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 ³⁷
Site EUI (ekWh/m ²)	-	103	115	121	-	212
Source EUI (ekWh/m ²)	113	167	189	196	120	-

The total utility spend for this facility during the study period is provided below (*Table 8*). Electricity represents 64% of the overall energy consumption and 85% of utility spending³⁸, indicating that electricity-saving measures will likely provide a better return on investment than gas-saving measures.

Table 8. Utility Spend for the Salus Karen's Place Building

Energy	Utility	2018 Spend (incl. HST)	2019 Spend (incl. HST)
Electricity	Hydro Ottawa	\$23,658	\$23,954
Natural Gas	Enbridge	\$3,725	\$4,143

The overall energy end use breakdown (all fuels) was determined using the calibrated building energy modelling (*Figure 26*). As seen in the graph, common areas and centralized HVAC and DHW systems accounted for 68% of the overall energy consumption, while in-apartment consumption accounted for 32%.

³⁵ Inspection of monthly energy and water trends suggest that the building likely achieved near full occupancy by January 2017.

³⁶ Primary energy or source energy includes the energy losses associated with generating and delivering the fuel to the building. For this study, Canadian source-site ratios used were based on Energy Star Portfolio Manager, Technical Reference, 2020.

³⁷ CMHC, 2001

³⁸ Based on 2019 annual spending.

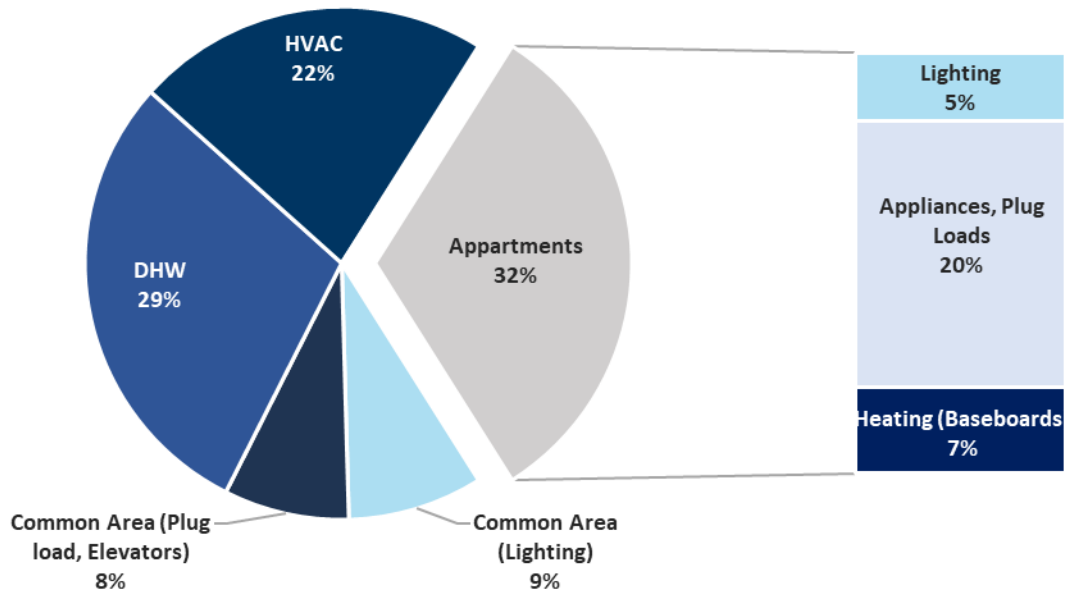


Figure 26. Overall Energy End Use Breakdown

During the summer of 2019, room ACs were distributed to tenants upon request and no data log was kept to track when each AC unit was reinstalled. As a result, it was not possible to separate the temporary room air-conditioners from the dataset. It is also important to note that it was not possible to assign a secondary cooling to the eQuest model, therefore the temporary air conditioners were included in the centralized HVAC category (as described in Appendix F: Building Energy Modelling). When analyzing model outputs, it appeared that the building cooling needs were not met on many occasions without adding the capacity provided from the room ACs. In other words, even with the new cooling capacity from the two additional chillers, the model predicts that the spaces will frequently be over the cooling set point temperature.

Although the in-apartment energy use is dominated by plug-loads and appliances, supplemental heating provided by electric baseboards is not negligible. Electric baseboards accounted for 7% of the building's consumption and were mostly use when exterior temperatures dropped significantly. Space heating accounted for 32% of the centralized HVAC system energy use. Space cooling also represented 29% and finally ventilation and auxiliary equipment was at 39%. As mentioned above, space cooling includes both centralized and in-unit cooling systems. Since the building was still subject to cooling adjustments, more details will be provided after the next cooling season when the building has operated under normal conditions.

- HVAC loads represented a much lower portion of overall energy demand than the Canadian average for MURBs.** The CMHC Benchmark for MURBs³⁹ indicates that for typical buildings, 60% of overall energy is used for space heating and almost nothing for cooling. In the case of the Salus Karen's Place building, the HVAC load represented just 29% (including 7% from baseboard heating), with a portion of this coming from cooling loads. The reduced heating loads and increased cooling loads are attributed to the building's high-performance envelope and heat recovery system.

³⁹ CMHC, 2015

- **Lighting represented a lower portion of total energy use than the Canadian average for MURBs.** Salus Karen's Place building is exclusively equipped with LED lights, some of which are coupled with occupancy sensors. However, it is important to note that some occupants installed their own stand-alone lights, which are captured in the in-unit plug loads category.

When expressed on a per suite basis, the total annual energy consumption is 7,149 ekWh/suite/yr. The table below shows how the building compares to others (*Table 9*). The significant difference between the low, average and high scenario is mainly due to unit size. Considering that the Salus Karen's Place units are relatively small, the 'Low' scenario is considered to be the most representative.

Table 9. Comparison of Salus Karen's Place energy consumption per suite to Key Benchmarks⁴⁰

	Salus Karen's Place (2018)	Salus Karen's Place (2019)	Low Mid-Rise MURB	Average Mid-Rise MURB	High Mid-Rise MURB
ekWh/suite	6,742	7,149	8,800	17,200	27,800

3.5.2 Electricity Consumption Breakdown

Monthly electricity consumption profiles (*Figure 27*) were developed using 15-minute interval readings from the bulk electricity meter. Total electricity consumption was 191,175 kWh in 2018, which was 16% higher than in 2017. As discussed above, this is attributed to the use of room AC units to address thermal comfort challenges in the summer of 2018, and to some degree may also reflect that the building did not achieve full occupancy until March 2017. In 2019, total electricity consumption was 192,809 kWh, which was 1% higher than 2018. This increase is likely attributable to the upgrade of supply fan motors at the end of 2018 as this directly impacts electricity consumption.

Four key trends can be noted:

- First, electricity consumption increased steadily as construction was completed and occupancy occurred in the later months of 2016.
- Second, despite full occupancy not occurring until March 2017, electricity consumption plateaued starting in January 2017, which allowed for a year over year comparison from 2017 to 2019.
- Third, a spike in electricity consumption occurred from June to September 2018 and 2019, corresponding to the use of temporary in-unit room air-conditioners to address thermal comfort issues in the building during extreme summer heat during both summers.
- Fourth, the years 2018 and 2019 show similar electric consumption except early in the year, prior to the replacement of the fan motors.

⁴⁰ CMHC, 2017

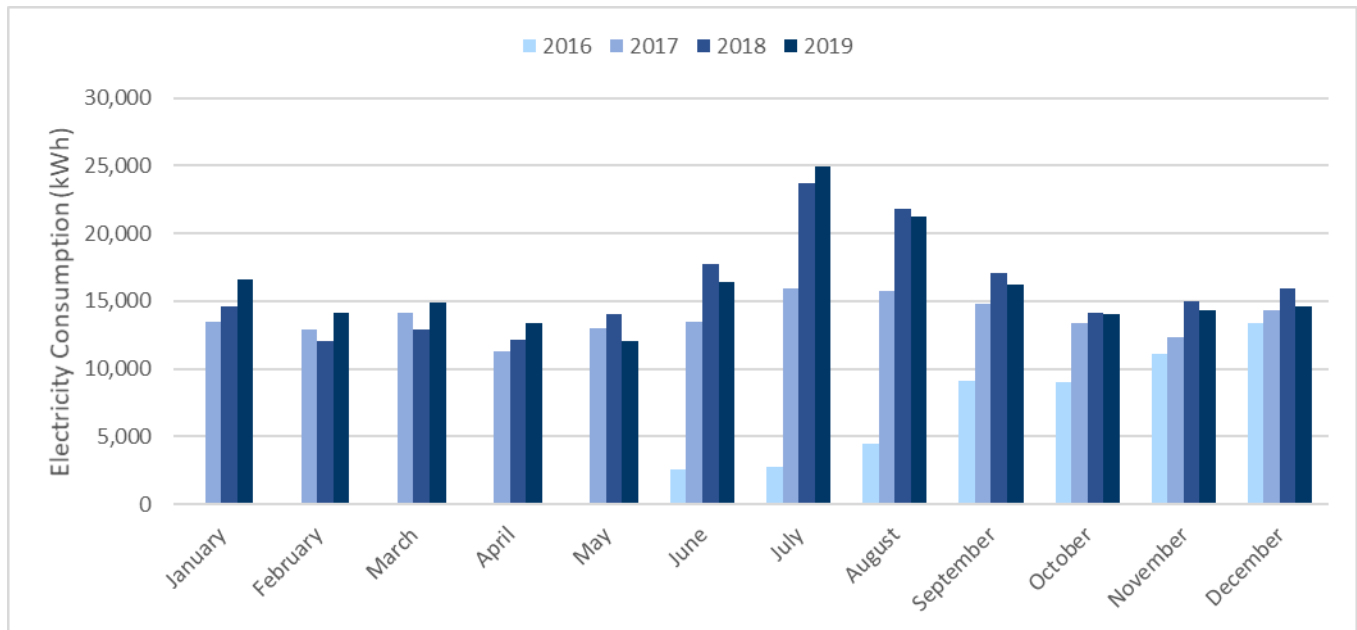


Figure 27. All Historic Electricity Consumption Data for the Salus Karen's Place Building

To properly assess the 2019 building performance and identify the impacts of the 2018 building modifications, a weather normalization was performed based on 2018 consumption data. Weather normalization yielded a predicted annual consumption total of 183,179 kWh. The actual consumption of 192,809 kWh in 2019 represents a 5% increase compared to the projection. Since room ACs were in use during both summers, the 2019 increase is likely attributable to the additional chillers and supply fan power (*Table 10*).

Table 10: Electric Consumption and Degree-Days Comparison between 2018 and 2019

	2018	2019	Expected 2019
Summer Consumption (May-October)	108,567	104,909	99,270 (-6%)
CDD (@18°C)	374	229	
Winter Consumption (November-April)	82,608	87,901	83,909 (-5%)
HDD (@18°C)	4,546	4,732	

In October 2018, the central chiller capacity was increased from 21 kW to 49 kW (133% increase) and the MAU fan was increased from 1.1 kW to 1.5 kW (33% increase). The extensive increase in the chiller and supply fan capacity, coupled with only a moderate increase in normalized energy consumption (5%) indicates that the new equipment along with the controls updates and system rebalancing were an effective energy management strategy.

Key pieces of electricity-consuming equipment in the Salus Karen's Place building include major in-unit and common area appliances (stoves, refrigerators, etc.), lights, resident-owned devices, and auxiliary equipment (elevators, circulating pumps, fans, etc.).

To determine the end use breakdown of electricity consumption in the building, lighting and key electricity-using 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.

Several observations can be noted (*Figure 28*)

- HVAC systems (heating, cooling, pumps, fans, AC 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).
- Supplemental heating use via the electric baseboards represented 10% of electricity use in the building.

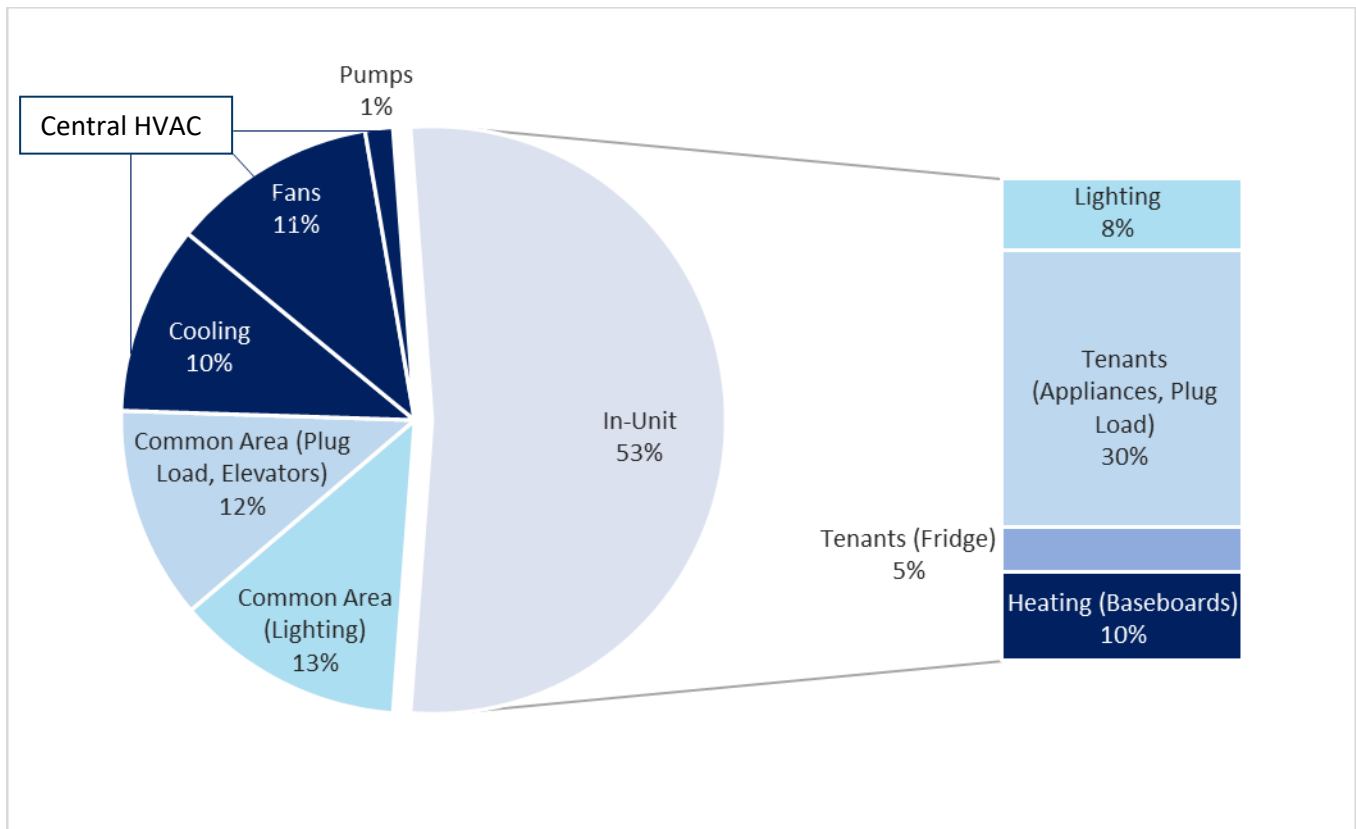


Figure 28. Salus Karen's Place Electricity Consumption by End Use

3.5.3 Electricity Demand

Peak demand is an important feature of a building's operation because it can have a significant impact on energy bills due to utility demand charges. The peak demand for this facility was available from January 2017 to December 2019 through Hydro Ottawa electricity bills. The monthly demand for this 36-month period is shown below (*Figure 29*).

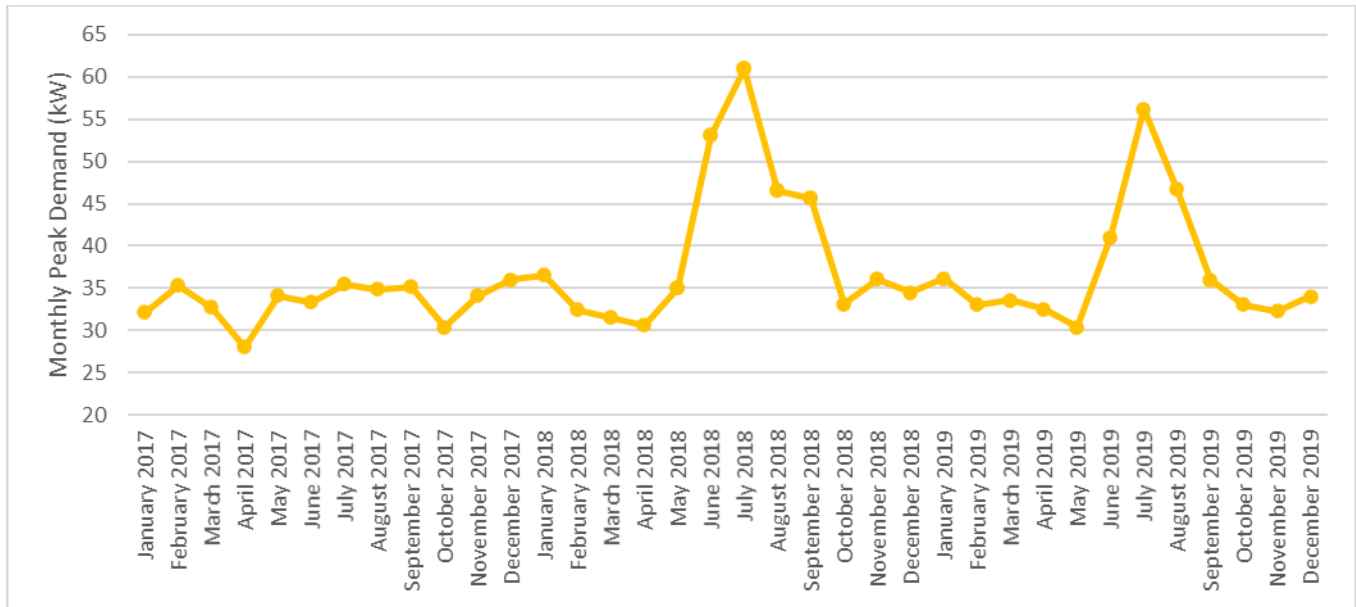


Figure 29. Monthly Demand Profile

In 2019, the **minimum demand was 30.4 kW and the maximum was 56.24 kW**, which is similar to 2018 when the **minimum was 30.64 kW and the maximum was 60.96 kW**. Given the similarity between the maximum building power consumption in 2018 and 2019, it seems that the contribution to peak of room air-conditioners was comparable for both years.

Also, as expected, the peak demand profile is aligned with the reported electricity consumption. The intense use of the cooling system and installation of the 42 AC units significantly increased the overall electricity demand of the building. The use of the AC units resulted in a near doubling of peak demand (and charges) in July 2018 and 2019 compared to the annual average, even though consumption only increased by 70%. It is also interesting to note that the hourly profile shows very little day-to-night variation in consumption. This can be observed throughout the year, including during the mechanical cooling period.

The peak variation between the AC cooling capacity compared to the building centralized cooling system can be clearly observed with the building modelling (*Figure 30 and Figure 31*)⁴¹. While the actual winter demand profile is nearly identical to the modelled results, the summer profiles show a noticeable variation due to the production of cooling through the AC units.

⁴¹ The energy building model considers that the chillers are the only source to cover the building cooling needs.

