City of Ottawa - Kanata & Downtown Ottawa Aerial Thermography and Quantification Aggregate Analysis Interim Report

December 19, 2023

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1 Executive Summary

QEA Tech conducts comprehensive audits on building envelope performance through industrial drones, thermography, and proprietary software. In November 2022, QEA Tech conducted a thermography operation within two specific catchment areas in downtown Ottawa and in Kanata that were identified by the City of Ottawa. This operation consisted of capturing high resolution infrared images of at least one façade and the roof of the 190 buildings within these two catchment areas.

In this engagement, QEA Tech analyzed the data that was previously captured to evaluate and summarize the overall health of the building envelopes in these two catchment areas. Vintages or categories based on the building age were also used to segment the data. There were several assumptions associated with the analysis that were noted in the report.

The analysis documented poor performing building envelopes across both catchment areas and across all vintages. None of the building envelopes were found to be meeting the building code (Ontario Building Code 2017) requirements. Building envelopes in Kanata performed slightly better than downtown Ottawa. Every building had some form of building envelope issue. Key issues found included connections between different materials, thermal bridging, inconsistent or decay of insulation, heat loss through doors and frames, and moisture accumulation. Nearly two thirds (64%) of buildings showed signs of water ingress. Water ingress issues were found to be more common in downtown buildings. In downtown Ottawa, moisture issues were found to be more common with increased building age.

City of Ottawa's assumptions in the Energy Evolution Plan assumed building envelopes were performing better than what was found from the results of this study. Building envelopes will require even more upgrading for thermal resistance than was estimated in the City Energy Evolution Plan to achieve greenhouse gas (GHG) reduction targets. For 38 buildings within the data set that were further analyzed, the preventable GHG emissions ranged from 68 to 1,123 tonnes CO_2e per year.

Lessons learned from this project include extending the time of data collection and capturing a higher volume of thermal images per building, additional activities to capture the inside temperatures per building, and collecting spot surface temperature measurements for any subsequent catchment areas to increase the accuracy and precision of the results.

2 Introduction

QEA Tech provides comprehensive analyses on the thermal behaviour of building envelopes by using drones, thermography, and proprietary software. Our technology determines where and how much energy is being lost in a building's envelope and the analysis enables the client to prioritize repairs by evaluating the payback and ROI of repairs.

In a prior engagement, QEA Tech conducted its thermography operation within two specific catchment areas in downtown Ottawa and in Kanata that were identified by the City of Ottawa (sections are illustrated in the Methodology section below). This project consisted of capturing high resolution infrared images of at least one façade and the roof of the 190 buildings within these two catchment areas.

QEA Tech subsequently conducted further analysis of the high resolution and thermal images captured in the previous engagement for the two catchment areas in order to evaluate and summarize the overall health of the building envelopes in these two sample areas.

The scope of the analysis consisted of the following:

- Number and percent of buildings considered to have major issues associated with their building envelope in Kanata and downtown Ottawa
- Number and percent of buildings with evidence of water ingress
- Average effective R/U value of a building's envelope elements in Kanata and downtown Ottawa
- Average energy loss per metre square per building envelope in Kanata and downtown Ottawa
- Energy savings potential and GHG savings potential per square metre of building element in Kanata and downtown Ottawa
- Identify any other major patterns and trends / identify potential patterns and trends that need to be investigated further
- Average effective U-value for walls and roofs calculated by QEA Tech compared to City of Ottawa Energy Evolution assumptions table for age category

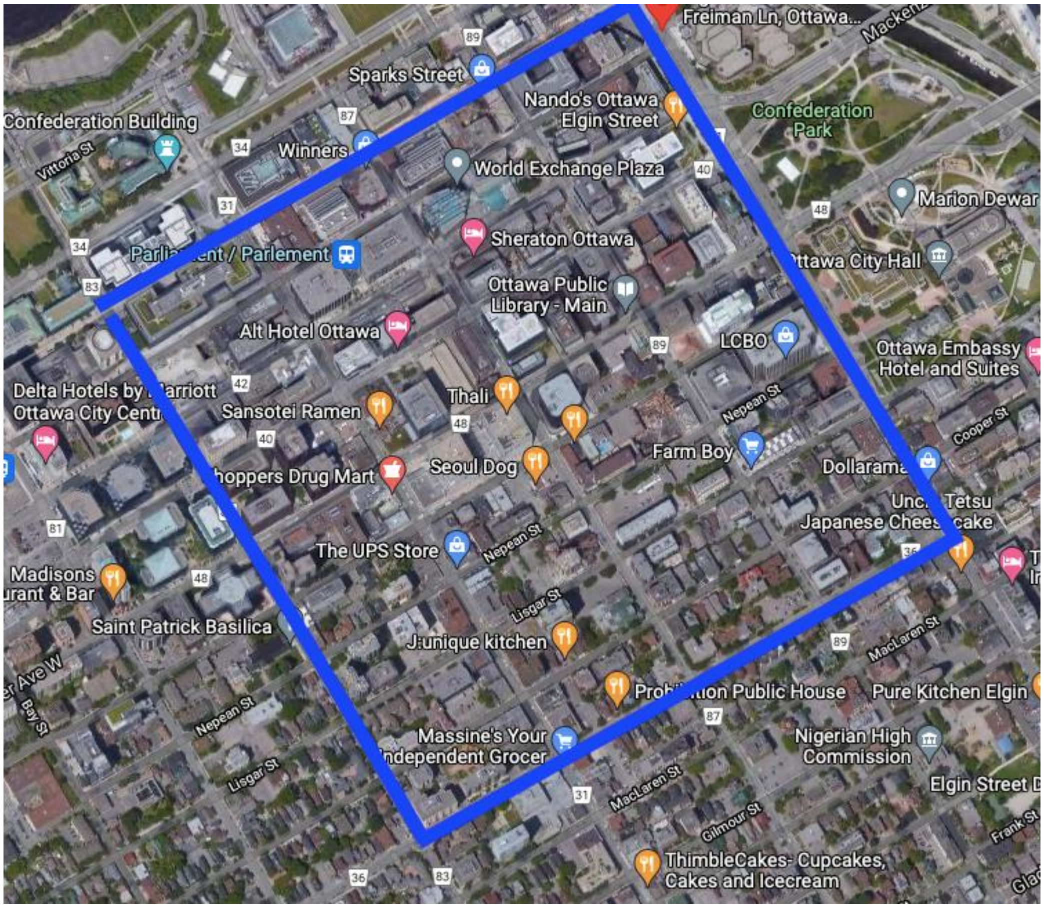
3 Methodology

In November 2022, three teams were mobilized to capture images of the two catchment areas. Two of the teams captured images of the building facades using a handheld camera while a third team captured images by flying a drone above. A total of 13,323 images were captured with the drone and 2,965 images were captured using handheld cameras. Approximately 5 thermal images were selected for the street facing façade of each building and 1-2 thermal images were selected for each building roof.