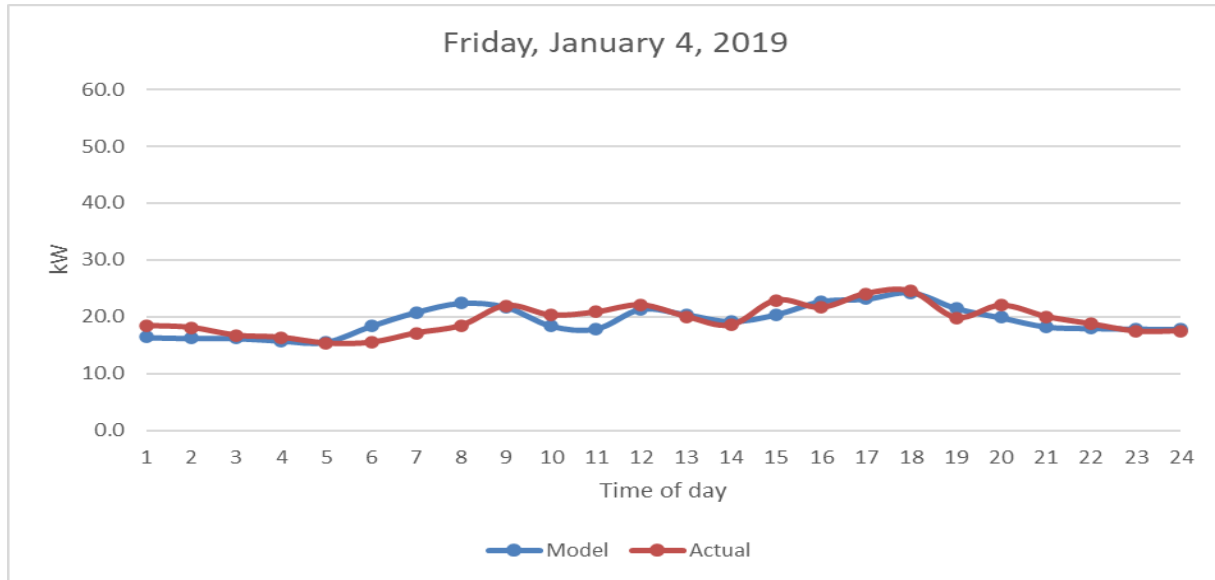


Figure 30: Hourly Profile for Electricity for a Sample Winter Day

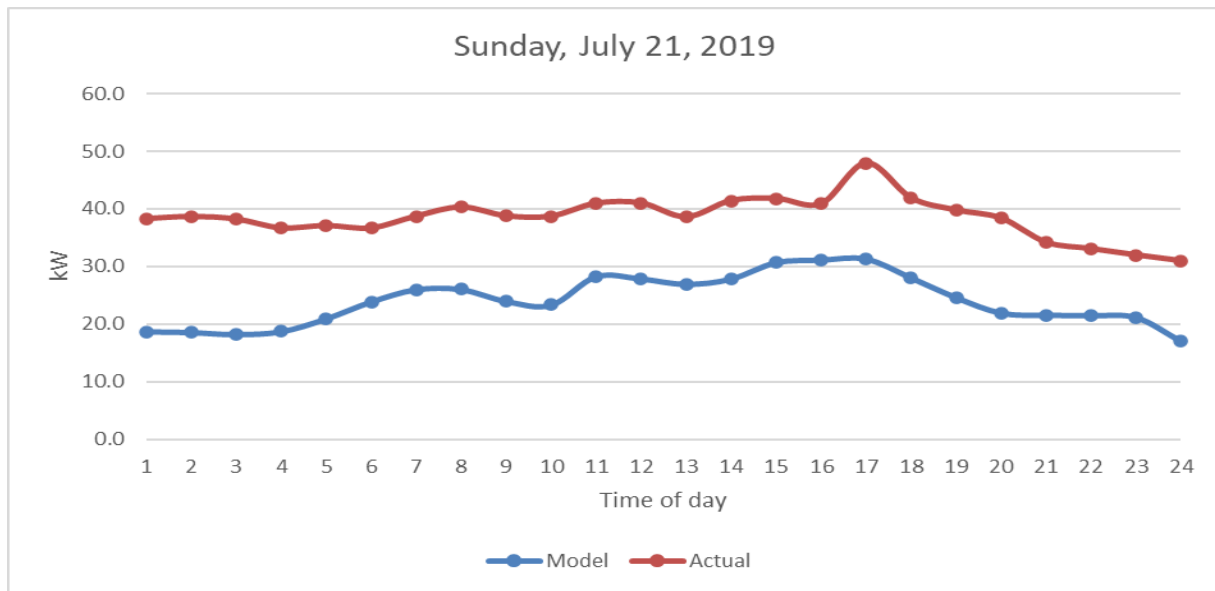


Figure 31: Hourly Profile for Electricity for a Sample Summer Day

An analysis of the power factor was also conducted using the interval data received from Hydro Ottawa. The power factor is the ratio between the actual power used in the buildings (kW) and the apparent power fed to the building by the utility company (kVA). The power factor is a measure of how efficiently the power is converted into useful power (kW). The utility company delivers kVA to the facility but typically only charges for the useful power (kW). Most utilities will add an additional charge if the power factor falls below a threshold, typically set at 90%.

For the Salus Karen's Place building, the power factor was 100% from October to June, 99% in July and September, and 98% in August. Overall, the power factor was very high due to the high level of resistive load. The difference between summer and winter months was likely due to the chiller motors and AC units.

3.5.4 Natural Gas Consumption Breakdown

Natural gas consumption profiles were developed using Enbridge gas bills (*Figure 32*), based on the actual bi-monthly gas meter readings. Total gas consumption in 2019 was 10,336 m³, 15% higher than 2018 with a total consumption of 9,010 m³.

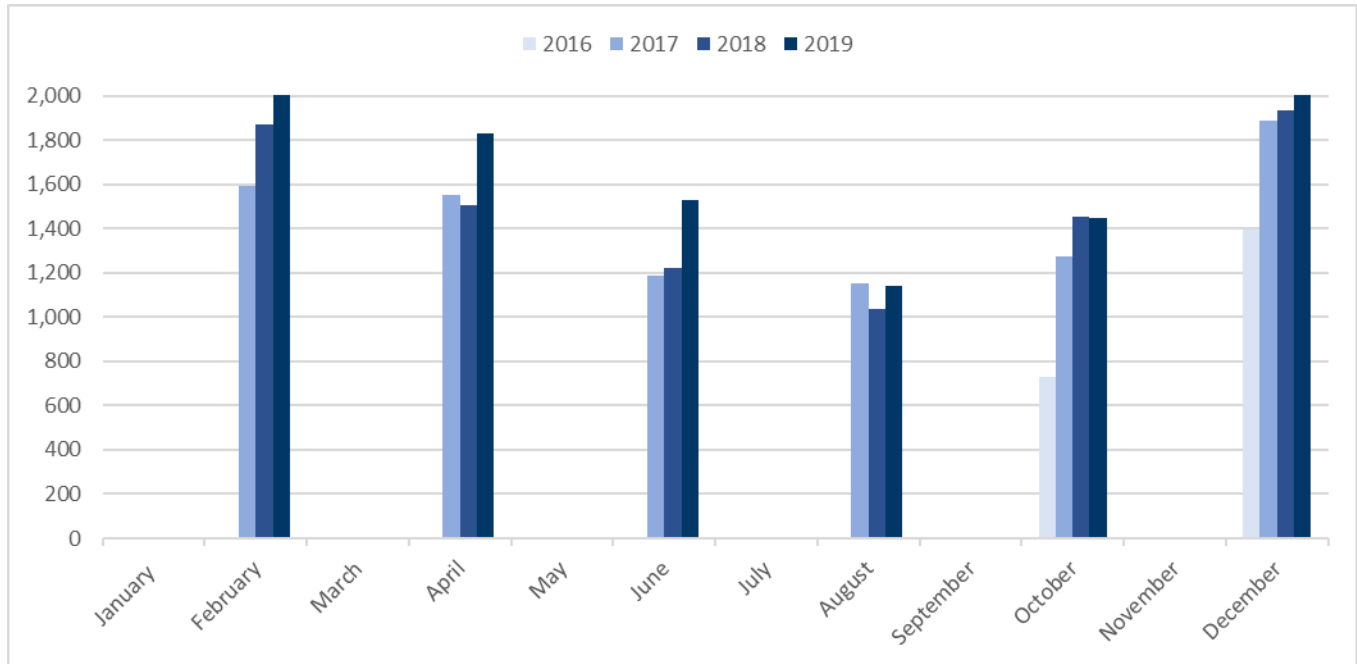


Figure 32. All Historic Natural Gas Consumption Data for the Salus Karen's Place Building (m³)

The building's only natural gas-consuming equipment are two condensing water heaters. The water heaters have a dual role of producing domestic hot water (DHW) and space heating via the ERV pre-heating coil. As was observed for the electricity profile, the consumption of gas appeared to plateau by early 2017 and then stayed relatively stable in 2017 and 2018.

However, in the first six months of 2019 gas consumption was 14% higher than in 2018 (Table 11). This mostly attributable to the MAUs installed in late 2018, which increase the flow of supply air into the building, and therefore increase the heat needed to pre-treat the fresh air intake.

Table 11: Gas Consumption and Degree-Days Comparison between 2018 and 2019

	2018	2019	Expected 2019
Annual Consumption (m ³)	9,010	10,336	9,093 (-14%)
HDD (@18°C)	4,546	4,732	

Gas consumption for DHW was estimated by assuming that there was little, or no space heating required in July and August, and that DHW demand did not vary significantly over the course of the year. The breakdown provided was determined using the calibrated energy model. DHW is responsible for 81.7% of the gas consumption in the building, which underlines Salus Karen's Place high efficiency envelope and HVAC design (*Figure 33*).

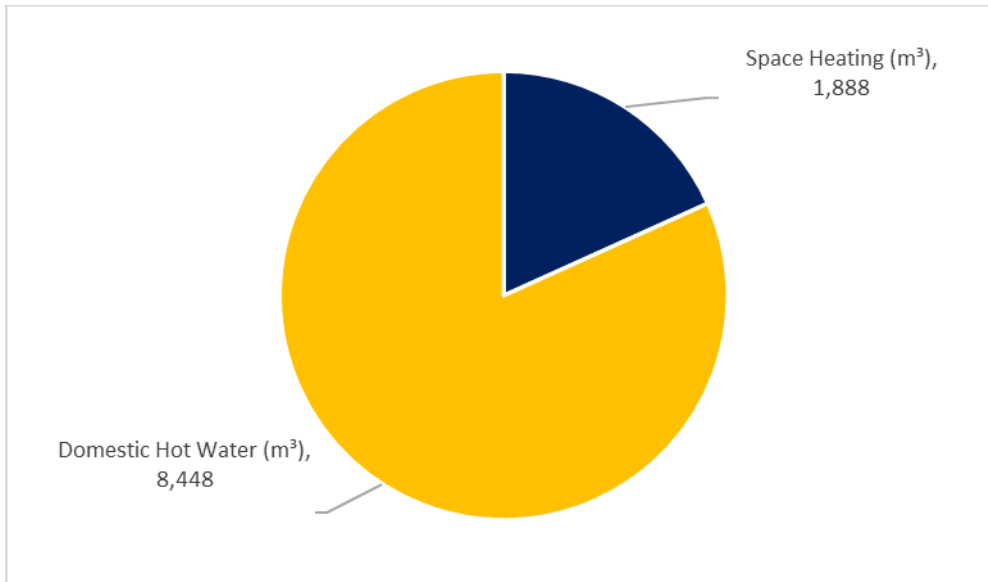


Figure 33. Salus Karen's Place 2019 Natural Gas Consumption by End Use (m³/yr)

3.5.5 Energy Performance by End-Use

This section outlines energy use in the Salus Karen's Place building's heating, ventilation, and air conditioning systems.

3.5.5.1 Heating

The heating for this building is provided by two condensing gas water heaters (*Figure 34*). These serve the dual purpose of providing domestic hot water as well as meeting the space heating needs by pre-heating make-up air via the ERV heating coils. The pumps serving the heating coil are variable speed but operate at constant speed due to the presence of a three-way bypass valve.⁴² Supplemental heating capacity (300 W per apartment) is also provided by in-unit electric baseboard heaters.

Ideally, under the Passive House design concept, internal heat gains, heat recovery units, and pre-conditioning of make-up air should be nearly sufficient to meet the building's heating needs. However, based on the calibrated building energy model, it seems that in-unit baseboards provided half of the building's heating needs (*Figure 35*).



Figure 34: Condensing Water Heaters that Provide Space Heating and DHW to the Building

⁴² It is unusual to have three-way valve when using VFDs and this configuration should be re-examined to see if using a two-way valve or restricting the bypass port of the three-way valve should be considered.

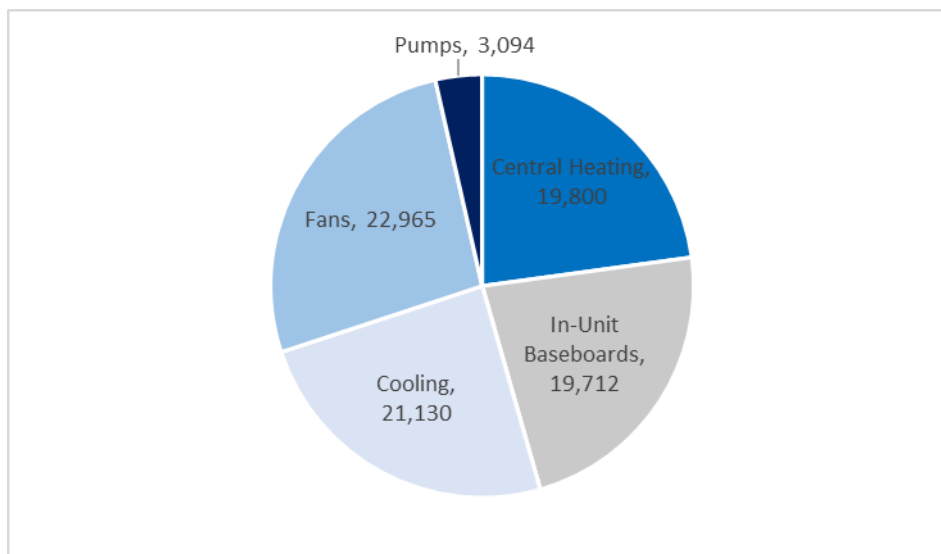


Figure 35. Calibrated Energy Model Results: Energy Use (Measured in ekWh) by HVAC Equipment

As presented below (*Table 12*), the heating consumption of the Salus Karen's Place building was low compared to the Ontario Building Code (OBC) performance path requirements. However, our evaluation indicates that it is slightly higher than the initial design and the Passive House standard.

Table 12. Salus Karen's Place Heating Energy Use Compared to Passive House Standard

	Salus Karen's Place Design Modelling ⁴³	Salus Karen's Place Actual Performance	Passive House Standard	OBC (NECB 2015 part 8)
Heating EUI (ekWh/m ² /yr)	14	16	15	41

3.5.5.2 Cooling

In buildings like Salus Karen's Place that have extremely tight building envelopes, heat gains from electricity consuming equipment can build up in summer months. This can lead to increased cooling energy consumption and reduced thermal comfort.

In the summer of 2018, daily highs reached 31°C and stayed high for several days in a row, leading to in-unit temperatures reaching over 35°C. This revealed issues with the cooling and ventilation system, and led the building manager to take actions to distribute temporary room AC units, and then to increase the building's central cooling capacity by adding 14 kW chillers (*Figure 36*), and augmenting ventilation capacity from a 1.5 hp fan to a 2 hp fan. During the summer of 2019,

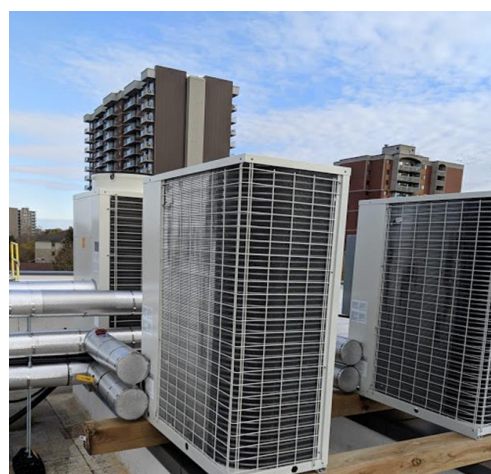


Figure 36. Additional Air-Cooled Chillers Installed at Salus Clementine Building in October 2018

⁴³ Performance path results as calculated by CSV Architects for the Salus Building.

as outside temperatures reached up to 30.1°C in June, interior temperatures in upper units reached 29.6°C. An improvement was observed from 2018 to 2019 but it was not sufficient to maintain acceptable thermal comfort levels. Following these observations, the building manager decided to redistribute the temporary AC units. All of these actions led to increase cooling electricity consumption as compared to the building model and contributed to an overall increase in the EUI of 12% in 2018 and 18% in 2019 as compared to 2017.

Despite additional capacity added to the building, the cooling consumption of the Salus Karen's Place building stayed in the Passive House requirements with a **cooling energy use of 9 kWh/m²/yr** in 2019. However, it should be noted that AC units were not sub-metered and might have had a bigger contribution than current assumptions.

3.5.5.3 Ventilation

A central make-up air unit located in the basement is used to provide ventilation to each apartment. The unit was modified in October 2018 to increase the size of the supply fan motor from 1.5 hp to 2 hp with the aim of increasing the flow in order to reduce some of the summer over-heating issues observed in June and July 2018. This lack of capacity explains why the data shows that the unit's VFDs were always operating at 100% speed. No formal airflow measurement was taken or provided following the replacement of the motor from 1.5 hp to 2 hp. The air pressurization test⁴⁴ has been performed after the motor installation.

3.5.5.4 Domestic Hot Water (DHW)

The DHW system is based on a recirculating loop served by the gas-fired condensing water heaters. In April 2017, the water heater set point was increased to 71°C. The building is equipped with efficient equipment including low-flow showerheads (1.75 GPM) and toilets (1.28 GPM) and ENERGYSTAR certified clothes washers.

In 2019, it was estimated that 8,448 m³ of natural gas was used for water heating, which includes a small portion for laundry purposes (1%). Most of the time, the clothes washers were used on cold-water cycles. The occupant survey did not reveal any concerns regarding inadequate hot water supply and the system was observed to be in good condition and using very efficient equipment.

3.5.5.5 Appliances, Plug Loads, Elevators and Lighting

Using efficient appliances is particularly important in a building with airtight envelopes like Salus Karen's Place because waste heat from inefficient appliances could build up and increase the building's cooling demand.

Although there was some contribution from common room equipment and the elevator, the Salus Karen's Place non-HVAC or DHW related loads were primarily driven by in-suite appliances, including fridges, stoves, TVs, personal computers, and other diverse plug loads.

Refrigerators are the most important energy consuming appliances in the apartments, representing 16% of the in-suite plug-load (*Table 13 and Figure 37*). The consumption observed for refrigerators in Salus Karen's Place was

⁴⁴ Summarized in Airtightness, and described in full in Appendix G.

somewhat lower than the ENERGY STAR standard, likely because the apartments are all single occupancy units while ENERGY STAR ratings are set by considering a variety of usage conditions (such as for families).

Table 13. Measured Annual Refrigerators Consumption

Annual Consumption	kWh/yr
In-unit Refrigerator	231
Common Area Refrigerator	252



Figure 37. In-unit Major Appliances

3.5.5.6 Building Controls

The building has an extensive building automation system (BAS) located in the basement mechanical room. The BAS controls the central plant equipment as well as the terminal VAV boxes serving the common areas and apartments. The BAS can also control the occupied/unoccupied set points, including in the apartments as well as the electric baseboards. In addition, the system has sensors on the apartment windows and it will shut off air-supply to apartments where an open window sensor is triggered.

The system implements efficiency measures such as resetting the make-up air unit supply temperature based on return temperature and scheduling the chiller. However, due to the continuous occupancy of the building and the operating issues linked to the ventilation system (low airflow), it does not implement any type of scheduling or resetting of the static pressure in the supply air duct.

During our first building visit, it was noted that there could be an opportunity to improve the controls protocols further. Given the building's relatively low HVAC energy consumption, the potential energy savings from controls retro-commissioning would be small, however could also result in improved occupant comfort.

After the summer 2019, the property manager decided to invest in a new system (Figure 38) with better trending capabilities and remotely accessible for the property manager.

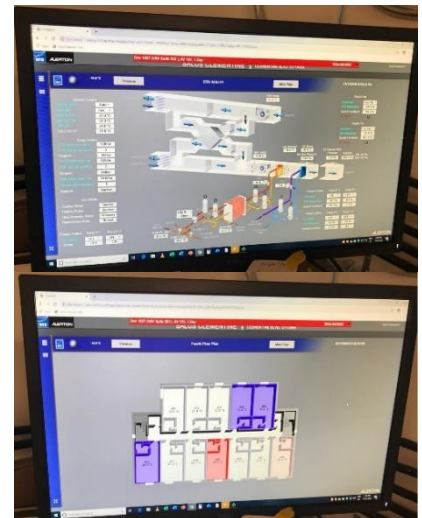


Figure 38. BAS Control Panel Interface after upgrade

3.5.6 Impact of Building System Modifications

To track the impact of the heating and cooling system modifications, we compared the building's energy consumption to a weather-normalized baseline and prepared cumulative sum (CUSUM) graphs.

The building's electricity and gas CUSUM trends are presented below (*Figure 39 and Figure 40*).

Based on the graphs, we observed the following:

- **Summer heat waves:** Weather-adjusted electricity consumption showed a sharp increase in energy consumption in the summer of 2018, initially as a result of the building's chiller trying to meet increasing cooling loads, and later as a result of the use of in-apartment AC units. The same pattern was observed in the summer of 2019.
- **Increased chiller and ventilation capacity:** By October 2018, the chiller and MAU capacity had been increased, leading to steadily elevated consumption due to the additional power draw from the more powerful MAU.
- **Impact on electricity consumption:** The initial increase due to changes in chiller operation represented between 2,240 kWh and 3,360 kWh while the room AC added an additional 10,710 kWh to 15,680 kWh of consumption⁴⁵. The change to the make-up air unit added another 4,210 kWh of consumption over a 2-month period. It is important to note that all of those values are weather corrected to 2017 to take into consideration the initial size increase of the make-up air pre-heating coil heat exchanger in the baseline.
- **Impact on gas consumption:** In the final months of 2018, a steady increase in the cumulative gas consumption curve is observed after the MAU capacity was increased. The consistency of the increase in 2018 and in 2019 and the slow down during the cooling season indicates that it is likely attributable to the building's increased ability to deliver heat to the apartments via the larger MAU fans.

Overall, the building modifications appeared to have slightly improved the thermal comfort in the apartments. However, the new equipment and heating/cooling operations increased the use of energy in the building.

⁴⁵ Ranges correspond to the difference between the summers of 2018 and 2019.

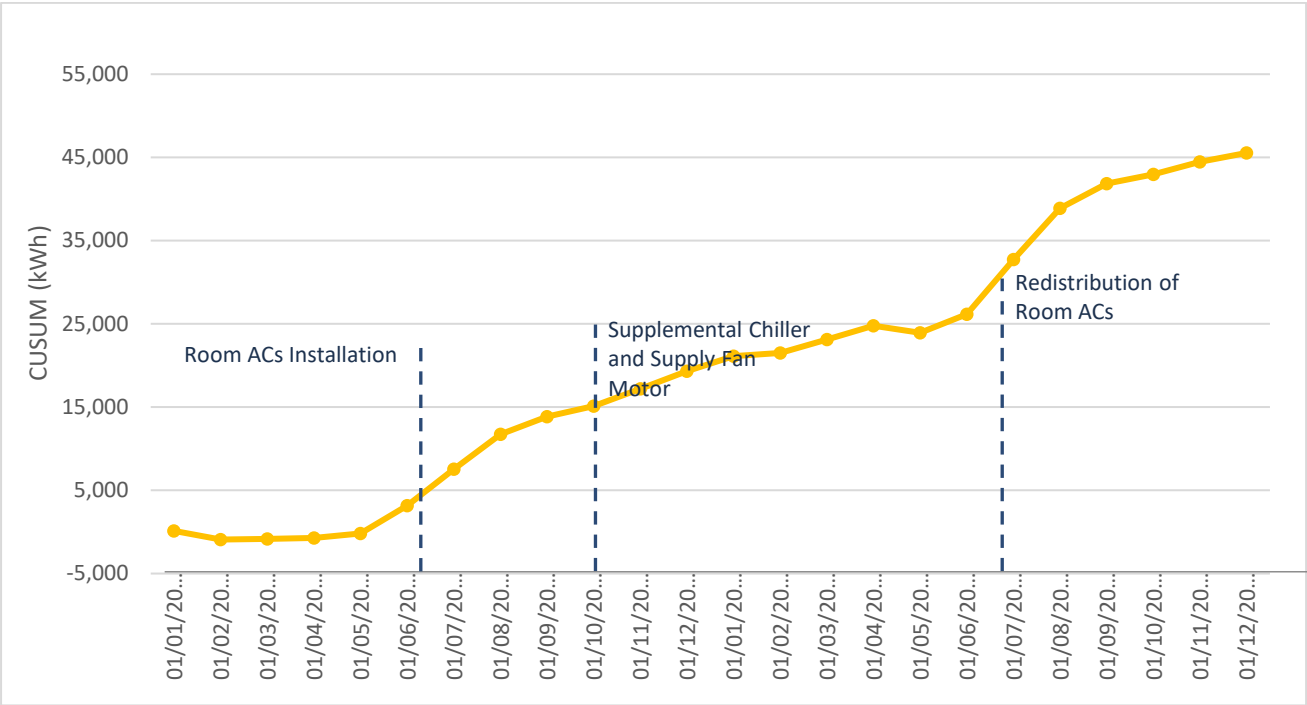


Figure 39. Electricity Consumption CUSUM Graph

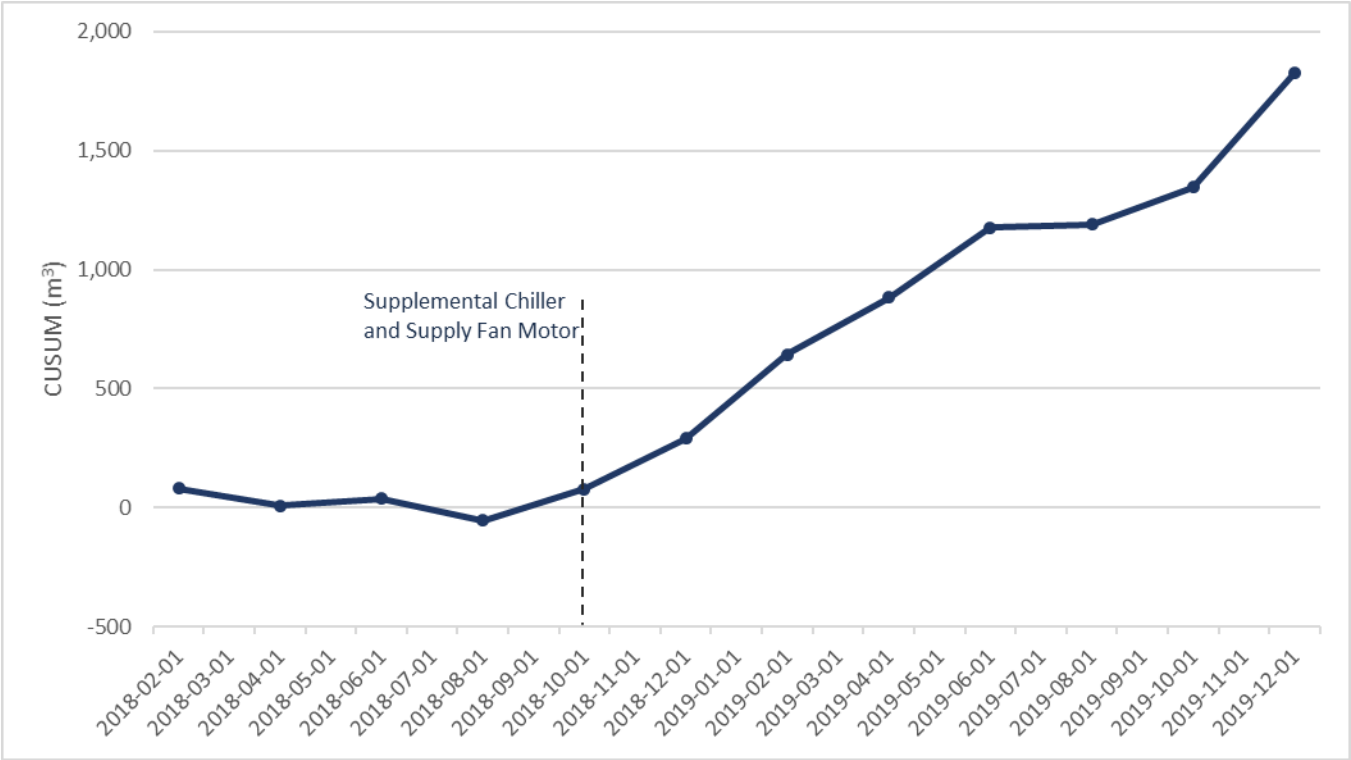


Figure 40. Natural Gas Consumption CUSUM Graph

3.5.7 Energy Performance Key Findings

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

Heating energy use was low, but the tight building envelope led to significant cooling needs:

- Heating is provided by the central gas fired system, but it requires a fair amount of supplemental heat from in-unit electric baseboards during cold weather. The heating load in 2019 was 6% higher than the Passive House standard.
- Cooling needs represented 7% of total energy consumption in 2019 or 8.5 kWh/m², which is in the same range as other multi-residential buildings and slightly higher than expected for a high-efficiency building. The chiller capacity and ventilation rates were increased to respond to the building overheat challenges during heat waves, which led to an overall higher energy consumption.
- Changes to the building systems and equipment to address thermal comfort issues have not yet been fully addressed, and a more permanent solution is still under investigation. The solution may lead to increased energy use in the years to come.

There are a handful of potential improvements that could be considered by the building owner:

- Updates to the ERV heating coil pumping and 3-way valve configuration could yield energy savings, but it is unlikely that the measure would be cost-effective.
- Retro-commissioning may be considered given the recent retrofits to the HVAC system, but energy savings are anticipated to be low. However, it may be justified based on the expected improvements to occupant comfort it could deliver.

Further monitoring of the building is needed to evaluate its energy performance under normal operations that maintain acceptable summer thermal comfort thresholds:

- On-going monitoring of the make-up air temperature will be important to ensure that the most recent measures implemented solve the overheating issues. The 2021 summer season will be decisive in determining the final building operation conditions.
- Increased chiller capacity did not entirely alleviate all overheating concerns. One possibility is that the building airflow is too low. Airflow should be measured when the new chillers are brought online to assess this issue.

With a high-performance envelope such as Salus Karen's Place, space heating represents a smaller share of total energy consumption. Consequently, in-unit energy consumption makes up a significant portion of the energy use (25% of the buildings total consumption is attributable to in-unit non-heating and cooling related loads). As a result, Salus could consider running an occupant energy conservation and water awareness campaign to reduce in-unit consumption of water, as well as from plug loads and resident-owned appliances.

3.6 Acoustics: Occupant Experience

The building acoustics were evaluated qualitatively through the occupant survey alone - no acoustics tests were conducted on the site to verify noise or vibration levels. In the occupant survey, residents were asked about noise levels both external to the apartment building, including from traffic, as well as internal to the building, including from neighbouring units and corridors, building HVAC systems, and in-unit appliances and equipment. Overall satisfaction with external noise levels shows an even distribution among respondents, with more than three-quarters reporting being very satisfied, satisfied, or neutral (*Figure 41*). Noise levels from traffic are also reported, with more than half reporting no or very little noise (*Figure 42*).

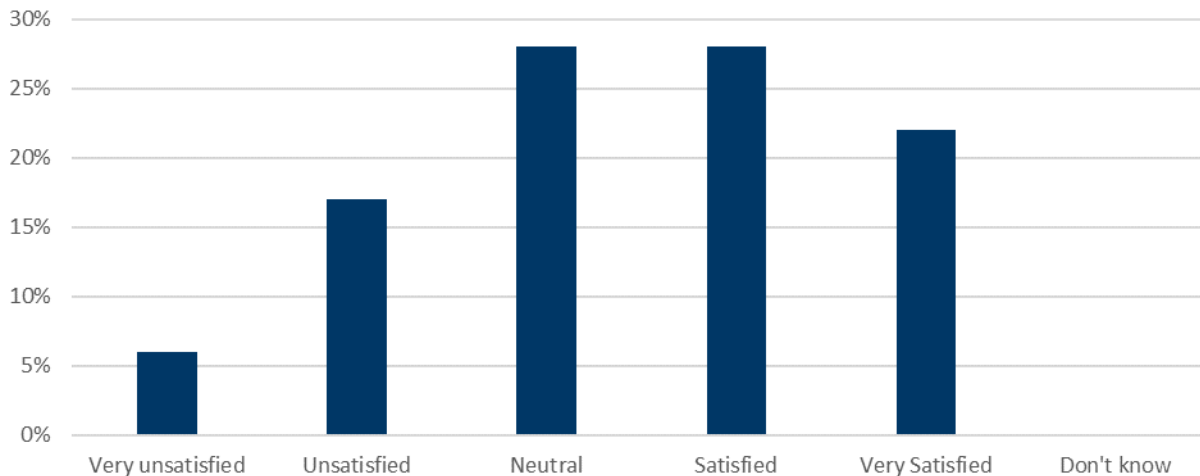


Figure 41. Occupant Satisfaction with External Noise Levels

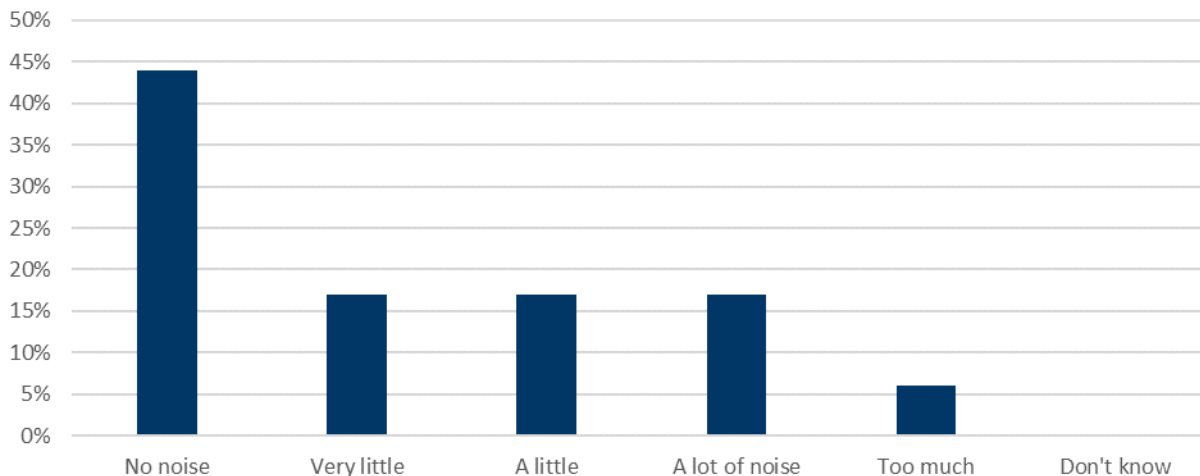


Figure 42. Reported Noise Levels from Traffic

Residents were asked about noise levels from the apartment units beside, above, and below them, as well as in the corridor. Noise from other units did not seem to be a problem for occupants, with the majority reporting no noise from the units beside and below them, and only a slightly higher proportion reporting noise from the unit above them (*Figure 43*). Residents described higher noise levels in the corridor, however, with 37% of survey respondents reporting either a lot or too much noise.

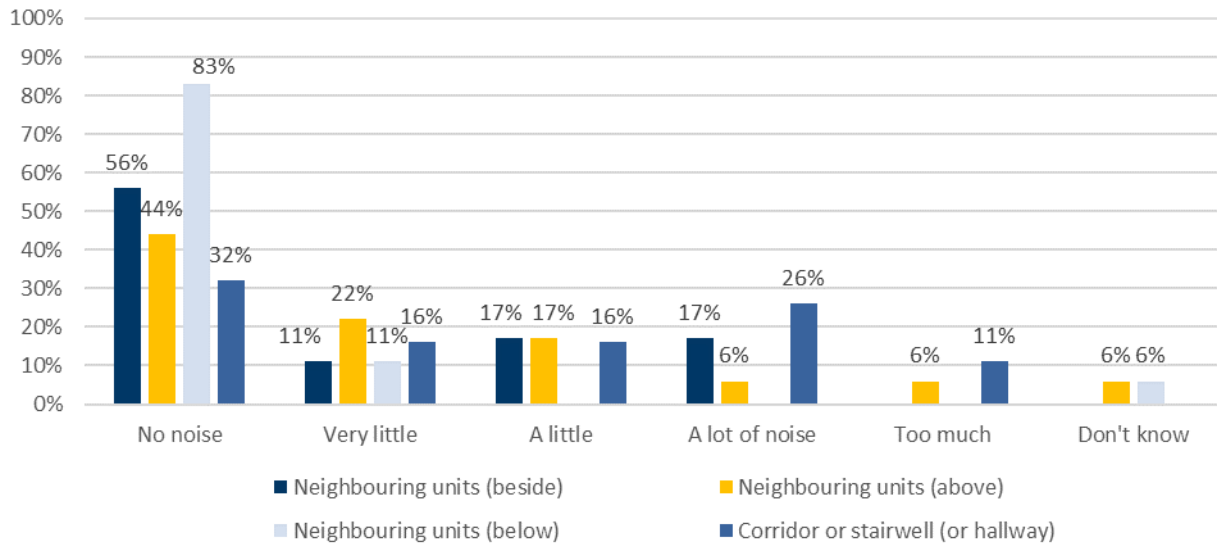


Figure 43. Noise Levels from Neighbouring Units and Corridor Reported by Occupants

No concerns of noise were raised with respect to kitchen hood, building systems, plumbing, or elevator noise.

Several survey respondents noted some vibration on the 4th floor. This is thought to be due to the building's steel structure moving as a result of passing traffic (including a bus line) on the road in front of the building, and likely cannot be mitigated.

3.6.1 Acoustics Key Findings

Overall, occupants appeared to be satisfied with the degree of noise transmission and vibration within their apartments. Although some of the residents living on the top floor experienced some vibrations in the building, this is thought to be due to the building's steel structure moving as a result of passing traffic on the road in front of the building and likely cannot be mitigated.

4 SUMMARY OF FINDINGS

Overall, the Salus Karen's Place building demonstrates high energy efficiency and better-than-average water consumption performance. Several major changes were made to the building's HVAC system over the course of the study, however, which could not be fully captured in the results. The building meets Passive House standards in many categories and performs significantly better than the Canadian MURB benchmarks in most cases. However, there are a few areas where the building did not perform to the benchmarks, most notably for the thermal comfort targets.

The building's performance by each performance area covered in the report is presented below, as compared to relevant benchmarks (*Table 14*). A further comparison of the Salus buildings to two other Supportive Housing MURB POE results is presented in Appendix A.