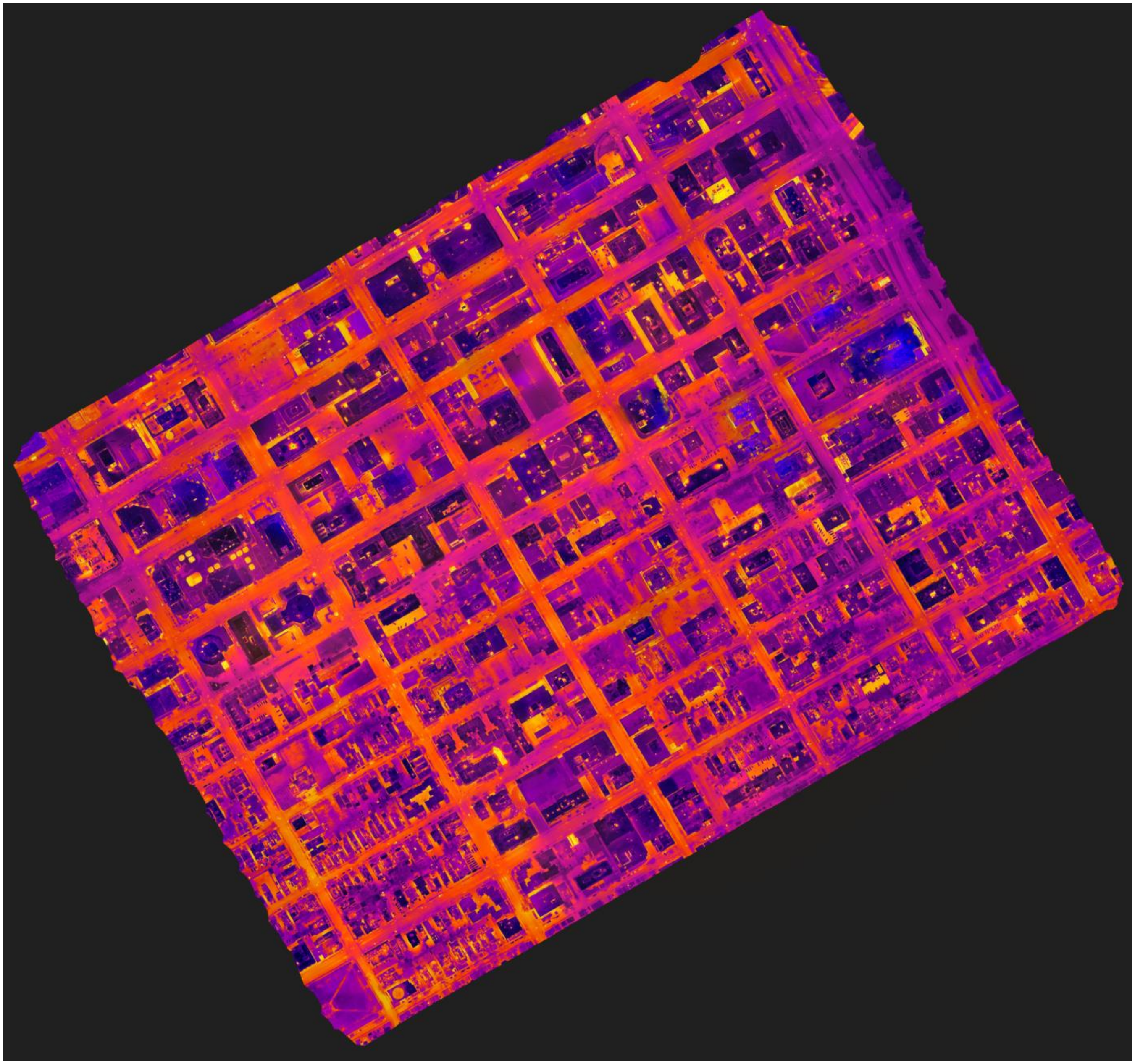
QEA Tech's Building Science Team used QEA Tech's software to analyse and generate individual summary reports for each property. These reports provided a summary of the thermal performance of a limited number of facades for each building. There are various factors and data inputs that go into QEA Tech's calculation of the U-values of building elements. Key variables that QEA Tech incorporated into the calculation of U-values for this project included outside temperature (T-outside), inside temperature (T-inside), inside surface temperature (Ts-inside) and outside surface temperature (Ts-outside).

QEA Tech had all relevant permits and licences to collect these images. The City of Ottawa communicated with all building owners through several channels to make building owners and occupants aware of this work.

Facade scanning operation for Area 1 (Downtown Ottawa) illustrated below was conducted on November 27, 2022.



The image below shows a complete thermal orthomosaic of the downtown catchment zone which was generated by stitching approximately 4,000 images. Note that not all of the buildings inside the catchment area were in scope of the current study.



Facade scanning operation for Area 2 (Kanata North) illustrated below was conducted on November 28, 2022.

See link to map with both catchment areas here.

To complete further analysis of the data that is outlined in this report, 44 data points were extracted from each building to create a single database. The buildings were categorized into the two catchment areas and further categorized into different vintages. The vintage categories are as follows:

- Vintage 1: 2005-present
- Vintage 2: 1980 – 2004
- Vintage 3: 1961 – 1979
- Vintage 4: Before 1960

In order to search for different issues on the buildings, eleven categories of building envelope issues were used.

- Connection Between Wall and Fenestration
- Connection Between Roof and Exterior Wall
- Thermal Bridge Between Structural Load-Bearing Elements and Their Connection to Others
- Connection Between Exterior Walls at Corners
- Inconsistent Insulation/Decay of Insulation
- Connection Between Cladding Tiles/Panels
- Heat Loss Through Door and Door Frames
- Heat Loss Through Frame and Insulated Glass Units (IGUs)

- Connection Between Foundation and Exterior Wall
- Moisture Accumulation within Roofing Membrane/Tiles
- Moisture Accumulation on Building's Exterior Elements

The database was read with *Matlab* and automated scripts were generated to visualize the data in a consistent manner on the different catchment zones and vintage groups.

4 Assumptions & Limitations

Several assumptions were made for this engagement including:

- There was a limited amount of data captured during the operations for Downtown Ottawa and Kanata and there are several variables that could impact the U-value calculations of the building envelope elements. The report was based on the analysis of the images captured for one façade and roof per building in the previous thermography operation conducted in November 2022. Approximately 5 thermal images were selected and utilized for the street facing façade of each building. Approximately 1-2 thermal images were selected and utilized for each building roof. The facades were used as a sample of each building and are not considered complete representations of the entire health of each building. For standard building envelope energy audits on specific buildings, QEA Tech usually captures thousands of thermal images of a given building. However, due to time constraints, the volume of images per façade were significantly reduced. In addition, for more accurate results, QEA Tech usually captures façade and roof images using a drone at a distance of 10-15 meters. This allows the software to analyze the building envelope more accurately. In the current study, roof images were taken at a higher altitude and all the façade images were captured from ground level using the handheld camera. This could cause an error of up to ±10% in the U-value calculations of building elements.
- The inside temperature of the buildings was assumed to be 21°C. The City of Ottawa communicated with the building managers, where possible, to inform them of the time of thermal image capture so that inside temperatures could be set accordingly to 21°C, where it could be controlled by building operators and permitted by lease structures. The actual inside temperature for every building was not monitored and only confirmed in select buildings. An adjustment factor to be considered is that the U-value could be overstated by up to 20% higher if the inside temperature were 17°C instead of the assumed 21°C based on historical data on other projects completed by QEA Tech.
- For accurate calculations, buildings should be at equilibrium in steady state. In steady state, the four temperatures (outside temperature, inside temperature, inside surface temperature, outside surface temperature) are fixed and not in flux. Best effort was made to ensure steady state with the City of Ottawa notifying building managers of the operation. However, there was little direct control over how the buildings were managed the night of the thermography operation.
- The exterior building envelope materials were identified; however, the wall assembly of each façade was not known. This is typically done by studying architectural drawings of each building.