Table 14. Summary of Salus Karen's Place Performance by Performance Area

	Benchmark	Salus Actual Performance
Envelope Performance (ACH@50 Pa)	Passive House Standard: ≤ 0.6	0.4
Thermal Comfort – Temperature	<i>See ASHRAE comfort zone in thermal comfort section</i>	Summer temperatures vary among units, and will not be representative of current centralized system conditions Winter temperatures in 2019 are mainly on targets which is an improvement compared to 2018.
Thermal Comfort – Humidity	<i>See ASHRAE comfort zone in thermal comfort section</i>	Summer RH often in the high range of the targets Winter RH often lower than targets
Indoor Air Quality	ASHRAE Guideline: 1000-1100 ppm CO ₂	Average summer: 565 ppm CO ₂ Average winter: 802 ppm CO ₂
Water Consumption	Canadian Average: 91.6 m ³ /resident/yr Salus Karen's Place 2018: 58.6 m ³ /resident/yr	65.6 m ³ /resident/yr
Energy Performance – Overall Primary Energy Use Intensity (source energy)	Passive House Standard: 120 ekWh/m ²	196 ekWh/m ²
Energy Performance – Overall Energy Use Intensity (site energy)	Standard MURB – CMHC: 212 ekWh/m ²	121 ekWh/m ²
Energy Performance - Heating Energy Use Intensity	Passive House Standard: 15 ekWh/m ²	16 ekWh/m ²
Frequency of overheating (>25°C)	Maximum 10%	Up to 12% (Unit 5)
Energy Performance - Cooling Energy Use Intensity	Passive House Standard: 15 ekWh/m ²	9 ekWh/m ²

4.1 Key Take-Aways

Based on the POE results of the Salus Karen's Place building, the following key points emerged:

- **The building met the Passive House standards in almost all categories, and far out-performed the typical Canadian MURB benchmarks for energy use and envelope performance:** The building exhibited an extremely low energy use intensity, despite the use of supplemental air-conditioning during the summer months. Water performance was about 28% better than the Canadian average and the interior air-quality appeared to be maintained at adequate levels.
- **Energy use in the building was extremely low for heating; but cooling loads are equivalent to other Canadian MURB:** The building's high-performance envelope helps to minimize heating needs in the building to just 13% of all energy used in the building. The envelope also appears to cause the building to have no better than typical cooling loads, however, representing 7% of all energy.
- **Occupant thermal comfort suffered during summers and some challenges were also observed in the winter:** The building's extremely airtight and highly insulated envelope, along with its potentially undersized cooling and ventilation equipment, led to thermal comfort challenges in the summer of 2018, with indoor temperatures climbing well above acceptable levels. While the added chillers capacity and the increased ventilation rates improved the building thermal comfort, the thermal comfort issues were not entirely addressed. Moreover, in the winter 50% of heating was delivered from the supplemental electric resistance baseboards and humidity levels were lower than ideal because of the lack of humidification equipment.
- **Energy use in the building was impacted by the corrective actions taken to address thermal comfort challenges:** The increase in the building's chiller and ventilation capacities increased the building's EUI by 5% compared to 2018 (8% once weather normalized).
- **Additional data will be available after the summer 2021 POE data gathering period has been completed:** Although improvements were made to correct the building thermal comfort issues in 2019, the 2020 cooling season revealed that the building has insufficient capacity to cool the apartments during prolonged heat waves. Further corrective actions and equipment additions are being discussed, and at the time of writing it is expected that the final POE data gathering will take place in the summer of 2021 to capture their impacts on the building's thermal comfort performance. Moreover, the cost-benefit assessment of the heating/cooling systems will be conducted, once all the relevant costs have been accrued.

APPENDICES

Appendix A: Comparison to other Supportive Housing MURB POE Results

In recent years, we conducted two other POE studies for CMHC to evaluate the performance of newly constructed affordable housing projects in the Ottawa area. Each project employed its own design strategy to achieve high energy efficiency and occupant comfort, and each encountered its own challenges in meeting these objectives.

While this is not a formal comparison of the performance of each building (for example, the energy consumption was assessed in different years and not weather normalized), this study offers the opportunity to compare the high-level results from each of these three buildings.

- Salus Karen's Place; Passive House and LEED Platinum Certification
- Affordable Housing Project 1: LEED Gold Certified campus development with a central Geothermal plant
- Affordable Housing Project 2: Built to LEED Gold Standards (did not pursue certification) employing high efficiency as boilers and rooftop chillers.

The high-level results below show that from an energy use perspective all three buildings achieved similar high performance despite the varied designs and equipment employed.

Table A - 1: Supportive Housing Performance Comparison (non weather normalized)

	Salus Karen's Place	High Efficiency Affordable Housing Project 1	High Efficiency Affordable Housing Project 2
CFM50 / ft²	0.2 (corrected to 50 Pa)	0.35	N/A
Overall EUI (ekWh/m²)	121	126	112
Heating EUI (ekWh/m²)	16	15	22
Cooling EUI (ekWh/m²)	9	3	10
Water use (m³/m²/yr)	1.1	0.97	1.4
Average CO₂ Winter (ppm)	802 ⁴⁶	653	N/A

⁴⁶ Average CO₂ levels reduce to 718 ppm once the tenant who blocked the air intake is excluded.

Appendix B: Occupant Survey Results

Below are the results of the occupant survey performed in November 2017. The survey represents 18 of the 42 tenants of the building (42.9%).

Table B - 1: Survey Results - Air Quality and Temperature

1. Unpleasant smells	% based on participants	Number of answers
Yes	39%	7
No	61%	11
Comments	Cigarette smells	
2. During Winter		
Humidity		
Too humid	0%	0
Somewhat humid	6%	1
Just right	53%	9
somewhat dry	29%	5
too dry	12%	2
don't know	0%	0
Air Quality		
Very unsatisfied	6%	1
Unsatisfied	18%	3
Neutral	24%	4
Satisfied	29%	5
Very Satisfied	24%	4
Don't know	0%	0
Temperature		
Too cold	0%	0
Somewhat cold	12%	2
Just right	65%	11
Somewhat hot	12%	2
Too hot	12%	2
Don't know	0%	0
2. During Summer		
Humidity		
Too humid	12%	2
Somewhat humid	18%	3
Just right	35%	6
somewhat dry	29%	5
too dry	6%	1
don't know	0%	0
Air Quality		
Very unsatisfied	6%	1
Unsatisfied	18%	3
Neutral	35%	6
Satisfied	29%	5
Very Satisfied	12%	2
Don't know	0%	0
Temperature		
Too cold	0%	0
Somewhat cold	6%	1

Just right	47%	8
Somewhat hot	18%	3
Too hot	29%	5
Don't know	0%	0
3. A part of the apartment feels hotter or colder		
Yes	33%	6
No	67%	12
Comments	Question not really understood	
4. Uncomfortable variations of temperature during the day		
Yes	6%	1
No	94%	17
5. Operate a humidifier		
Yes	0%	0
No	100%	18
6. Operate a dehumidifier		
Yes	0%	0
No	100%	18

Table B - 2: Survey Results - Noise Levels

7. Satisfaction with the amount of external noise	% based on participants	Number of answers
Very unsatisfied	6%	1
Unsatisfied	17%	3
Neutral	28%	5
Satisfied	28%	5
Very Satisfied	22%	4
Don't know	0%	0
8. Rate the noise levels		
Neighbouring units (beside)		
No noise	56%	10
Very little	11%	2
A little	17%	3
A lot of noise	17%	3
Too much	0%	0
Don't know	0%	0
Neighbouring units (above)		
No noise	44%	8
Very little	22%	4
A little	17%	3
A lot of noise	6%	1
Too much	6%	1
Don't know	6%	1
Neighbouring units (below)		
No noise	83%	15
Very little	11%	2
A little	0%	0
A lot of noise	0%	0
Too much	0%	0
Don't know	6%	1

Corridor or stairwell (or hallway)		
No noise	32%	6
Very little	16%	3
A little	16%	3
A lot of noise	26%	5
Too much	11%	2
Don't know	0%	0
Traffic		
No noise	44%	8
Very little	17%	3
A little	17%	3
A lot of noise	17%	3
Too much	6%	1
Don't know	0%	0
Kitchen Hood		
No noise	50%	9
Very little	28%	5
A little	22%	4
A lot of noise	0%	0
Too much	0%	0
Don't know	0%	0
General buildings fans, pumps or other system noises		
No noise	61%	11
Very little	17%	3
A little	22%	4
A lot of noise	0%	0
Too much	0%	0
Don't know	0%	0
Plumbing		
No noise	83%	15
Very little	6%	1
A little	11%	2
A lot of noise	0%	0
Too much	0%	0
Don't know	0%	0
Elevators		
No noise	78%	14
Very little	22%	4
A little	0%	0
A lot of noise	0%	0
Too much	0%	0
Don't know	0%	0

Table B - 3: Survey Results - Lighting

9. How bright is the lighting	% based on participants	Number of answers
Kitchen		
Too dark	0%	0
Somewhat dark	0%	0
just right	94%	17
somewhat too bright	6%	1
Too bright	0%	0
Don't know	0%	0
Bathroom		
Too dark	0%	0
Somewhat dark	0%	0
just right	100%	18
somewhat too bright	0%	0
Too bright	0%	0
Don't know	0%	0
Living Room		
Too dark	6%	1
Somewhat dark	6%	1
just right	83%	15
somewhat too bright	6%	1
Too bright	0%	0
Don't know	0%	0
Hallways		
Too dark	0%	0
Somewhat dark	0%	0
just right	94%	17
somewhat too bright	6%	1
Too bright	0%	0
Don't know	0%	0
Laundry room		
Too dark	0%	0
Somewhat	0%	0
just right	89%	16
somewhat too bright	6%	1
Too bright	0%	0
Don't know	6%	1
Exterior pathways		
Too dark	0%	0
Somewhat dark	11%	2
just right	83%	15
somewhat too bright	6%	1
Too bright	0%	0
Don't know	0%	0
10. Do you keep your lights on		
Yes	12%	2
No	88%	15

Table B - 4: Survey Results - Energy Consumption

11. How often do you...	% based on participants	Number of answers
Use the range hood		
Never	6%	1
Rarely	22%	4
Sometimes	39%	7
Often	22%	4
Don't know	11%	2
Use the living room ceiling fan		
Never	0%	0
Rarely	11%	2
Sometimes	17%	3
Often	72%	13
Don't know	0%	0
Keep windows open in summer		
Never	6%	1
Rarely	17%	3
Sometimes	22%	4
Often	50%	9
Don't know	6%	1
Keep windows open in winter		
Never	28%	5
Rarely	28%	5
Sometimes	22%	4
Often	17%	3
Don't know	6%	1
Use a plug-in electric heater		
Never	94%	17
Rarely	0%	0
Sometimes	6%	1
Often	0%	0
Don't know	0%	0
Use a plug-in AC		
Never	100%	18
Rarely	0%	0
Sometimes	0%	0
Often	0%	0
Don't know	0%	0

Table B - 5: Survey Results - Other Observations

Condensation on window in the winter	% based on participants	Number of answers
Yes	6%	1
No	94%	16
Water Leakage		
Yes	0%	0
No	100%	17
Drafts		
Yes	24%	4
No	76%	13
Comments		
Stains or mold growth		
Yes	6%	1
No	94%	16
Comments	At the front of my bed towards the wall stains appear / At windows	

Summary of Data Collection Activities

Following the development of the POE plan, we proceeded with the following data collection activities:

Walk-Through Audit and POE Monitoring Set-Up: We visited the building to complete a walk-through audit of the facility and install key equipment sub-meters. To prepare for the walk-through, we first reviewed project designs and performance goals. We also interviewed both the design and management teams to further understand building functioning and operational protocols. Once on-site, we collected equipment specifications and operational schedules for key heating, ventilation, and air conditioning (HVAC) equipment, took inventory of additional energy-using devices, performed in-unit air leakage tests, and installed electricity and water monitoring equipment.

Heating and Cooling Period Operational Assessments: To understand the building performance under high demand conditions, we visited the building when it was operating in full heating mode (less than 0°C ambient conditions) and again when it was operating in full cooling mode (greater than 25°C ambient conditions). During each visit, we observed the performance of key equipment and collected thermal comfort and indoor air quality data in 15-minute intervals over a 10-15 day period.

Bulk-meter Data: The building has bulk meters for electricity, natural gas, and water, as seen in Table C-1 below.

Table C - 1: Summary of Bulk Meters in the Salus Karen's Place Building

Service Provider	Connected Load	Data Collection
Hydro Ottawa	In apartment and common area use	Historical billing data available starting September 2016. 15-minute interval data (from Hydro Ottawa) for the duration of the study. Monthly billing data.
Enbridge	Condensing water heaters, ERV heating coil	Historical billing data available starting September 2016 (actual readings every two months).
City of Ottawa	In-apartment and common area use	Monthly billing data and 4x per day data (from City of Ottawa) for the duration of the study.

Additional Data Collection, Analysis, and Reporting: In addition to historical consumption data, we collected 15-minute interval electric use data from the utility as well as apartment and equipment submeters over the study period, which are summarized in Table C-2 below.

CO₂, Temperature, RH and electrical submetering was conducted in three units:

- **Unit 1:** South-West corner, middle floor
- **Unit 2:** East-facing, middle floor
- **Unit 3:** West-facing, top floor

Finally, we compiled all data sources, including sub-meters and monitoring equipment results, to assess the building performance, the results of which are presented in this report.

These activities were repeated for both POE monitoring periods (January 2018 – December 2018 and January 2019 – January 2020)

Table C - 2: Summary of Data Used in the Study

Data	Source	Application in Study
Building design documents	CSV Architects	Review of key energy- and water-consuming equipment.
Gas, water, and electricity bills	Ottawa Salus Corporation.	Analysis of the building energy and water consumption.
Electrical meter interval data	Hydro Ottawa.	Analysis of the building energy consumption.
Water meter interval data	City of Ottawa.	Analysis of the building water consumption.
On-site visual readings: Natural gas meter and installed water sub-meters	Readings performed by Salus Staff.	Analysis of the building energy consumption and end-use breakdown.
Electrical sub-metering of apartments	Collected by the Dunsy Team, three apartments logged on 15-minute intervals.	Analysis of the apartment consumption and end-use breakdown.
BAS data	HTS data collected by Salus Corporation Staff.	Allowed tracking of HVAC equipment, as well as in-unit temperature and airflow.
Laundry usage	Coinamatic and water sub-metering	Establishment of the end-use breakdown.
In-Apartment CO ₂ , temperature, and relative humidity (winter)	Collected by the Dunsy Team, three apartments equipped with a CO ₂ logger and three apartments with an USB temperature logger.	Analysis of the building winter thermal comfort and air quality.
In-Apartment CO ₂ , temperature, and relative humidity (summer)	Collected by the Dunsy Team, three apartments equipped with a CO ₂ logger and three apartments with an USB temperature logger.	Analysis of the building summer thermal comfort and air quality.
Occupant survey	Conducted by the Dunsy Team in November 2017.	Provided occupant perspective of indoor environment quality (including temperature, humidity, etc.).

Table C - 3: Location of Installed Sub-meters

Type	Equipment	Installed Location in the Building	Accuracy
Electric	1 HOBO logger H22-001	Electric Panel of the 3 rd Floor	0 to 2 seconds for the first data point and ± 5 seconds per week at 25°C.
	6 Split-core 0-100 Amp CT Current Transformers	Electric Panel of the 3 rd Floor	$\pm 0.5\%$ from 10-120% of rated current
	2 Kill-a-watt Electric Monitors	One in the common kitchen One in a unit on the 4 th floor	$\pm 0.2\%$
Water	4 P3 P0550 Water Meter	In the building laundry room (clothes washers)	$\pm 1/10$ th of a gallon
Thermal Comfort	Temperature and Humidity Loggers and CO ₂ loggers	Unit 1: South-West corner, middle floor Unit 2: East-facing, middle floor Unit 3: West-facing, top floor	USB loggers Temperature: $\pm 1^\circ\text{C}$ Humidity: $\pm 3\%$ CO₂ loggers (incl. temperature & RH) CO ₂ : 50ppm $\pm 5\%$ of reading Temperature: $\pm 0.6^\circ\text{C}$ Humidity: $\pm 3\%$ (at 25°C, 10-90% RH) Humidity: $\pm 5\%$ (at 25°C, <10 & >90% RH)

Installed Measuring Equipment

The figures below display the different measuring equipment installed during the study.



Figure C - 1: Current Transformers Connected to the HOBBO Logger



Figure C - 2: Water Submeters

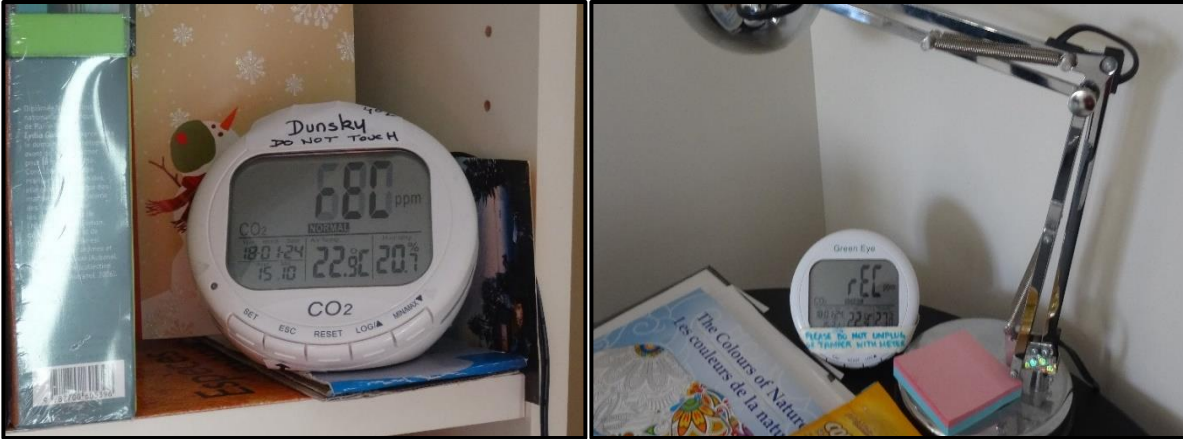


Figure C - 3: CO2 Loggers (including temperature and relative humidity measurements)



Figure C - 4: USB Temperature and Relative Humidity Logger



Figure C - 5: Kill-a-Watt (installed in the common kitchen)

Appendix D: Additional Study Data

During the POE study period, we analysed a large amount of data. The tables and graphs below include additional data not included in the main sections of the report.