- The ages of 7 of the buildings (6 buildings in Downtown Ottawa and 1 building in Kanata) in the data set were not known. Buildings with an unknown age were included in the overall catchment results but not placed into any of the four vintage categories.
- Weather conditions were only collected at a central location each night at the start of the operation and not consistently measured and captured throughout the night. As a result, a single value was assumed for all buildings. For Downtown Ottawa, the outside temperature was -1^{o}C, 65% humidity, with 2.22 m/s wind speed. For Kanata, the outside temperature was -1^{o}C, 78% humidity, with 1.67 m/s wind speed.
- GHG savings potential per building could only be calculated for a subset of 38 buildings because the total square m of each building envelope element of each building in the full data set was not known. Typically, this information is obtained through a high-resolution 3D model of the building created by 3D reconstruction of thousands of visual images captured by a drone for each building.
- There were several lessons learned throughout the process of this engagement. In any subsequent projects of a similar nature, QEA Tech would spend additional time capturing data including additional thermal images per façade, weather conditions throughout the operation, and the inside temperature of buildings.

5 Results

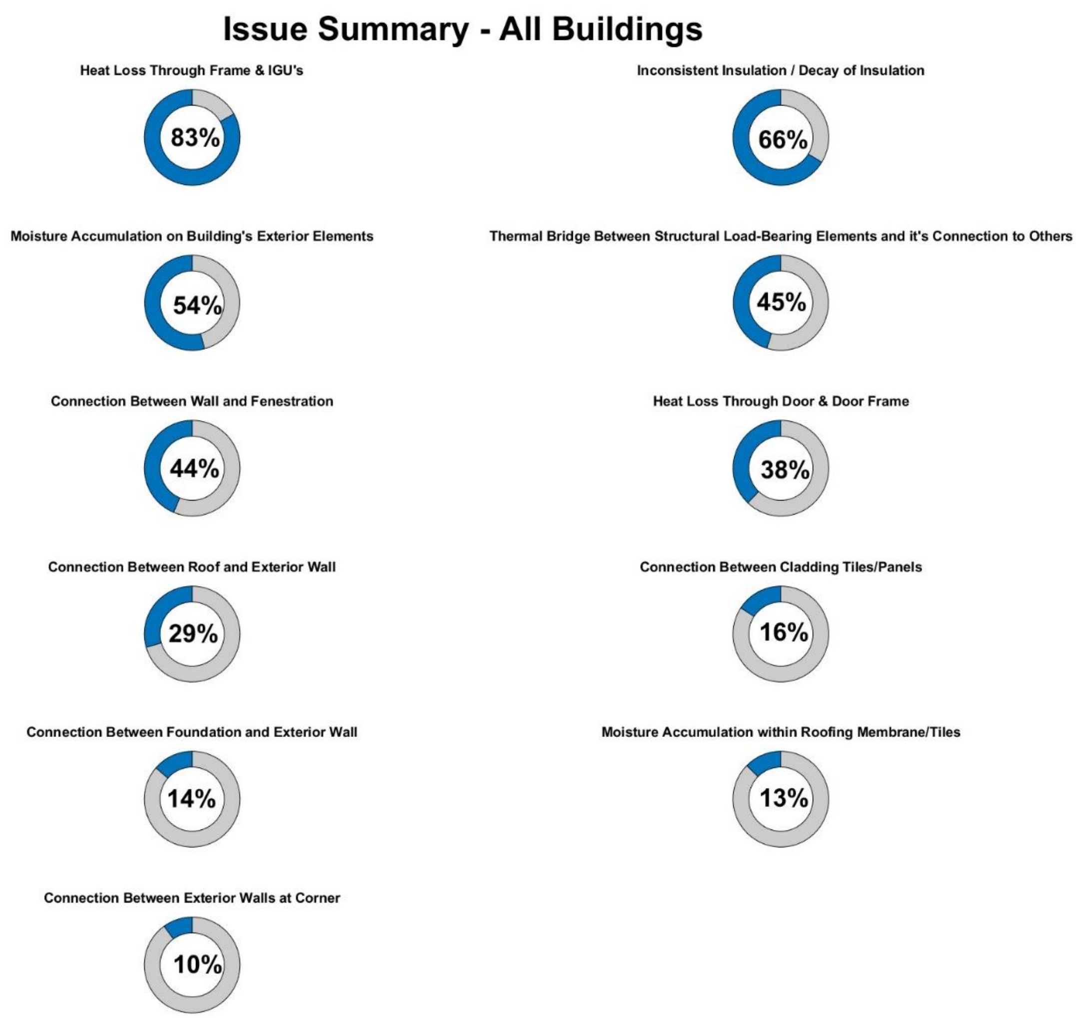
For each property, a separate report was prepared and presented to the City of Ottawa. The following section summarizes the findings from the study conducted from a high level, with the objective of highlighting trends in the dataset.

5.1 Summary of Issues Found in the Building Envelope

Every building analyzed across the two catchment areas showed at least one instance of a building envelope issue. The three most frequently found issues in buildings were:

- Heat Loss Through Frame & IGUs
- Inconsistent Insulation / Decay of Insulation
- Moisture Accumulation on Building's Exterior Elements

The "Number of Buildings Found" only indicates the number of buildings regardless of the number of issues of the same category found on unique buildings, whereas the "Number of occurrences" of an issue for a single building may be greater than 1. A detailed breakdown of the issues found in each catchment area and per different vintage groups is included in the Appendix.



Issue Type	Number of Buildings Found	Number of Occurences
"Heat Loss Through Frame & IGU's"	158	320
"Inconsistent Insulation / Decay of Insulation"	126	266
"Moisture Accumulation on Building's Exterior Elements"	103	276
"Thermal Bridge Between Structural Load-Bearing Elements and it's Connection to Others"	86	144
"Connection Between Wall and Fenestration"	83	137
"Heat Loss Through Door & Door Frame"	72	90
"Connection Between Roof and Exterior Wall"	56	70
"Connection Between Cladding Tiles/Panels"	30	48
"Connection Between Foundation and Exterior Wall"	26	26
"Moisture Accumulation within Roofing Membrane/Tiles"	24	31
"Connection Between Exterior Walls at Corner"	19	21

Figure 1: Summary of Issues Found in All Buildings

5.2 Water Ingress on Buildings

QEA Tech's software can identify potential locations of moisture accumulation through the analysis of thermal and visual images. Water ingress is further categorized into moisture accumulation on roof and other exterior surfaces.

Table 1 summarizes all the water ingress issues found in the buildings for both catchment areas in the study. Note that the ages for six buildings in the Downtown Ottawa catchment and one building in the Kanata catchment were not known. These buildings are included in the totals but do not appear in each Vintage break out in the table below.

Table 1: Summary of Water Ingress Found

Dataset	Sample/Dataset	Moisture on Exterior Element			Moisture on Roof		
	No. Buildings	No. of Buildings	No. of Occurrences	% of Buildings	No. of Buildings	No. of Occurrences	% of Buildings
Downtown	138	79	233	57%	20	27	14%
Downtown - Vintage Group 1	21	8	22	38%	3	4	14%
Downtown - Vintage Group 2	32	12	27	38%	7	11	22%
Downtown - Vintage Group 3	45	32	109	71%	8	10	18%
Downtown - Vintage Group 4	34	23	67	68%	2	2	6%
Kanata	52	24	43	46%	4	4	8%
Kanata - Vintage Group 1	5	0	0	0%	0	0	0%
Kanata - Vintage Group 2	43	21	38	49%	4	4	9%
Kanata - Vintage Group 3	3	2	4	67%	0	0	0%
TOTAL	**190**	**103**	**276**	**54%**	**24**	**31**	**13%**

103 out of 190 (54%) buildings analyzed were found to have moisture on exterior elements and 24 out of 190 buildings (13%) were found to have moisture on the roof. Due to higher altitude of the drone flight during this engagement, the image resolution is lower than QEA Tech's standard service. As a result, there may have been additional moisture issues that were not detected by QEA Tech's software.