ENERGY CONSUMPTION

Table D - 1: Annual End-Use Breakdown Data (2019)

Usage	Electricity (kWh)	Gas (ekWh)	Total (ekWh)
Space Cool	21,130	-	21,130
Heat Reject.	-	-	-
Refrigeration	-	-	-
Space Heat	19,712	19,800	39,512
HP Supp.	-	-	-
Hot Water	-	87,643	87,643
Vent. Fans	22,965	-	22,965
Pumps & Aux.	3,094	-	3,094
Ext. Usage	3,381	-	3,381
Misc. Equip.	84,699	-	84,699
Task Lights	15,667	-	15,667
Area Lights	22,161	-	22,161
TOTAL	192,809	107,443	300,252

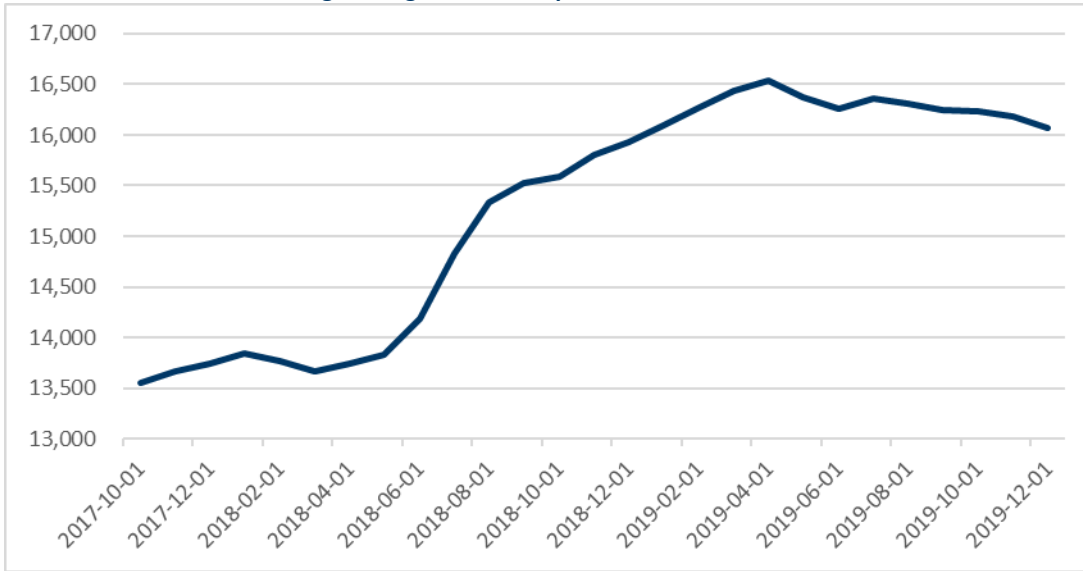
Table D - 2: In-unit Measured Electrical Consumption (kWh) - 2018

Month	Unit A	Unit B	Unit C
Feb 2018 (13 days missing)	50.83	90.55	56.77
Mar 2018	138.98	187.09	108.72
Apr 2018	144.98	164.45	154.55
May 2018	142.31	99.94	106.94
Jun 2018	169.95	153.48	178.98
Jul 2018	230.18	411.12	574.11
Aug 2018	161.33	341.94	575.34
Sep 2018	142.09	251.24	459.77
Oct 2018	179.40	143.88	186.78
Nov 2018	183.65	158.54	207.60
Dec 2018	219.96	186.44	241.70
Jan 2019	171.24	189.89	149.30
TOTAL	1,934.90	2,378.56	3,000.56
TOTAL (adjusted to a full year)	1,990	2,476	3,062

Table D - 3: In-unit Measured Electrical Consumption (kWh) - 2019

Month	Unit A	Unit B	Unit C
Aug 2019 (8 days missing)	88.14	277.51	139.54
Sep 2019	126.39	184.22	221.55
Oct 2019	177.09	155.35	221.54
Nov 2019	159.49	231.74	240.48
Dec 2019	153.30	165.16	243.12
TOTAL	704.40	1,013.98	1,066.23

Table D - 4: 12-Month Trailing Average of Consumption



From the graph above, the following trends are observed:

- 1) A steep increase in consumption starting in July 2018 which is attributed to the use of room AC units in the building
- 2) A steady rise in consumption from October 2018 to May 2019, which is attributable to the increase MAU capacity (the chillers were generally not in use during these months)
- 3) The consumption curve largely flattens from May – December 2019 which indicates that the building consumption is starting to stabilize.

WATER CONSUMPTION

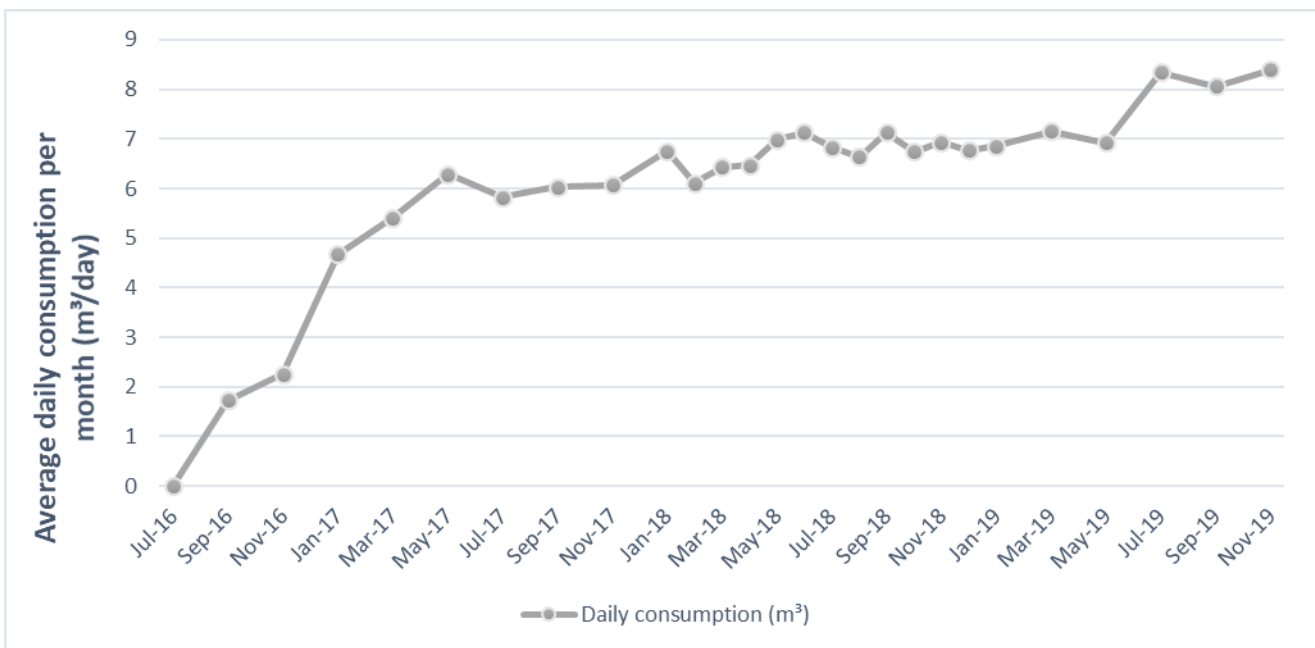


Figure D - 1: Water daily Use (m³/day) since building construction

Table D - 5: Laundry Room – Clothes Washers Water Consumption (gallons)

	Clothes Washer 1		Clothes Washer 2	
Reading Date	Meter 1 (hot)	Meter 2	Meter 3	Meter 4 (hot)
24-Jan-18	1,8	19,6	0	0
26-Jan-18	0	12,6	41,4	0
29-Jan-18	13	83,1	43,7	0
30-Jan-18	0	0	13,3	0
01-Feb-18	0	25,1	133,9	9,4
02-Feb-18	4,1	10,3	12,9	5,1
05-Feb-18	8,1	56,6	185,8	7,8
06-Feb-18	0	22,7	71,7	0
08-Feb-18	0	39,3	13,5	0
27-Mar-18	73,8	567,1	403,8	87,9
24-Apr-18	82,6	724,5	101,6	72,7
06-Jun-18	154,3	934,3	607,7	126,5
24-Jul-18	115	957,9	921,6	138,9
24-Jul-18	0	19,9	0	0
30-Jul-18	19,1	120,4	154,9	22
31-Jul-18	8,2	31,5	51,7	9,4
01-Aug-18	8,4	55,3	76,6	10,1
02-Aug-18	8,5	22,8	32,9	7,2
03-Aug-18	0	0	5,1	0
08-Aug-18	17,4	133,4	138,5	10
09-Aug-18	0	0	0	0
10-Aug-18	0	0	12,8	18,9
13-Aug-18	47,3	144,8	60,2	0
05-Sept-18	73,5	524,3	458,3	62,4
12-Oct-18	295,9	722,2	972,5	266,1
24-Oct-18	324,2	833,3	185,8	291,1
27-Nov-18	441,8	620,8	280,2	432,5
02-Jan-19	588,9	112	141,5	550
04-Feb-19	692,1	98,1	590,7	710

Appendix E: Additional HVAC System Description

Ventilation

A central make-up air unit located in the basement is used to provide ventilation to each apartment. The flow of air is controlled by a variable air volume valve for each apartment. The typical minimum flow setpoint was observed at 11 L/s with a maximum of 22 L/s. This make-up air unit has a glycol heating section as well as a hydronic cooling section and is a variable flow unit. It also has an energy recovery section based on an alternating flow plate-type heat exchanger. Therefore, this unit allows recovering the exhaust air to preheat or precool the incoming outdoor air. The supply and exhaust motors have Variable Frequency Drives (VFDs) since the unit is designed as variable flow. The unit was modified in the fall of 2018 to increase the size of the supply fan motor from 1.5 hp to 2 hp with the aim to increase the flow in order to reduce some of the summer overheating issues that were observed in 2018. This lack of capacity explains the trending data which shows that the unit's EFVs are always operating at 100% speed. No formal airflow measurement was taken or provided following the replacement of the motor from 1.5 hp to 2 hp.



Figure E - 1: ERV Serving the Building

Table E - 1: ERV Specifications after October 2018 Modifications

Make	Model	Flow (design – L/s)	Supply motor (hp)	Return Motor (hp)	ERV Effectiveness (Design heating/Cooling)
TempEff	RG 2000	1055	2	1.5	0.88/0.77

Heating

The heating for this building is provided mostly by two condensing hot water heaters. These hot water heaters serve the dual purpose of providing domestic hot water as well as meeting the space heating needs. The hot water heaters serve a single heating loop going to a water-to-glycol plate heat exchanger. The glycol side of the heat exchanger is connected to a heating coil located in the make-up air unit. This heating coil provides most of the building's heating load, using the make-up air unit to deliver the heat to the various spaces. Each apartment also has some supplemental electric heat in the form of a single baseboard heater of 300 W capacity in a typical

apartment. The common room as well as the office also have supplemental electric heating. The trend data clearly showed that the electric heating is used both in the suites as well as in the common area.

The pumps serving the heating coil are variable speed. Despite the presence of the VFDs, the heating coil has a three-way valve and the pumps operate at a constant pre-establish speed. It is unusual to have three-way valve when using VFDs and this configuration should be re-examined to see if using a two-way valve or restricting the bypass port of the three-way valve should be considered. Given the small size of the pumps, only low-cost measures can be economically considered. Changing a valve is not considered a low-cost measure in this case.

The heating coil for was replaced at the end of the winter 2017 to add additional heating capacity.

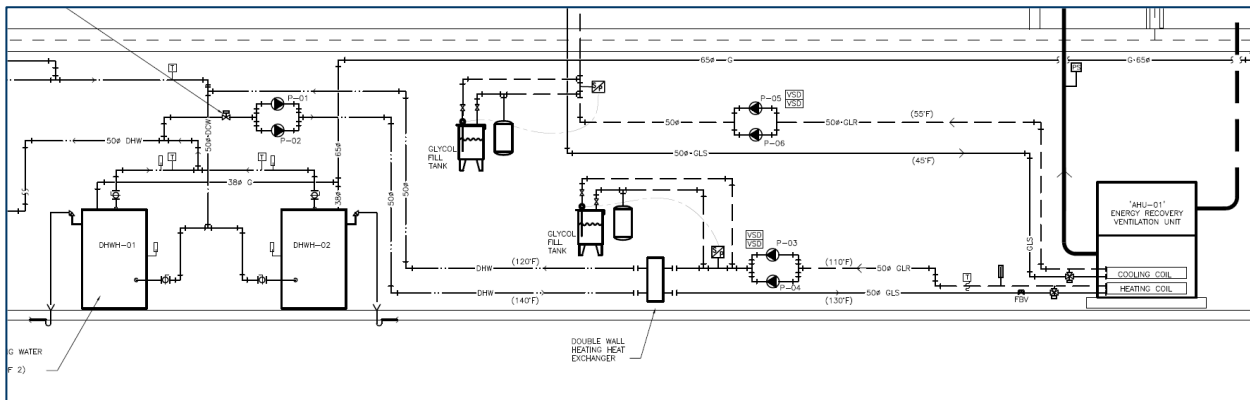


Figure E - 2: Hydronic Heating System Configuration.



Figure E - 3: Heating and Cooling Pump and Three-way Valves (Ref. to red circle)

Cooling

Cooling for the building was initially provided by a single air-cooled chiller mounted on the roof. The original design called for two 21 kW (cooling capacity, 9 kW electric input) chillers but only one unit was installed. The chiller

provides chilled water to a coil in the make-up air unit, as seen in Figure 2. The loop has variable speed pumps but, just like the heating coil, a three-way valve is installed on the cooling coil despite the presence of a VFD on the pump and operates at constant speed.

Cooling is distributed to the various spaces through the make-up air unit airflow. This limits the available cooling capacity since the air can only be delivered down to a certain temperature, typically 13°C, to ensure adequate comfort conditions. Therefore, with the current make-up air unit, the cooling capacity can, at times, be limited by airflow rather than chiller capacity. However, early in 2018 warm weather in June caused significant overheating, especially on the fourth floor. To remediate this situation, mobile air conditioners were installed in the apartments. The impact of these units can clearly be observed in the utility analysis. More permanent remediation measures were taken at the end of the summer. Two additional air-cooled units were installed on the roof to increase the installed capacity from 21 kW to 49 kW of cooling capacity. This capacity would allow cooling the existing airflow of the make-up air unit from 32°C to 0°C if no dehumidification was present. This would result in entirely unacceptable operating conditions for the make-up air unit as the supply would be too cold, even if dehumidification loads were integrated in the equation. Therefore, another measure was implemented, namely the upsizing of the make-up air unit supply fan and rebalancing of the airflows. The supply fan motor was changed from a 1.5 hp model to a 2 hp model. Flow to the basement was reduced to divert most of it to living areas.

The new configuration may help with the overheating issue but it is also important to note that the supply temperature of the airflow was often very low and the new chillers are unlikely to resolve the problem during warm periods since the airflow would then be the limiting factor. Indeed, the building airflow after the supply fan motor upgrade is assumed to be around 2,550 CFM. Based on the energy modelling, a minimum airflow of 8,700CFM would be necessary to meet the building cooling needs assuming a supply air temperature of 8.9°C (48°F). When assuming a supply air temperature of 12.8°C(55°F), an airflow of 10,100 CFM would be necessary.

The portable air conditioners were re-installed in the summer of 2019 since the additional chiller did not resolve the over-heating issues, likely due to the flow limitations.



Figure E - 4: Air Cooled Chillers – New Units (2x) in Front, Existing Unit (back)

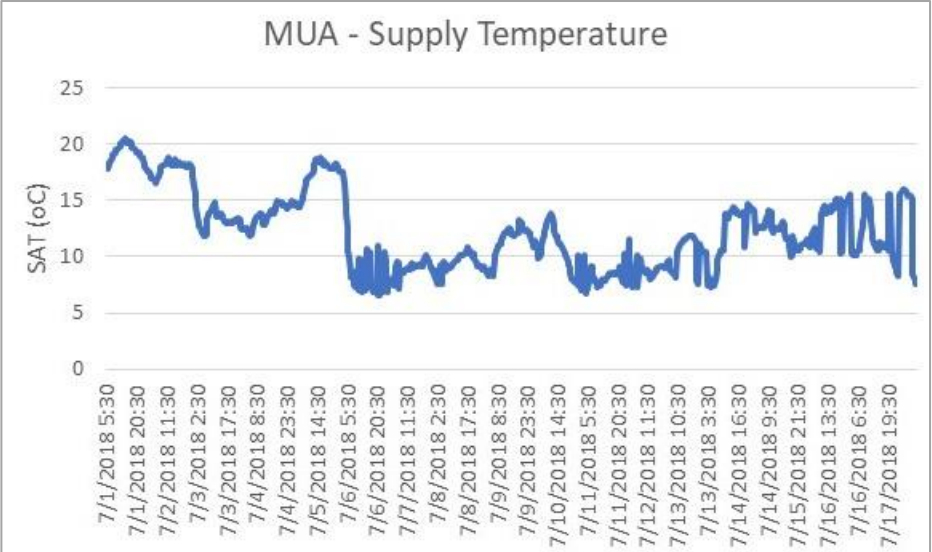


Figure E - 5: Supply Air Temperature Trend Data (sample)

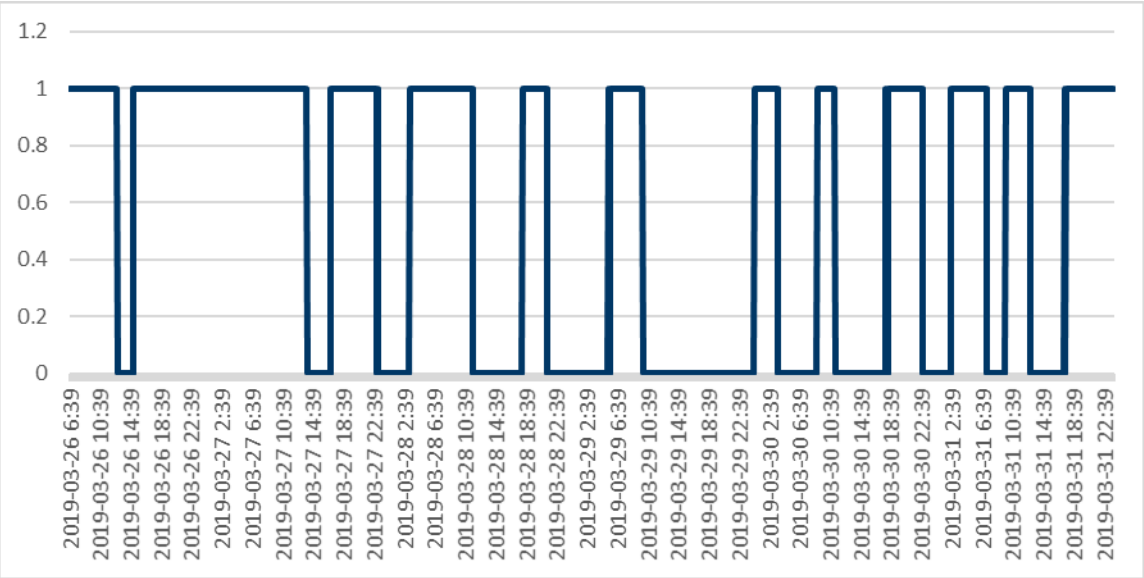


Figure E - 6: Electric Baseboard Operation (unit sample)

Building Energy Modelling Description

The energy model for this building was established in eQuest version 3.65. It is based on the December 2018 to November 2019 period using Ottawa Airport weather data. The initial step in obtaining a valid simulation model of the building is to construct a detailed model. The model features are described below:

Building Occupancy

The building was 100% occupied during the period used for calibrating the energy model. Given its residential vocation, the building is continuously occupied. The typical building occupancy is 42 permanent occupants.

Ventilation

In eQuest, a Variable Volume System was selected to define the system, which is an exact representation of the unit. The system is also defined as 100% outside air with heat recovery, just as it is in the actual design. Flows to each thermal zone is based on the design values, which are coherent with the trend values from the BAS.