5.3 Effective U-Value of Building Elements

U-value is a measure of the heat transmission through a material. The U-value is lower for better insulated material. The units of measurement for U-value are W/m²K. In this section, the U-values for different building elements are plotted on a distribution graph to provide insight on how these values change between the different sites and different vintage groups. These values are also compared against the current building code (Ontario Building Code 2017) and the city of Ottawa Energy Evolution Assumptions.

5.3.1 U-Value of Building Envelope Elements

Figure 2 below shows distribution plots for the U-values of walls, windows, doors, and roof for all the buildings in the two catchment areas. Each plot contains the following metrics:

- Number of Data Points / Buildings
- Maximum Value
- Minimum Value
- Mean Value
- Median Value
- Range of Values
- Standard Deviation

Table 2: Average U-values (W/m2K) for building envelope elements Downtown Ottawa and Kanata

Building Envelope Element - Downtown Ottawa	U-Value (W/m²K)	% Difference vs Building Code	% Difference vs EEP
Wall	1.27	411	212
Window	3.27	127	N/A
Door	3.86	170	N/A
Roof	1.14	570	243

Building Envelope Element - Kanata	U-Value (W/m²K)	% Difference vs Building Code	% Difference vs EEP
Wall	1.20	385	199
Window	3.26	127	N/A
Door	3.80	167	N/A
Roof	1.11	555	237

Values from the building code are outlined in Section 5.3.2 EEP values for the wall are 0.5678 – 0.6309. In the table, U-values are compared against the average of 0.5993. EEP Values for roof are 0.3053 – 0.6300. In the table, U-values are compared against the average of 0.4676.

Further breakdown of the U-values based on the catchment areas and the vintage groups is detailed in Appendix C – U Values Details.

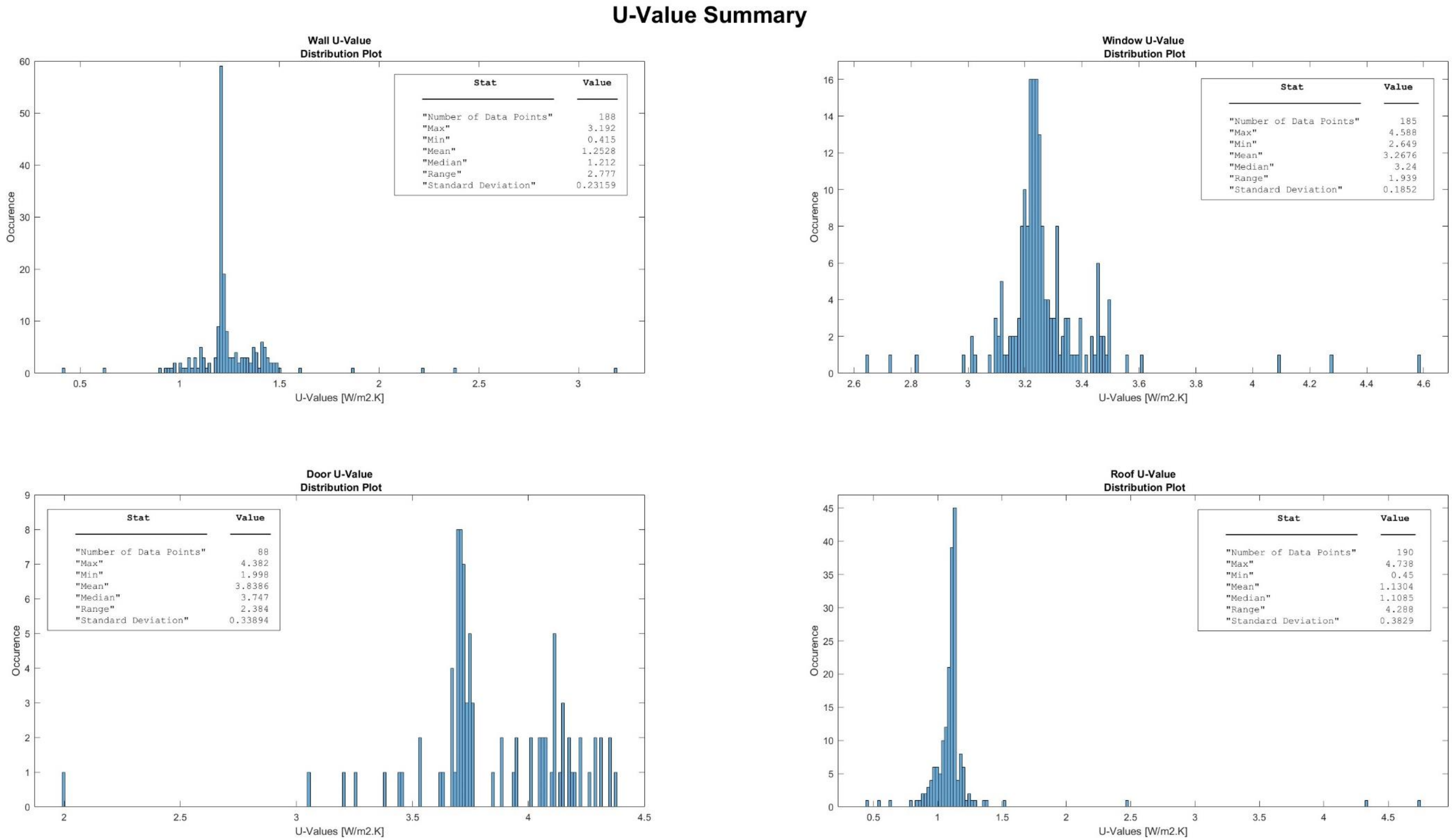


Figure 2: Summary of U-Values of All Buildings

5.3.2 Comparison with Building Code and Ottawa Energy Evolution Plan

In this section, the mean U-value of each building element for each catchment zone is compared against the current building code (Ontario Building Code 2017) and the expected values obtained from the Ottawa Energy Evolution Plan (EEP). The red lines in the graph indicate the current U-values from the building code and the green dashed lines indicate the minimum and maximum values from the EEP. EEP values were only available for wall and roof elements. The building code values for different elements are listed below:

- Wall: 0.310 W/m^2K
- Roof: 0.20 W/m^2K
- Window: 2.56 W/m^2K
- Door: 2.27 W/m^2K

Based on this dataset, the average building envelopes are performing 75% worse compared to current building code (based on the walls which are most of the envelope), all of which are significantly worse than current building code (Ontario Building Code 2017).

Furthermore, the buildings analyzed also showed that the assumptions in the City of Ottawa's Energy Evolution assumed building envelopes to have approx. 50% lower U-values than actuals identified through this study, meaning the envelopes are further from current building code and levels of energy efficiency from original municipal assumptions.

In the current database, only 2 buildings have wall U-values that meet the EEP expectations. Similarly, only 3 buildings have roof U-values that are within the EEP expected limits.