The zoning used in the model is based on an almost exact replication of the actual thermal zoning, which is based on a single zone per residential Suite. The typical floor zoning used in the model is shown below:

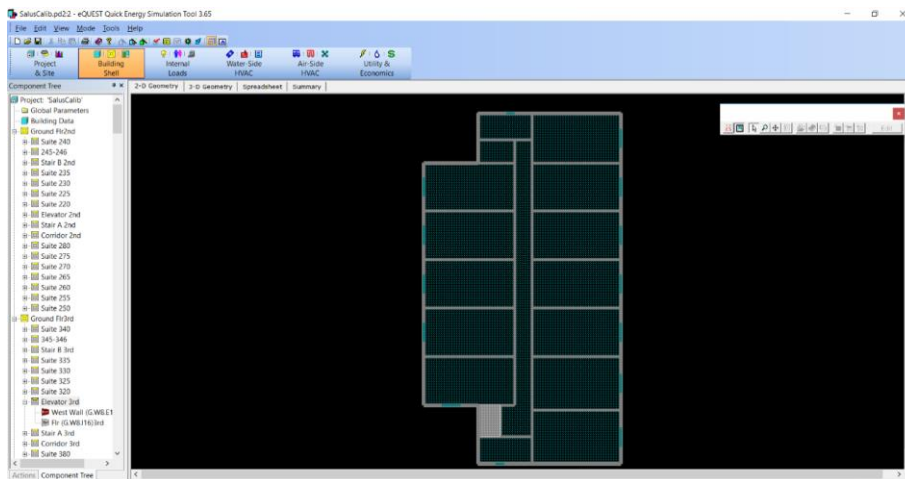


Figure F - 1: Typical floor Zoning scheme in eQuest

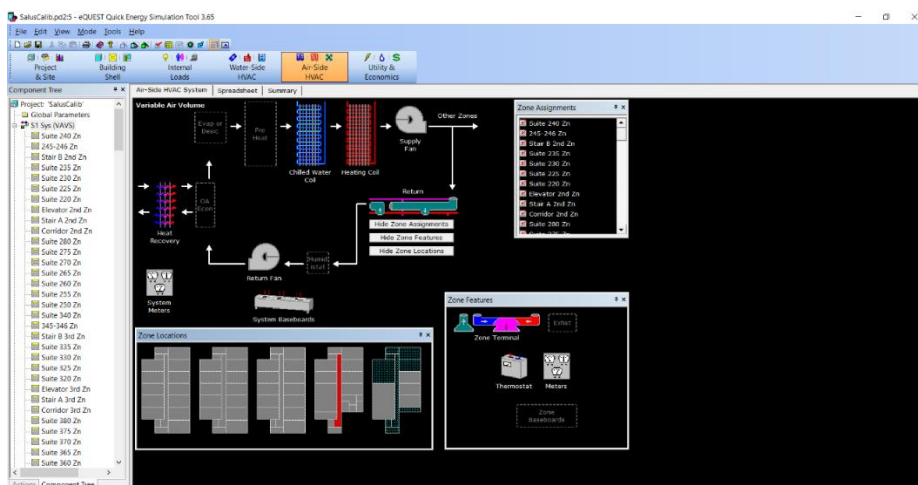


Figure F - 2: HVAC System in the eQuest model

Heating

The eQuest model uses a single heating loop to define both the space heating loop and domestic hot water (DHW) loop, as per design. The DHW load is defined as a process load. This heating loop is assigned two condensing boilers. The electric supplemental heating was also defined in each thermal zone as electric baseboard. It is important to mention that, in eQuest, thermostatically controlled baseboards always have priority to meet the load, unlike what is occurring in this building. Therefore, the operation of the baseboard was defined as being controlled based on outdoor air temperature (outdoor reset). This was observed qualitatively in the trend data with the use of supplemental heating being more prominent in the coldest periods.

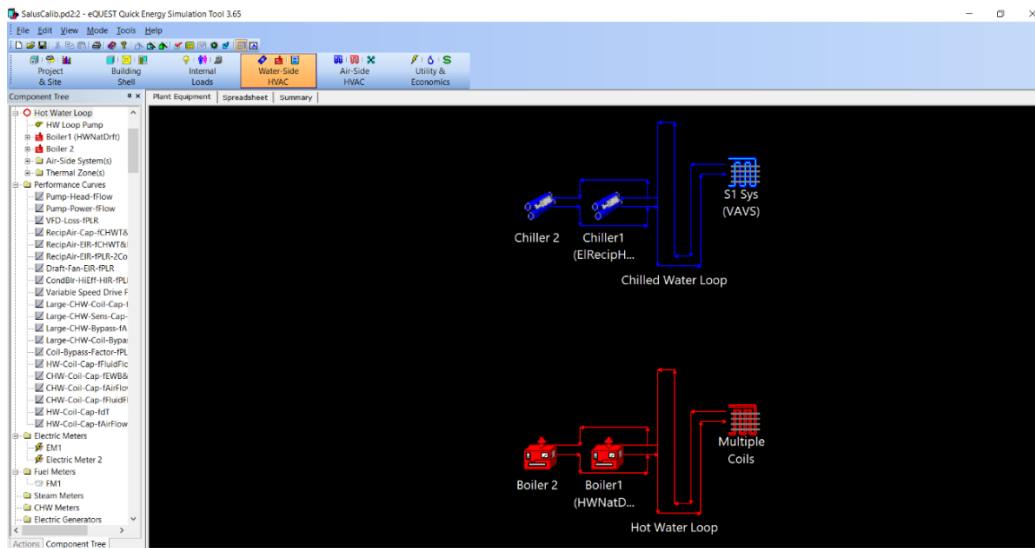


Figure F - 3: Heating and Cooling Loops in the eQuest model

Cooling

The cooling loop duplicates the actual system with one exception. The room air-conditioners cannot be defined. Indeed, eQuest does not allow any given zone to be served by two distinct HVAC system and a room air-conditioner qualifies in eQuest as an HVAC system, just as the main variable flow make-up air unit. Therefore, the model does not account for the additional demand and cooling consumption for the peak cooling period (July and August). Therefore, the model cannot be calibrated against those two months while the room air-conditioners are installed.

Lighting

The lighting level used in the model were based on the available lighting drawing for the building that were verified by the site walk through performed during the site visits.

Equipment Loads, Domestic Hot-Water

The eQuest model uses the main heating loop as its source for DHW, and incorporates a monthly schedule to vary the city water temperature. The other main electrical loads are made up of the in-unit tenant equipment (white Goods, televisions, small kitchen appliances and various other small plug load). These were represented in the model as being identical in each unit with the density of equipment power and schedule based on the sub-metering done on three units.

Calibration Results

The simulation model incorporates the HVAC schedules, the lighting design and schedule, the occupancy loads, the equipment loads as well as all the major HVAC equipment for this building. The results of the calibrated simulation for Salus Karen's Place are presented below (*Table F - 1 and Figure F - 4, Figure F - 5, Figure F - 6*).

Statistical criteria results for monthly data are shown below (*Table F - 2*). These results show that the calibrated model is within ASHRAE recommended values, except for the NMBE for Demand, which is very slightly outside the recommended range. The model is within 1% of the total building electricity use. The annual difference is 1.4% for gas. On a monthly basis, the largest difference, excluding July and August, is 10.6% for electricity in May 2019. For natural gas, the largest monthly difference occurred for January 2019 with a 23.5% overestimation by the model. This difference could be due to how electric baseboard are controlled or to how tenants use their operable windows. However, it must be noted that this gas usage for January does not correlate as well to heating degree-days as the other months, making a close fit with the model less likely. Validation with hourly data was also performed to ensure that night and day profiles adequately matched the available data. The statistical results for the hourly calibration are presented below (Tables F -1 to F -4)

Table F - 1: Monthly Calibration Results

	Electricity						Gas		
	Actual kWh	Model kWh	Difference kWh	Actual kW	Model kW	Difference kW	Actual m ³	Model m ³	Difference m ³
Jan	16,570	18,200	-1,630	33	32	0	1,111	1,372	-261
Feb	14,159	15,360	-1,201	30	30	1	1,051	1,124	-73
Mar	14,829	15,440	-611	30	29	1	1,049	1,026	23
Apr	13,280	14,290	-1,010	29	26	3	946	820	125
May	12,182	13,470	-1,288	27	23	4	842	785	57
Jun	16,689	17,320	-631	39	37	2	753	690	63
Jul	24,841	20,760	4,081	51	39	12	651	659	-8
Aug	21,133	18,810	2,323	43	37	6	581	602	-21
Sep	16,127	16,130	-3	34	36	-3	657	619	38
Oct	14,024	13,990	34	30	28	2	736	712	24
Nov	13,859	14,520	-661	30	28	1	875	899	-24
Dec	15,973	16,180	-207	31	30	2	1,015	1,107	-92
Total	193,665	194,470	-805				10,265	10,414	-148

Table F - 2: Monthly Calibration Statistics

	Electricity	Demand	Gas
CV(RMSE)	6.1%	7.8%	11.1%
NMBE	-4.9%	5.5%	-1.4%

It is important to indicate that the statistical results exclude the months of July and August for electricity and demand.

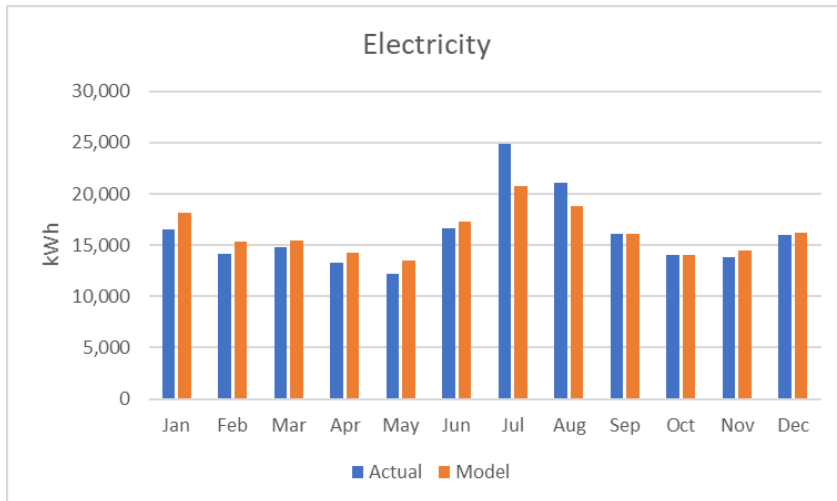


Figure F - 4: Monthly Calibration Profile for Electricity (kWh)

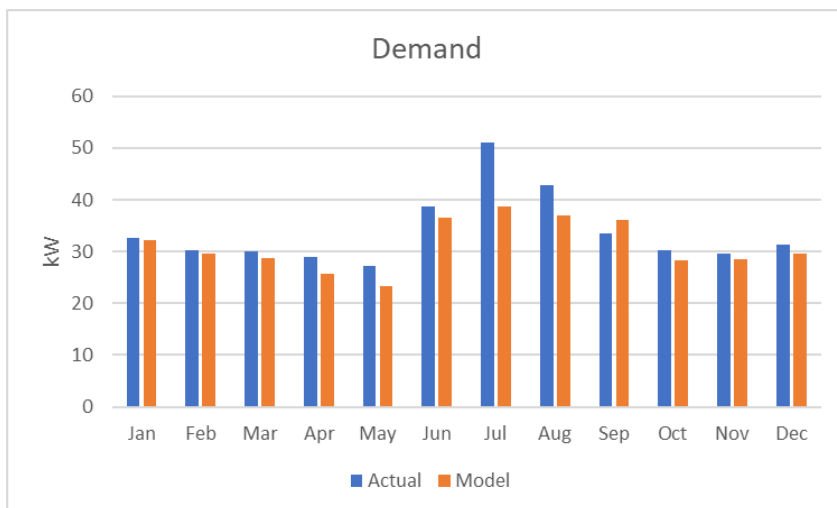


Figure F - 5: Monthly Calibration Hourly Profile for Demand (kW)

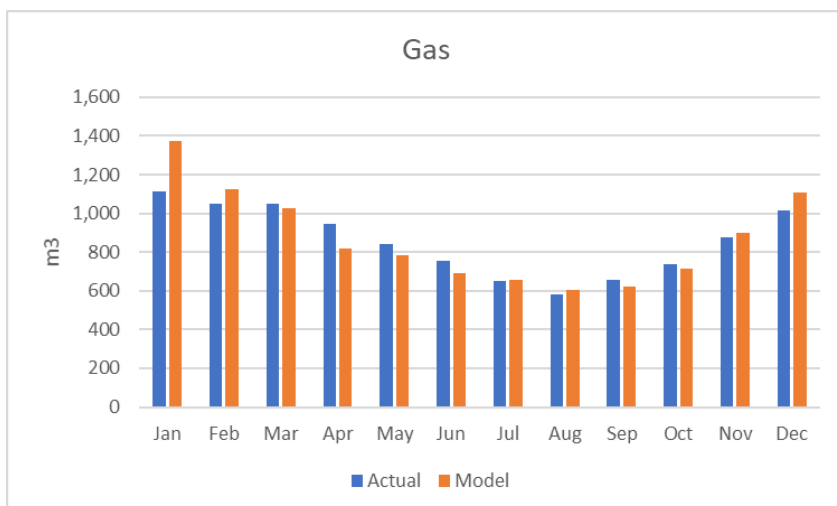


Figure F - 6: Monthly Calibration Hourly Profile for Gas (m³)

Values shown in red do not meet ASHRAE 14 and July and August are excluded from the actual calibration.

Table F - 3: Hourly Calibration Statistics

	Electricity	Required
CV(RMSE)	18.7%	30%
NMBE	-4.3%	+/-10%

Table F - 4: Hourly Calibration Statistics by Month

Jan	CV(RMSE)	20.9%
	NMBE	-9.7%
Feb	CV(RMSE)	17.2%
	NMBE	-8.3%
Mar	CV(RMSE)	15.9%
	NMBE	-3.9%
Apr	CV(RMSE)	16.1%
	NMBE	-7.1%
May	CV(RMSE)	20.2%
	NMBE	-12.0%
Jun	CV(RMSE)	22.1%
	NMBE	-5.3%
Jul	CV(RMSE)	24.2%
	NMBE	16.8%
Aug	CV(RMSE)	20.1%
	NMBE	11.6%
Sep	CV(RMSE)	21.1%
	NMBE	0.5%
Oct	CV(RMSE)	16.2%
	NMBE	0.1%
Nov	CV(RMSE)	16.1%
	NMBE	-1.4%
Dec	CV(RMSE)	21.7%
	NMBE	-9.9%

Model Output: End-Use Breakdown

The end-use breakdown for energy and demand are presented on a monthly basis.

Table F - 5: Electricity Consumption by End-Use (MWh)

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
Space Cool	0	0	0	0	0	4.44	7.58	5.52	3.19	0.57	0	0	21.31
Heat Reject.	0	0	0	0	0	0	0	0	0	0	0	0	0
Refrigeration	0	0	0	0	0	0	0	0	0	0	0	0	0
Space Heat	5.18	3.66	2.48	1.72	0.6	0.27	0.12	0.15	0.24	0.37	1.94	3.16	19.88
HP Supp.	0	0	0	0	0	0	0	0	0	0	0	0	0
Hot Water	0	0	0	0	0	0	0	0	0	0	0	0	0
Vent. Fans	1.97	1.78	1.97	1.9	1.97	1.9	1.97	1.97	1.9	1.97	1.9	1.97	23.16
Pumps & Aux.	0.21	0.19	0.21	0.2	0.2	0.35	0.39	0.37	0.34	0.27	0.2	0.21	3.12
Ext. Usage	0.36	0.26	0.29	0.28	0.2	0.19	0.2	0.31	0.3	0.31	0.35	0.36	3.41
Misc. Equip.	7.24	6.55	7.26	7.03	7.27	7.03	7.26	7.25	7.02	7.26	7.02	7.24	85.42
Task Lights	1.34	1.21	1.34	1.3	1.34	1.3	1.34	1.34	1.3	1.34	1.29	1.34	15.8
Area Lights	1.9	1.71	1.9	1.85	1.9	1.84	1.9	1.9	1.84	1.9	1.82	1.9	22.35
Total	18.2	15.36	15.44	14.29	13.47	17.32	20.76	18.81	16.13	13.99	14.52	16.18	194.45

Table F - 6: Electricity Demand by End-Use (kW)

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
Space Cool	0	0	0	0	0	14.17	16.33	14.15	13.9	6.23	0	0	64.78
Heat Reject.	0	0	0	0	0	0	0	0	0	0	0	0	0
Refrigeration	0	0	0	0	0	0	0	0	0	0	0	0	0
Space Heat	9.5	7.6	8.49	3.7	1.3	0.19	0.11	0.1	0.01	0.11	6.08	6.92	44.12
HP Supp.	0	0	0	0	0	0	0	0	0	0	0	0	0
Hot Water	0	0	0	0	0	0	0	0	0	0	0	0	0
Vent. Fans	2.65	2.65	2.65	2.64	2.64	2.64	2.64	2.64	2.64	2.64	2.64	2.64	31.73
Pumps & Aux.	0.31	0.3	0.3	0.29	0.28	0.57	0.55	0.58	0.53	0.51	0.29	0.29	4.79
Ext. Usage	0.9	0.25	0.05	0.25	0.05	0.05	0.05	0.5	0.5	0.05	0.9	0.9	4.45
Misc. Equip.	12.16	12.17	10.88	12.22	12.22	12.22	12.21	12.2	12.19	11.58	12.17	12.17	144.4
Task Lights	2.33	2.33	2.33	2.33	2.33	2.33	2.33	2.33	2.27	2.33	2.27	2.33	27.86
Area Lights	4.37	4.37	4.01	4.37	4.37	4.37	4.37	4.37	4.15	4.76	4.15	4.37	52.05
Total	32.22	29.68	28.7	25.8	23.21	36.55	38.6	36.88	36.18	28.22	28.49	29.63	374.16

Table F - 7: Gas Consumption by End-Use (MBTU)

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
Space Cool	0	0	0	0	0	0	0	0	0	0	0	0	0
Heat Reject.	0	0	0	0	0	0	0	0	0	0	0	0	0
Refrigeration	0	0	0	0	0	0	0	0	0	0	0	0	0
Space Heat	20.29	13.89	7.23	0.81	0	0.55	0	0	0.98	0.58	8.98	14.43	67.74
HP Supp.	0	0	0	0	0	0	0	0	0	0	0	0	0
Hot Water	0	0	0	0	0	0	0	0	0	0	0	0	0
Vent. Fans	0	0	0	0	0	0	0	0	0	0	0	0	0
Pumps & Aux.	0	0	0	0	0	0	0	0	0	0	0	0	0
Ext. Usage	0	0	0	0	0	0	0	0	0	0	0	0	0
Misc. Equip.	28.13	25.78	29	28.14	27.7	23.81	23.25	21.26	20.86	24.54	22.75	24.62	299.85
Task Lights	0	0	0	0	0	0	0	0	0	0	0	0	0
Area Lights	0	0	0	0	0	0	0	0	0	0	0	0	0
Total	48.42	39.66	36.23	28.95	27.7	24.36	23.25	21.26	21.84	25.12	31.73	39.06	367.59

Building Pressurization Test Procedure

Overview

This test is designed to help diagnose and quantify the airtightness of the whole envelope by putting air handling systems in 100% outdoor air mode to pressurize the building. This test determines the magnitude of envelope leakage so that the cost-effectiveness of correcting these envelope deficiencies can be assessed. The building pressurization test procedure is based on ASTM Standard E-779-99.

Test Equipment

The following equipment list applies to this test procedure.

- ABM-200 flow meter
- Fluke 922 Airflow Meter

Ambient Conditions on Test Day

The outdoor temperature the day of the test was -3 °C with wind speeds of about 1 km/h. Windspeed will therefore have no impact on the test results.

Step 1: Building Preparation

The building was first prepared for testing: all windows and exterior doors were closed. The initial test was scheduled on January 24, 2018 but too many tenants had their window opened, therefore, the test was performed on November 19th, 2018. Due to practical constraints, intentional openings (such as air inlets and outlets, as well as other mechanical penetrations) could not be sealed and not all interior doors were opened.

Step 2: Building Pressurization/Depressurization

Once the building preparation was complete, the air handling systems were run up to 100% outdoor air without return fans to pressurize the building envelope. It is important to note that this test is not as accurate as the blower door tests. This test should not be considered an equal to those tests and aims to provide a high-level estimate of the exfiltration rate. The major limitation of this test was that the HVAC equipment in place was not able to generate sufficient outdoor airflows and static pressure for a proper pressurization/depressurization to perform an accurate testing.

Step 3: Airflow Measurement

Once the indoor-to-outdoor pressure differential had stabilized, the airflow rate through the Fluke airflow meter was measured.

The pressures were taken in the entrance lobby, the ground floor lounge and in the top floor corridor, through a window located in the stairwell providing access to outdoor pressure. Two locations across the building envelope were selected for the measurements, avoiding exterior corners: ground floor (always lowest pressure) and top

floor (highest pressure). A traverse of flow measurement downstream of the heating coils was taken using the ABM flow meter to measure the flow with the supply fan at full speed (60 hz) and the return fan stopped.

The building static pressure measurements were done with and without the fan in operation (no gradual increase in pressure).

The airflow distribution throughout the building was left as found as it is under tenant control, but the BAS showed that units VAVs were all operating and providing air to the various apartments.

The pressure achieved during the test was 13 Pa.

Once all the flow rate and pressure differential data have been recorded, a mathematical analysis was used to develop a regression equation:

$$\text{Flow Rate (L/s)} = \text{Flow Coefficient (L/s.Pa)} \times \text{Indoor-to-Outdoor Pressure Differential (Pa)}^{\text{(flow exponent)}}$$

Step 4: Calculation of Airtightness Results

The test results are then combined with information on the building's size (envelope area and building volume) to generate a quantified airtightness result. The pressures from both locations have also been averaged.

Infiltration Test Results

Table G - 1: Infiltration Test Results

Building	Envelope Area ⁴⁷ (ft ²)	Pressurization Flow (cfm)	cfm/ft ²	Pressure Achieved (Pa)	CFM50/ft ² (corrected for 13 Pa)
Salus Karen's Place	39,400	3,600	0.09	13	0.2

Conversion to Air Change per Hour (ACH@50 Pa)

The conversion to ACH@50 Pa has been calculated as follow:

With:

Area of the building: 26,750 ft²

Height of the building: 36 ft

Volume = 954,856 ft³

$$\text{ACH@50 Pa} = \text{Envelope Area} \times \text{CFM50/ft}^2 \times 60 / \text{Volume} = 39,400 \times 0.18 \times 60 / 954,855.6 = 0.44$$

⁴⁷ Envelope area was estimated using architectural drawings.



ADDENDUM: SALUS KAREN'S PLACE POE UPDATE

August 2023

In the recently completed *Post-Occupancy Evaluation of the Salus Karen's Place Supportive Housing Project*, Dunsky performed a Post-Occupancy Evaluation to assess the building's energy, water, and thermal comfort performance in fully occupied mode and compare it to both the design objectives and recognized benchmarks.

Following the initial POE, further changes were made to the building's mechanical systems to address on-going cooling issues and provide adequate thermal comfort to the occupants. Given these updates, CMHC requested that Dunsky provide a new assessment to account for these modifications representing the final building operations. Therefore, this addendum includes:

1. A description of the final cooling design and a timeline update.
2. New thermal comfort and IAQ analysis from the 2022 data collection to ensure that the final design provides adequate comfort levels to the occupants.
3. New total TEUI compared with past values, Passive House standard, and other benchmarks.
4. HVAC performance in heating mode compared with a standard system.
5. Discussion of the issues or limitations with the originally installed cooling system.



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1 FINAL POST-OCCUPANCY BUILDING DESIGN

In response to challenges with maintaining thermal comfort in the building, several changes were made to the Salus Karen's Place heating, ventilation and air-conditioning (HVAC) systems and operation. These improvements had immediate effects on performance and significantly diverge from the initial design. Figure 44 summarizes the main building modifications from the full occupancy in 2017 to the most recent building operational design.

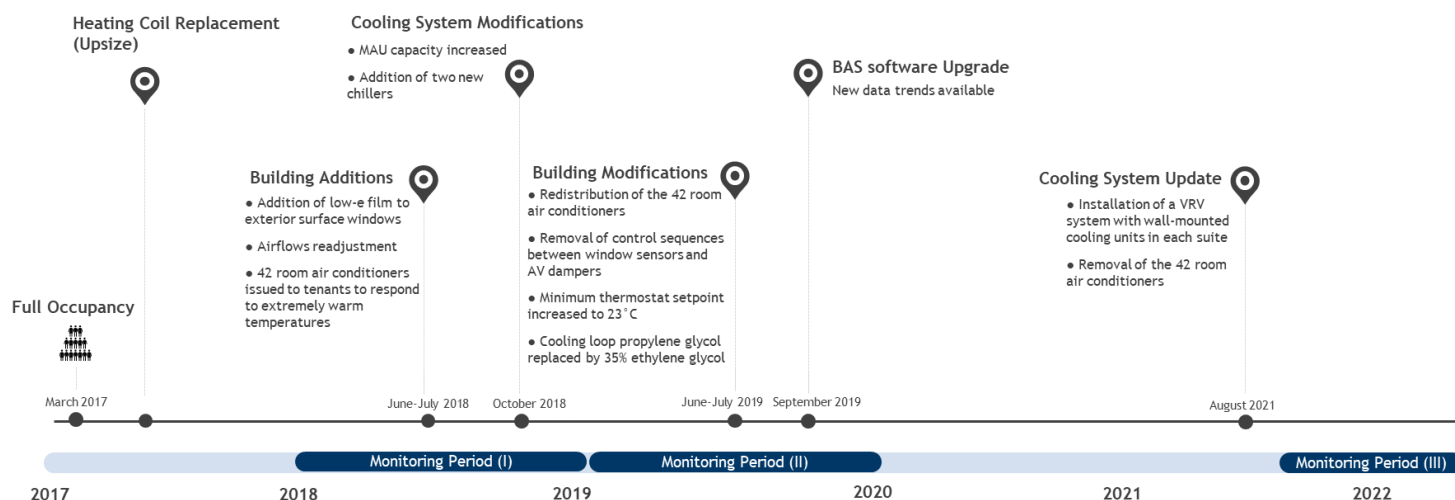


Figure 44: Building Modification Timeline

1.1 Salus Karen's Place: Updated design

The heating and cooling needs of Salus Karen's Place are met through:

- A central ventilation system which can deliver either heated or cooled air (see 1.1.1)
- A supplemental decentralized heating (baseboard) and variable refrigerant flow (VRF) cooling system (see 1.1.2).

1.1.1 Central ventilation system

The heating and cooling systems are made up of two hot water heaters, a makeup air unit (MAU) with an integrated energy recovery ventilator (ERV) and three air-cooled chillers. Figure 46 show an overview of the HVAC system, in which the following systems are presented:

- **Ventilation:** Fresh air is provided by a MAU with an integrated ERV (see Figure 45). Central heating and cooling are delivered to the building by conditioning the supplied air. Since there is only one ventilation loop in the building, the system uses a switch-over (probably based on outdoor air temperature, this information has not been confirmed), to change between cooling and heating. In the building, the air is supplied directly to VAV boxes in each suite's living rooms and exhausted in-unit kitchens and bathrooms. There is no separated ventilation loop for corridors.
- **Heating:** Space and water heating is provided by two 500,000 BTU/hr gas fired condensing water heaters located in the building basement.
- **Cooling:** Cooling is provided by three (3) air-cooled chillers located on the roof. One 21kW (6 ton) chiller and two 14kW (4 ton) chillers.

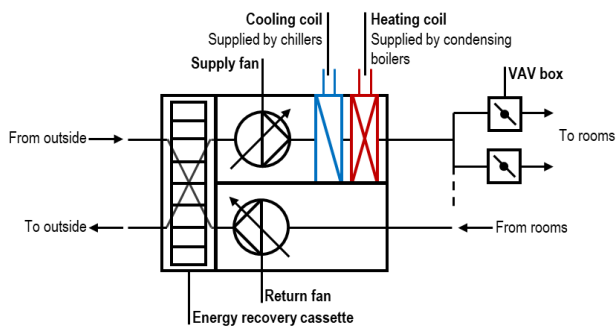


Figure 45: Ventilation system diagram

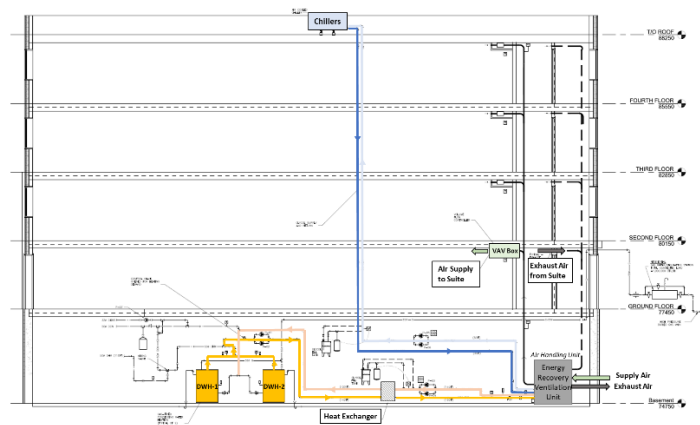


Figure 46: Central HVAC system diagram

1.1.2 Decentralized heating and cooling

Supplemental heating and cooling are necessary to meet the loads during winter and summer peaks. In the initial design, only a supplemental heating system was installed in the building, but cooling challenges forced building owners to implement additional cooling equipment (2021, see Figure 44).

- **Heating:** Each apartment is equipped with a 300 W electric baseboard resistance heater.
- **Cooling:** The building equipped with a VRF system comprised of 42 indoor wall-mounted fan coil units (0.5 ton each) connected to 7 outdoor roof-mounted condensers.⁴⁸ The estimated cost for this upgrade is \$420,000⁴⁹. Figure 47 shows a typical floor layout.

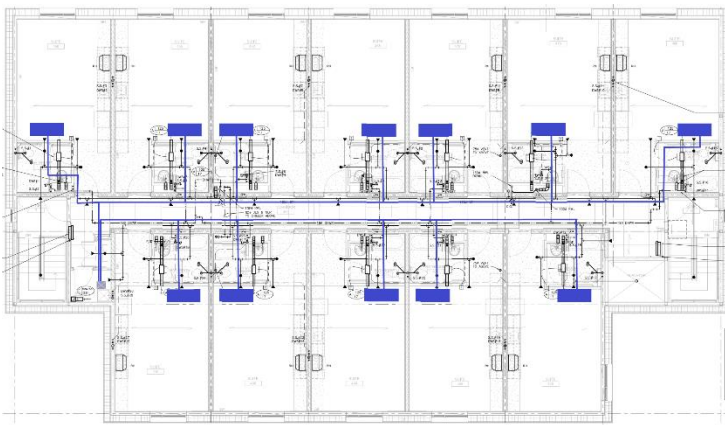


Figure 47 : Typical floor layout

⁴⁸ The decision of installing VRF units in each of the 42 units was motivated by the wish to provide equal conditions to all tenants. Indeed, the pre-installation analysis showed that relying solely on the centralized system for lower floors would not result in similar conditions during heat waves.

⁴⁹ Based on the report by Smith+Anderson.

2 BUILDING PERFORMANCE

After the upgrade of the cooling building systems, additional data was collected to capture the performance of the updated building design. Data collection activities included collection of the building's electricity, natural gas, and water bulk meter data, monitoring of indoor room temperature and air quality and additional meetings with the property manager and the company responsible for the building modifications.

2.1 Does the HVAC Design Provide Adequate Thermal Comfort and IAQ Levels?

2.1.1 Thermal comfort comparison

Three (3) units were monitored after the installation of the VRF system to determine its impact on indoor thermal comfort. Measurements were made between October 6th and December 1st, 2022.⁵⁰ Table 15 shows the outdoor conditions for the days on which the comparison was made, which were chosen for their similar weather conditions.

	Outdoor dry bulb temp. (°C)	Outdoor rel. humidity (%)
2019-08-14	23	53
2022-10-26	23	61

Table 15: Thermal comfort comparison days

The following sections (2.1.1.1 to 2.1.1.3) discuss how the VRF installation has impacted indoor conditions.

2.1.1.1 Unit 302

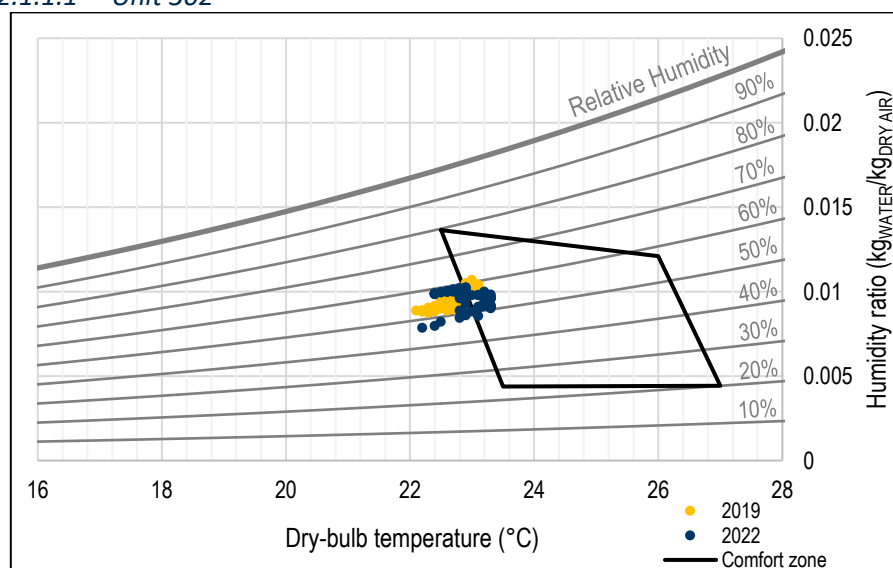


Figure 48: Indoor air conditions, unit 302

In unit 302, the conditions do not differ significantly between 2019 and 2022.

This could be explained by the fact that the 2019 conditions were already acceptable to the occupant (i.e., within the occupant's temperature set point).

⁵⁰ Data loggers were planned to be installed before the summer of 2022, but due to communication challenges, they were only installed in October 2022. The impacts of the VRF system can nevertheless be seen.

2.1.1.2 Unit 308

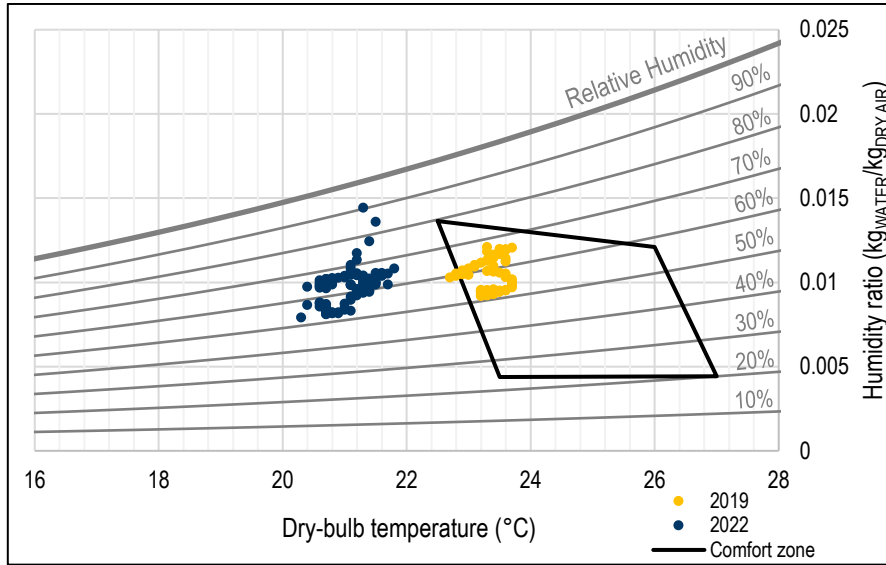


Figure 49: Indoor air conditions, unit 308

In unit 308, the impact of the additional cooling capacity seems obvious.

In 2019, the indoor temperature never went below 22°C, which, in 2022, is the maximum.

2.1.1.3 Unit 402

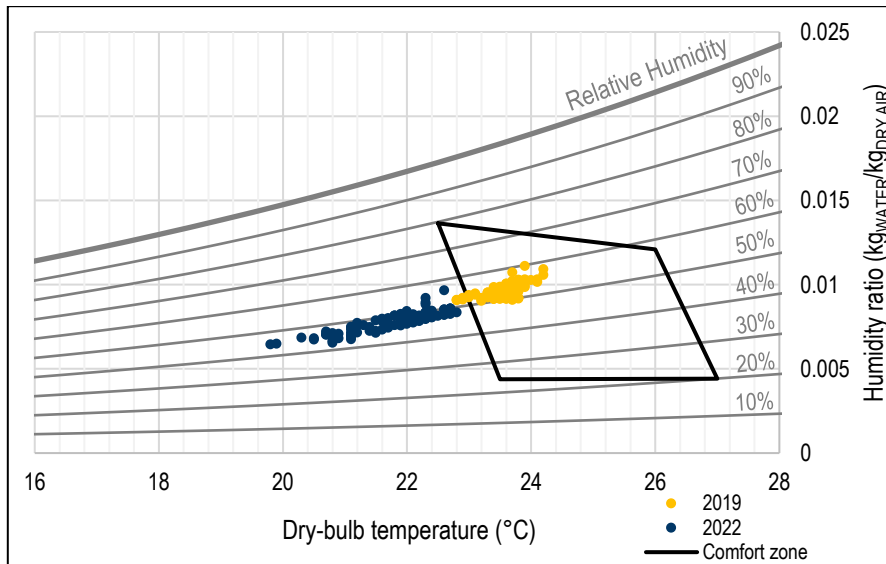


Figure 50: Indoor air conditions, unit 402

The conclusions for unit 402 are similar to those of unit 308.

The impact of the additional cooling capacity can be seen. Temperature recorded in 2022 are always around the lower limit of the theoretical comfort zone. Since the cooling system is controlled by the user, this is most likely a personal preference.

Based on this, the final therefore offers better thermal comfort to users, cooling-wise.

2.1.2 Indoor air quality comparison

The effect of the system upgrade on indoor air quality was also monitored. Figure 51 shows the CO₂ concentration in unit 3 on the days shown in Table 15.

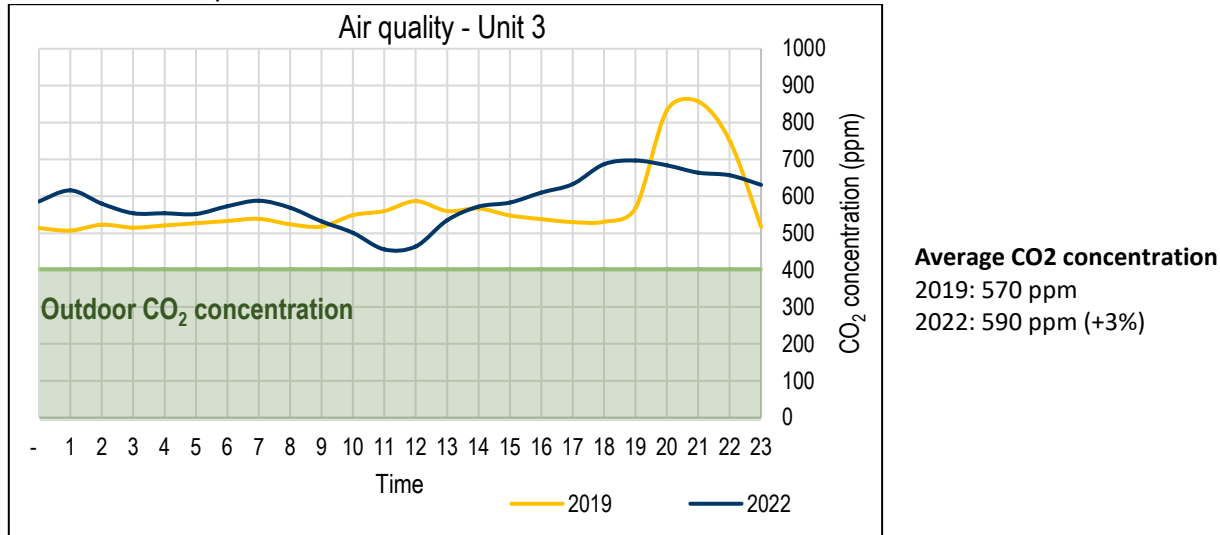


Figure 51: Daily indoor air quality comparison - Unit 3 - 2019 and 2022

There is no notable difference between the two recording periods, which is logical. In both cases, the same flow rate of outdoor air is supplied to the unit by the MUA.