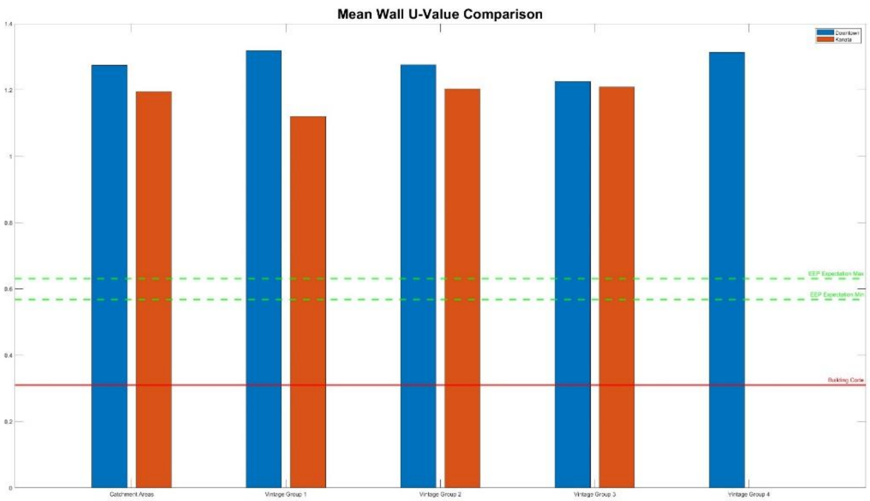


Figure 3: Comparison of Mean Wall U-values of All Buildings against Existing Building Code and EEP

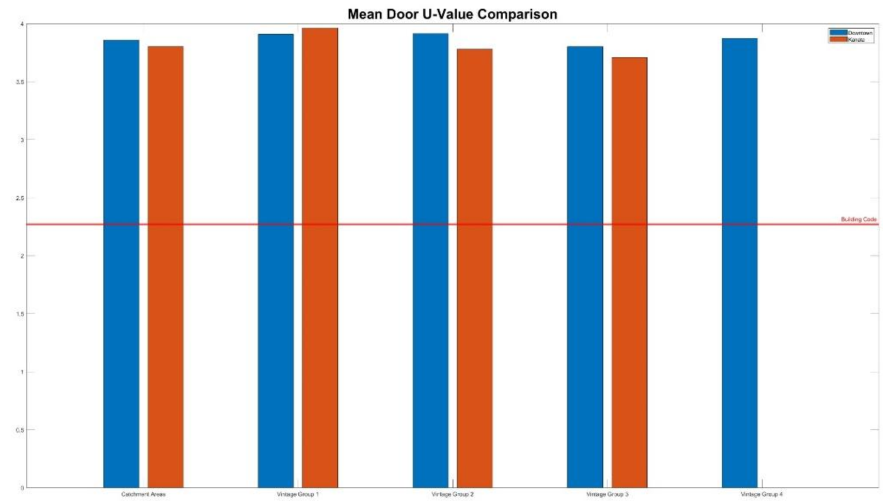


Figure 4: Comparison of Mean Door U-values of All Buildings against Existing Building Code and EEP

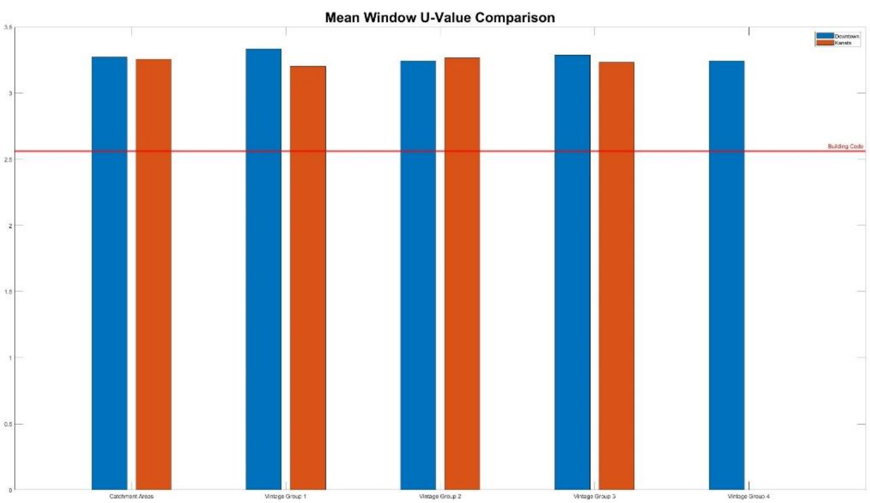


Figure 5: Comparison of Mean Window U-values of All Buildings against Existing Building Code and EEP

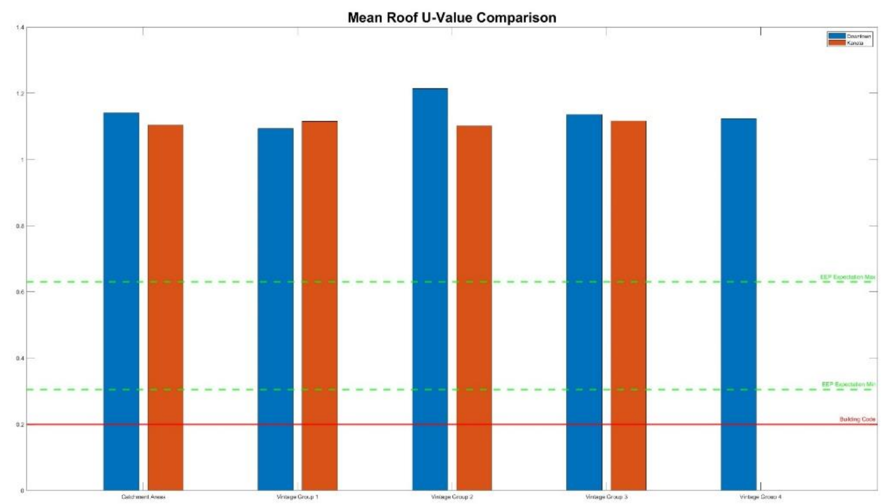


Figure 6: Comparison of Mean Roof U-values of All Buildings against Existing Building Code and EEP

5.4 Building Energy Loss

As part of the study, based on the average U-value of building elements obtained from the inspected facades, our software can estimate the amount of annual heat loss through the building façade. Since we did not have 3D models of the buildings and overall areas for the different elements, all the heat loss values have been normalized and reported as heat loss per square metre. Since only 1 façade was inspected for many of the buildings in this study, we did not have information for all the building elements for every property.

Table 3: Summary of average energy loss per m^2

Building Envelope Element	Energy Loss per m^2 (MWh/m^2)	
	Downtown	Kanata
Wall	0.2743	0.2417
Window	0.5220	0.7994
Door	0.4977	0.4805
Roof	0.1443	0.1422

Table 4 summarizes the results obtained for the two catchment areas.

Table 4: Summary of Annual Energy Loss Values per Square Metre

		Downtown	Kanata	Units
Wall	No. of Data Points	137	51	-
	Max	1.0320	0.6230	MWh/year
	Min	0.0123	0.0331	MWh/year
	Mean	0.2743	0.2417	MWh/year
	Median	0.2890	0.3110	MWh/year
	Range	1.0197	0.5899	MWh/year
	Standard Deviation	0.1412	0.1214	-
Window	No. of Data Points	133	52	-
	Max	10.0810	5.7769	MWh/year
	Min	0.0310	0.3851	MWh/year
	Mean	0.5219	0.7995	MWh/year
	Median	0.4130	0.4210	MWh/year
	Range	10.0500	5.3918	MWh/year
	Standard Deviation	0.8923	1.1058	-
Door	No. of Data Points	56	32	-
	Max	1.0790	0.5648	MWh/year
	Min	0.1360	0.2385	MWh/year
	Mean	0.4977	0.4805	MWh/year
	Median	0.4825	0.4820	MWh/year
	Range	0.9430	0.3262	MWh/year
	Standard Deviation	0.1447	0.0514	-
Roof	No. of Data Points	138	52	-
	Max	0.6014	0.1628	MWh/year

	Min	0.0030	0.1100	MWh/year
	Mean	0.1443	0.1422	MWh/year
	Median	0.1420	0.1430	MWh/year
	Range	0.5984	0.0529	MWh/year
	Standard Deviation	0.0616	0.0081	-

QEA Tech has provided data on a per square metre basis and provided average values for each building element per square metre. Because the building envelope surface areas are not known, energy loss per building was not calculated. If the size of the envelope is known, QEA Tech's average values per square metre can be multiplied by the size of the envelope.

Figure 7 and Figure 8 show the distribution plot for the annual energy loss values per square metre of different building elements.

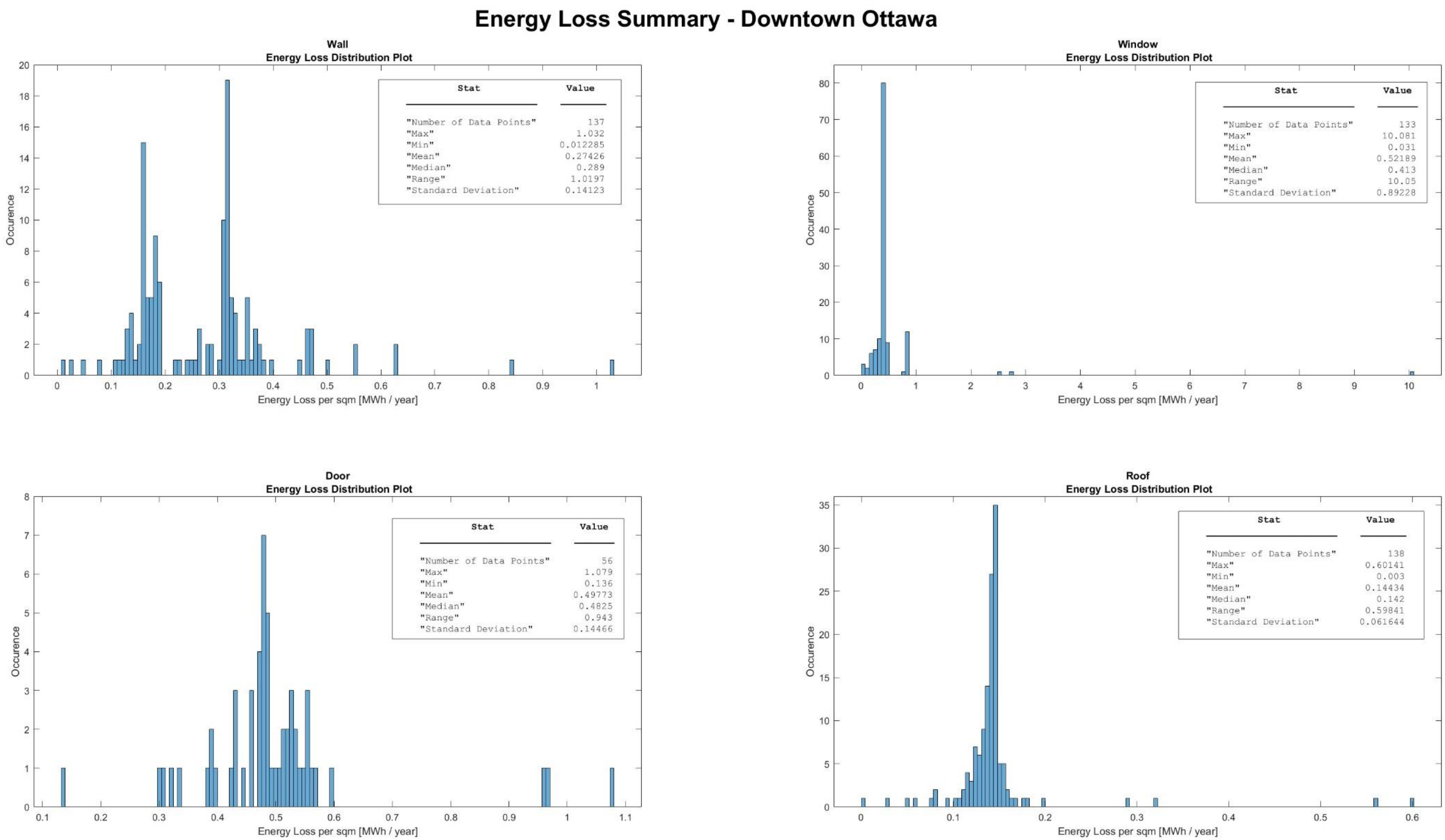


Figure 7: Distribution Plot for Annual Energy Loss for Different Building Elements in the Downtown Catchment