The updated design is therefore able to maintain adequate indoor air quality.

2.2 What Are the Changes in Water and Energy Consumption?

2.2.1 Water Consumption

While not directly impacted by the cooling system changes, annual water consumption was reviewed to identify any changes since the initial evaluation. Annual water consumption exhibits a constant year-over-year increase since the commissioning of the building, as shown in Figure 52. Since 2018, consumption has increased by 60%. A comparison to the benchmark used in the original POE Report, in Table 16, shows that the per capita consumption has reached the reference consumption.

While the consumption per area is still 20% under the benchmark, it is less relevant, since typically, occupants, not space, use water.

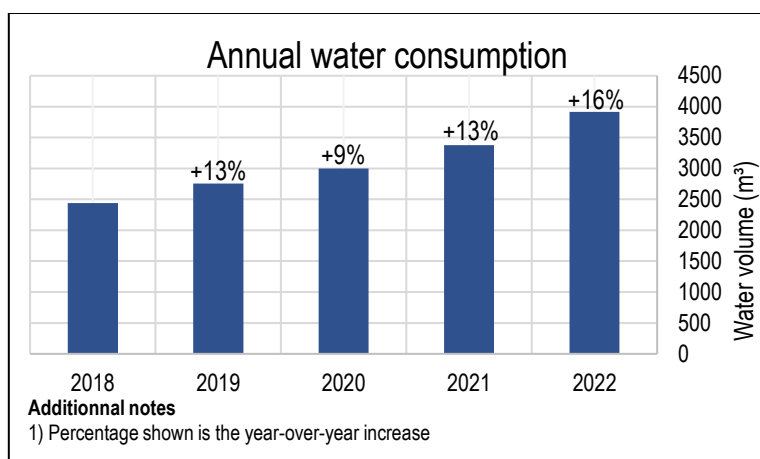


Figure 52: Water consumption evolution

	Benchmark	Salus 2021-2022
Per capita (m³/yr)	92 ⁵¹	93
Per area of living space (m³/yr)	2 ⁵²	1.6 (-20%)

Table 16: Comparison to benchmark

The metered data is not sufficient to determine the reason behind this trend, but the following factors could have had an effect.

- Behavioral changes, such as people spending more time indoors due to COVID measures and remote work.
- Dissipating impact of awareness programs.
- Changes in landscaping or irrigation practices.

Due to the continual increase, monitoring of water consumption should be continued using the water bills. If the upwards trend does not resorb itself, a water audit should be performed to better understand how water consumption is allocated and take measures accordingly.

2.2.2 Energy Consumption

Table 17 shows the EUI raised ~18% between 2018 and 2022. Electricity consumption has been mostly constant (see section 2.2.2.1). Most of the increase is due to an increase in natural gas consumption (see section 2.2.2.2). In 2022, when compared to the benchmark data:

- the source EUI was 30% lower than a standard MURB.
- the site EUI was 85% higher than the Passive House standard.

Salus Karen's Place	Design Modelling	Actual performance						Passive House Standard	Standard MURB: CMHC ⁵²
		2017	2018	2019	2020 ⁵³	2021 ⁵³	2022		
Site EUI (ekWh/m²)	-	103	115	121	146	162	149	-	212
Source EUI (ekWh/m²)	113	167	189	196	220	238	222	120	-
Year-over-year difference			+13%	+4%	+12%	+8%	-6%		

Table 17: Energy performance evolution and benchmarking

⁵¹ Environment and Climate Change Canada, 2011

⁵² CMHC, 2001

⁵³ The energy bills from May 2020 to July 2021 were not available. Average consumption from the previous years was used instead.

2.2.2.1 Electricity Consumption Data

Figure 53 shows the monthly electricity consumption since 2017. The consumption during the winter season has been very constant year after year. During summer, particularly in July, the impact of adding portable AC units can be seen as soon as they were installed. We can also notice that following the installation of the VRF system in 2021, the summer energy consumption is lower. Typically, permanent commercial AC systems are more efficient than portable units.

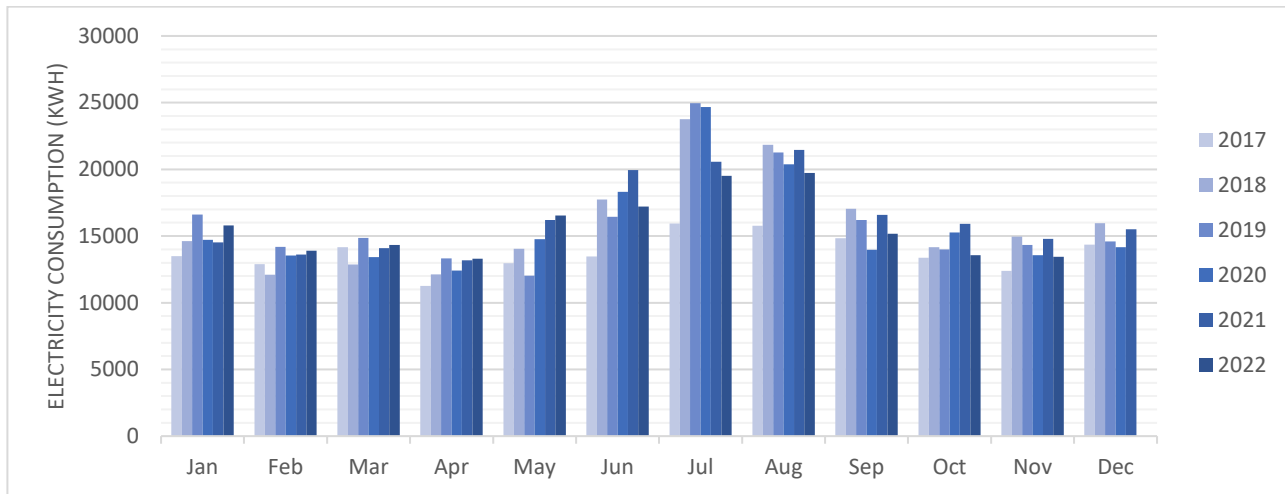


Figure 53: Electricity consumption, 2017-2022

Figure 54 shows the monthly energy demand for the same period. The demand reduction between 2018-2019 and 2022 also shows the impact of installing an efficient cooling system instead of using portable units.

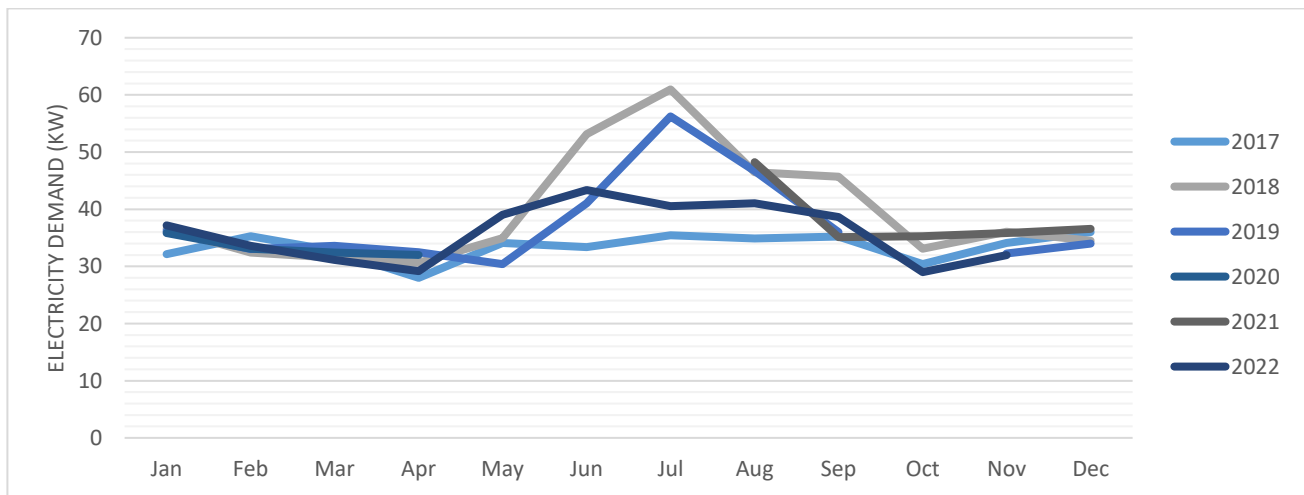


Figure 54: Electricity demand, 2017-2022

2.2.2.2 Natural Gas Consumption Data

Figure 55 shows natural gas consumption has been steadily raising since 2019. We have seen in section 2.2.1 that water consumption has also been steadily raising and domestic hot water heating is responsible for ~80% of the natural gas consumption. Nevertheless, when comparing the relative increase in water and natural gas consumption, it is clear DHW alone is not responsible for the increase.

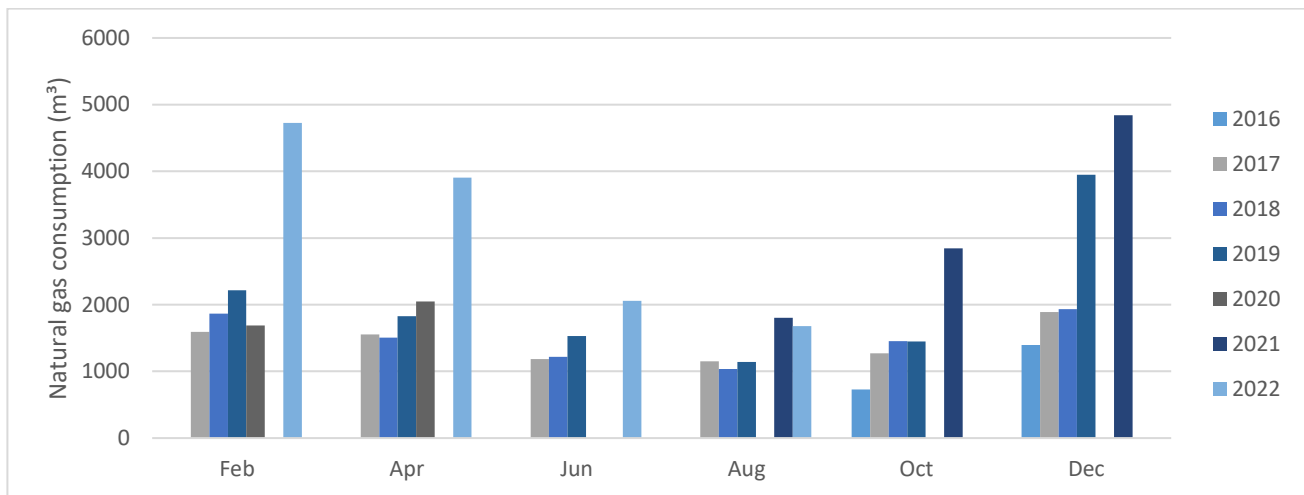


Figure 55: Bi-monthly natural gas consumption, 2016-2022

Figure 56 shows that, while water consumption has increased by 60% since 2018, natural gas consumption has increased by 120%.

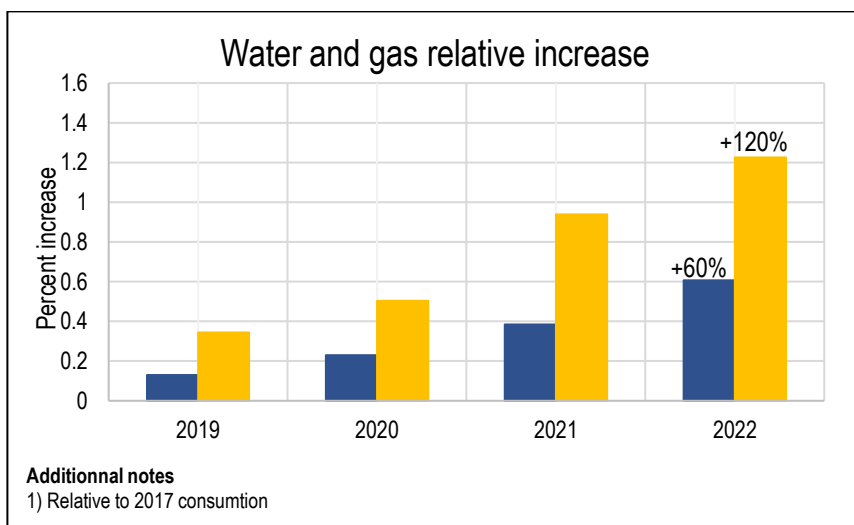


Figure 56: Water and gas relative increase since 2018

Unless there is a known explanation, an energy audit is required to identify why the natural gas consumption more than doubled.

Besides the probable increase in DHW, the following factors could have had an effect.

- Changes in hot water loop operating temperature which prevents the boilers from condensing.
- Operation issues with the heat recovery unit.

2.3 How Does the Heating and Cooling Performance Compare to Benchmarks?

2.3.1 Heating Performance

Table 18 shows the estimated heating intensity evolution since 2017. The intensity is calculated using the natural gas consumption, the space heating allocation from the POE report, and the increase in DHW consumption (using the hypothesis it is proportional to water consumption). Since 2021, the heating intensity has sharply increased and is now over Passive House standards (+46%). Nevertheless, it is still under the Ontario Building Code (OBC) benchmark by 46%.

Salus Karen's Place	Estimated performance						Passive House Standard	OBC (NEBC 2015)
	2017	2018	2019	2020	2021	2022		
Heating intensity (ekWh/m ²)	5.9	6.1	8	10	20	22	15	41
Year-over-year difference		+4%	+36%	+24%	+91%	-12%		

Table 18: Space and outdoor air estimated heating intensity

Compared to the OBC benchmark and based on current energy costs, the 2022 performance yields annual saving of approximately **1800 \$**. Using a 3% discount rate, the net present value of the savings on a 20-year period is approximately **28 000 \$**.

2.3.2 Cooling Performance

Table 19 shows the estimated cooling intensity evolution since the VRF system was commissioned, using a SEER of 16. The results show that, with the additional cooling capacity, the building cooling demand is 60% higher than the Passive House standard.

Salus Karen's Place	Estimated performance		Passive House Standard
	2021	2022	
Cooling intensity (kWh/m ²)	30	24	15
Year-over-year difference	-	-19%	

Table 19: Cooling and dehumidification estimated cooling intensity.

Compared to using portable AC and based on current energy costs, using the VRF system yields annual savings of approximately **\$700**. Using a 3% discount rate, the net present value of the savings on a 20-year period is approximately **\$14,000**. While the total savings are small compared to the cost of the VRF system - estimated at **\$420,000**, the following factors should be considered:

- The VRF system was installed to ensure occupant comfort, not yield energy savings.
- The costs could have been lower had the additional cooling capacity been integrated during design.

3 DISCUSSION: COOLING SYSTEM DESIGN

The overheating issues that led to the installation of additional cooling capacity brought into light the fact that the original systems were undersized with regards to the actual load. In the end, the installed cooling capacity had to be increased 6-fold from 21 kW (6 ton) to 125 kW (35 ton) to meet the building's needs.

In the event a similar project was to take place, the following factors should be considered:

- Maximizing solar heat gains to reduce the winter heating load has the effect of increasing the cooling load during summer. Passive solutions, such as well-designed shading devices⁵⁴ or strategically positioned deciduous trees can help minimize that effect.
- Even in a Passive House design, the required cooling capacity should be established using locally appropriate cooling load calculations⁵⁵. PHPP tends to be more conservative towards outdoor design conditions, as seen in Figure 57. This will help understand to what extent systems are being undersized.
- Based on the energy model load calculations, the required airflow to cool the suites varies between 80 and 90 L/s, the systems were designed for a maximum of 22 L/s per suite. While it is true Passive House aims to minimize installed cooling capacity, the maximum allowed was not reached in this project. This means additional capacity could have been included in the design while staying within the constraints of PH.
- In the event the required cooling capacity exceeds Passive House requirements, the maximum allowed capacity should be installed⁵⁶. In that situation, energy models can be a powerful tool to anticipate how the under-sizing will impact occupants.
- If a system is undersized, the initial design could still include room for additional capacity. In this case, the sizing of the fans and air distribution system did not allow for additional airflow. Oversizing both could have allowed for adding the required cooling capacity without adding a new VRF system. In the event the additional capacity is never required, the fans would be operated in part-load, which would benefit both energy efficiency⁵⁷ and acoustic comfort⁵⁸.
- Increased heat waves are one of the top climate risks facing Ottawa as well as many cities across Canada. This will result in increased building cooling demand which should be considered during design.

⁵⁴ The Bois Ellen cooperative, in Laval, Québec, had passive shading devices specifically designed to maximize winter solar gains while reducing the summer solar gains by 80%. CMHC. "[Bois Ellen Co-op](#)", Accessed March 10th, 2023

⁵⁵ The Ontario Building Code (9.33.2.2 Equipment Sizing) requires that, when a cooling system is installed, the cooling capacity should be based on good engineering practices, such as CSA F280, or ASHRAE standards.

⁵⁶ Salus Karen's Place Passive House Certification form shows an additional 6 W/m² could have initially been installed while respecting PH criteria.

⁵⁷ Fan affinity laws show that operating a fan at 70% capacity reduces energy use by 50%, and lower air speed in ductwork reduces friction.

⁵⁸ Lower air speed in ductwork reduces radiated sound levels.

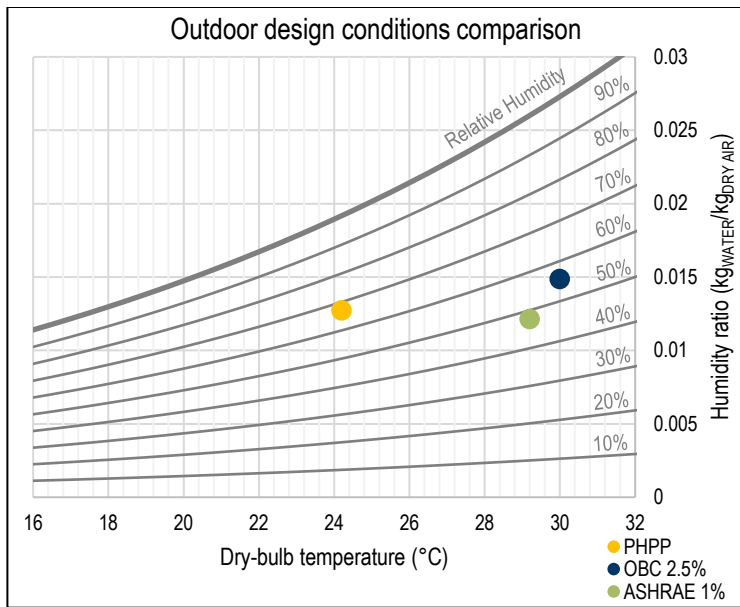


Figure 57: Outdoor design conditions comparison

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