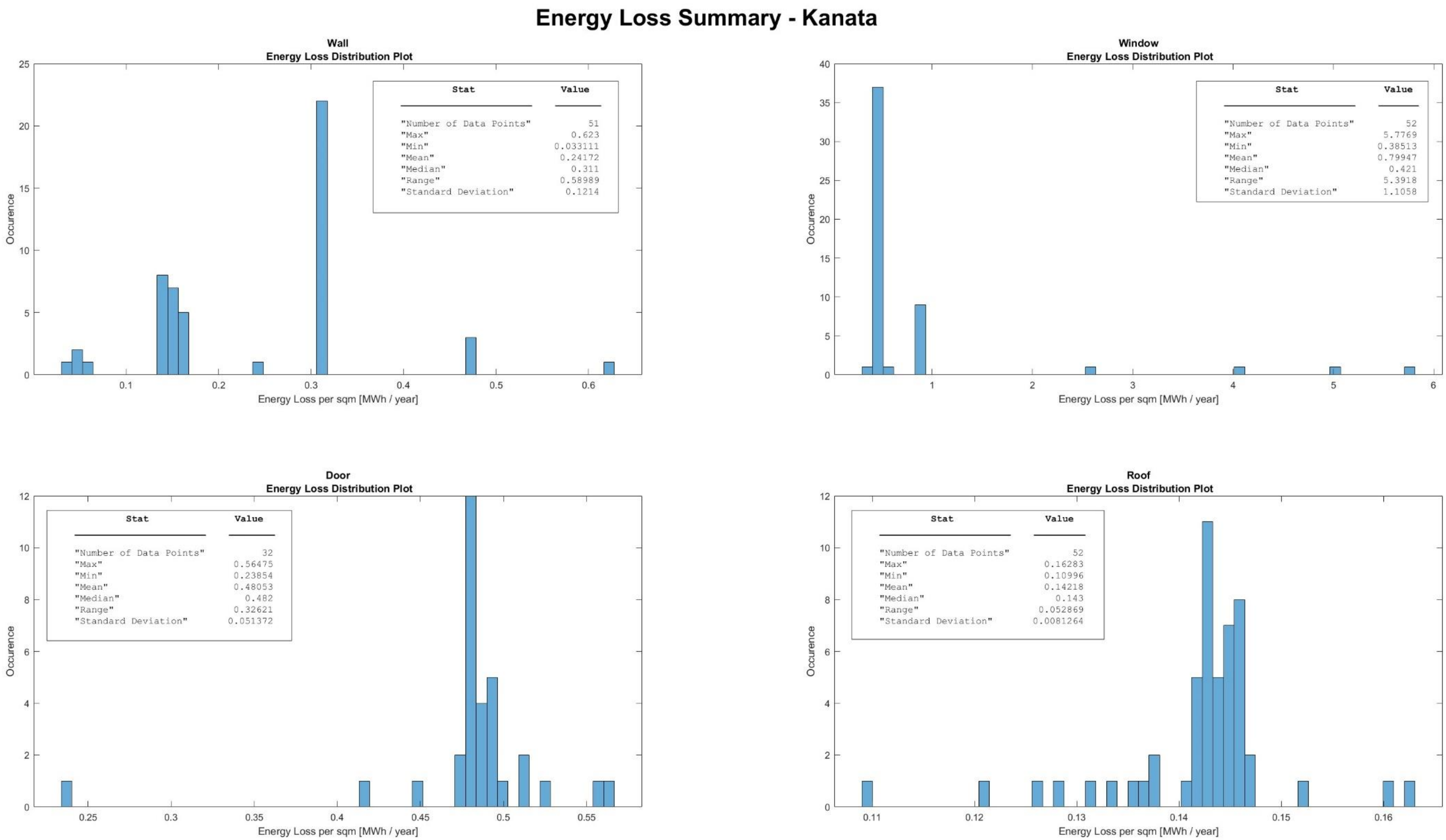


Figure 8: Distribution Plot for Annual Energy Loss for Different Building Elements in the Kanata Catchment

5.5 Building Preventable Energy Loss

After determining the U-value for the building elements, our software estimates the amount of energy that could be saved assuming that the specific element was equivalent to the building code value (Ontario Building Code 2017).

Table 5 summarizes the results obtained for the two catchment areas.

Table 5: Summary of Annual Preventable Energy Loss Values per Square Metre

		Downtown	Kanata	Units
Wall	No. of Data Points	136	51	-
	Max	1.1487	0.5623	MWh/year
	Min	0.0120	0.0222	MWh/year
	Mean	0.2156	0.1897	MWh/year
	Median	0.2175	0.2310	MWh/year
	Range	1.1367	0.5401	MWh/year
	Standard Deviation	0.1388	0.1035	-
Window	No. of Data Points	133	52	-
	Max	2.3337	1.4124	MWh/year
	Min	0.0080	0.0546	MWh/year
	Mean	0.1123	0.1854	MWh/year
	Median	0.0860	0.0895	MWh/year
	Range	2.3257	1.3578	MWh/year
	Standard Deviation	0.2048	0.2594	-
Door	No. of Data Points	56	31	-
	Max	0.5549	0.2798	MWh/year
	Min	0.0400	0.1415	MWh/year
	Mean	0.2102	0.2013	MWh/year
	Median	0.1910	0.1900	MWh/year
	Range	0.5149	0.1383	MWh/year
	Standard Deviation	0.0850	0.0272	-
Roof	No. of Data Points	136	52	-
	Max	0.7273	0.1370	MWh/year
	Min	0.0250	0.0841	MWh/year
	Mean	0.1217	0.1168	MWh/year
	Median	0.1160	0.1180	MWh/year
	Range	0.7023	0.0529	MWh/year
	Standard Deviation	0.0697	0.0082	-

Kanata is performing better than Downtown Ottawa on average in terms of annual preventable energy loss. Buildings in Downtown Ottawa show a greater range spread of values for annual preventable energy loss. The highest U-values in the dataset are seen in this catchment area likely due to the age of construction and materials.

Figure 9 and Figure 10 show the distribution plot for the annual preventable energy loss per square metre of different building elements.

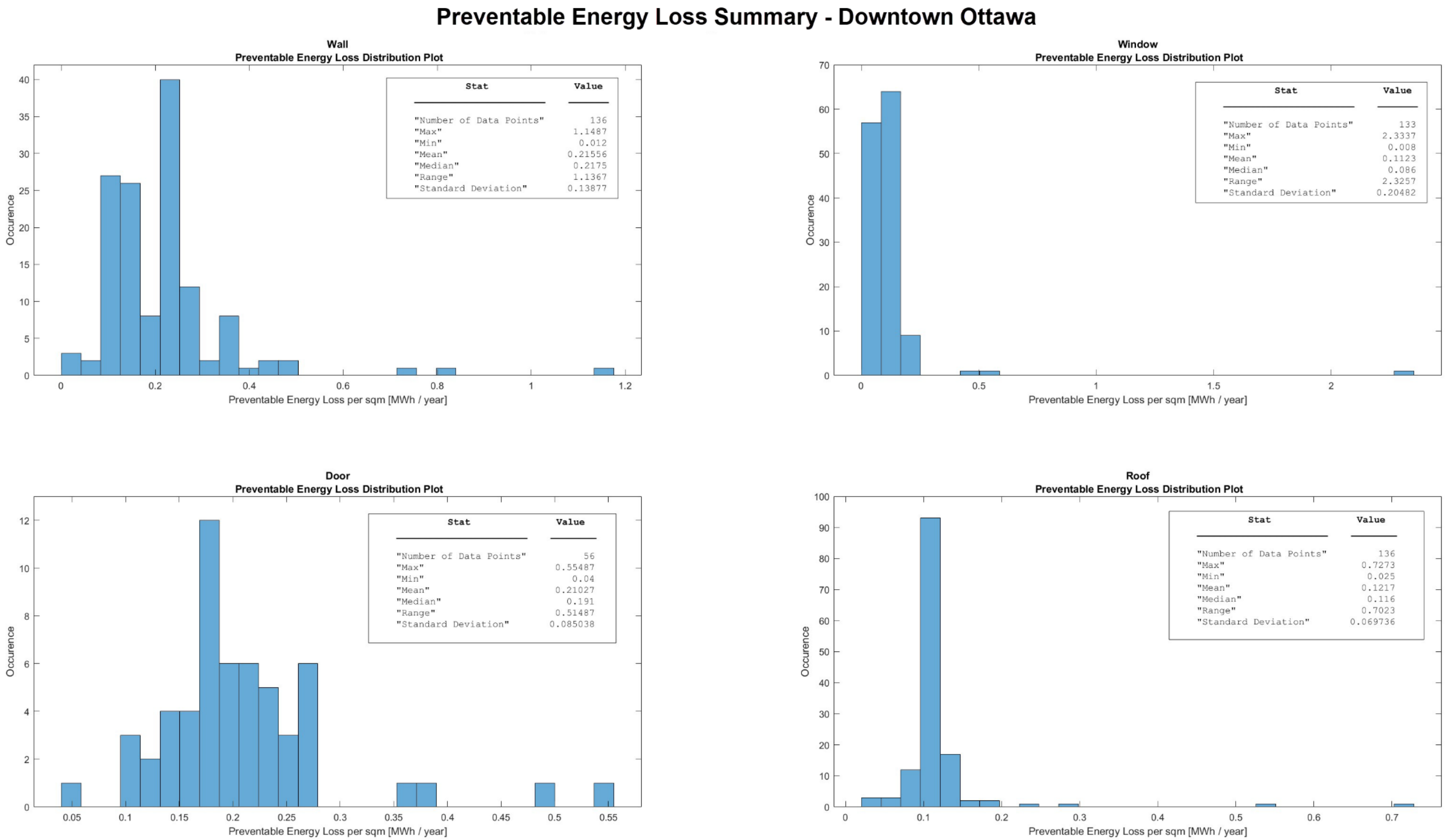


Figure 9: Distribution Plot for Annual Preventable Energy Loss for Different Building Elements in the Downtown Catchment

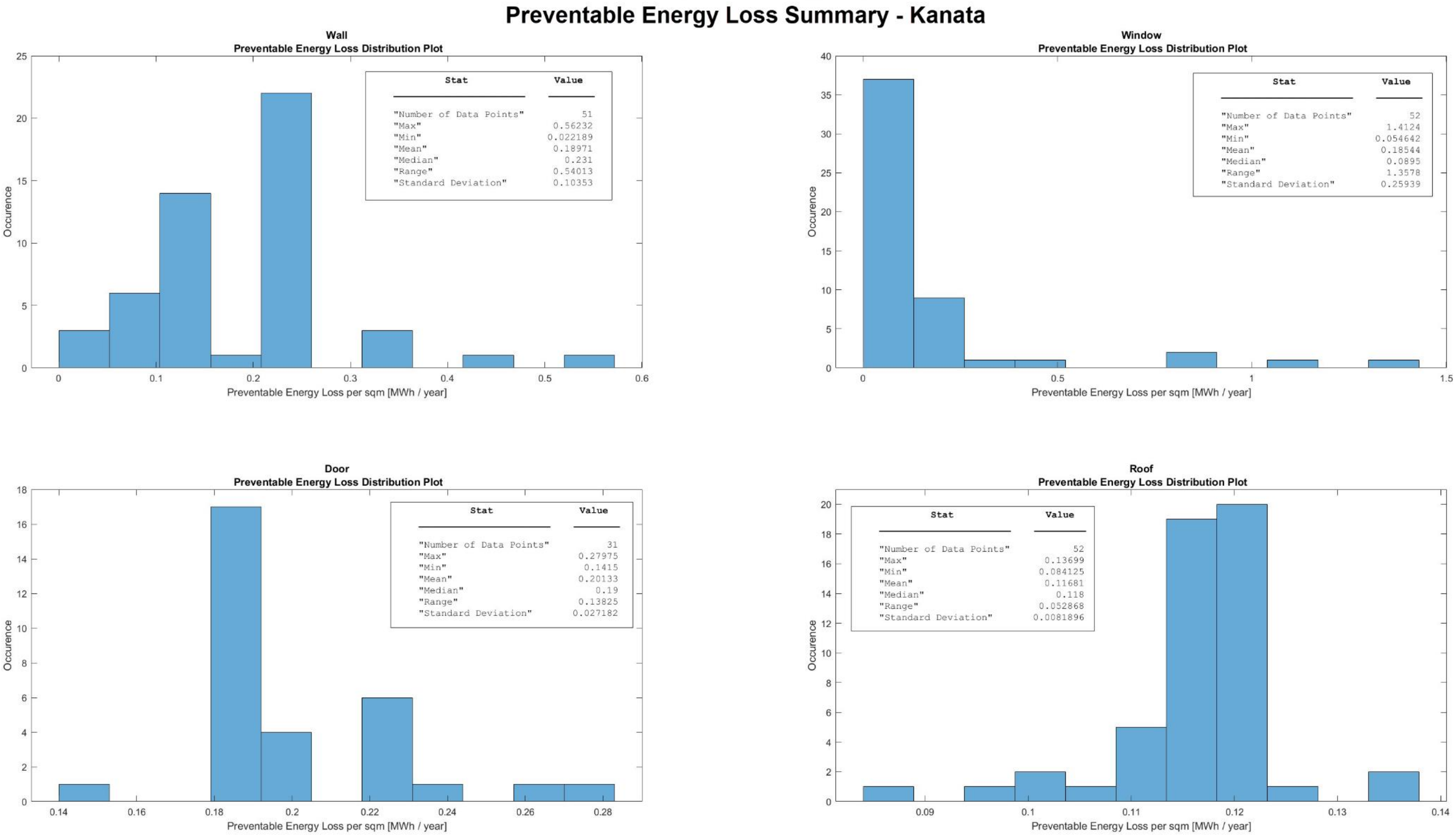


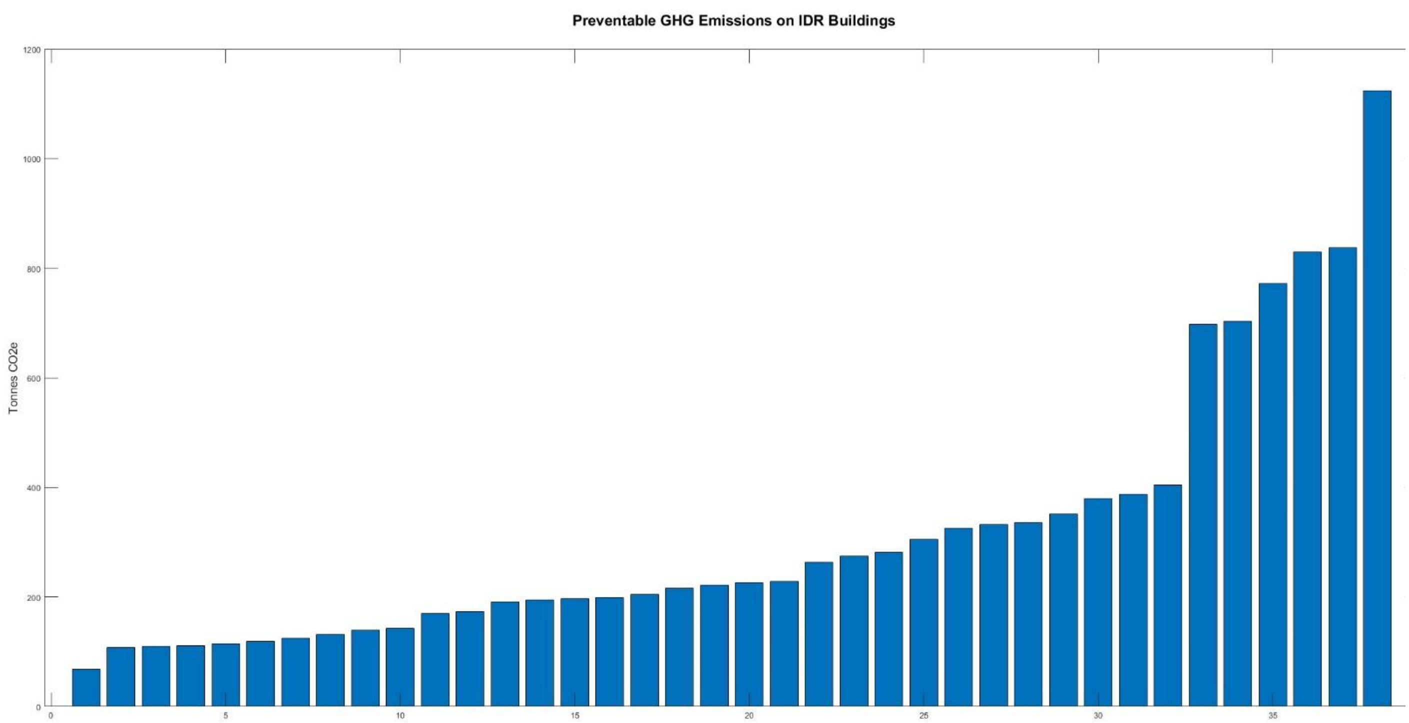
Figure 10: Distribution Plot for Annual Preventable Energy Loss for Different Building Elements in the Kanata Catchment

5.6 Preventable GHG Loss

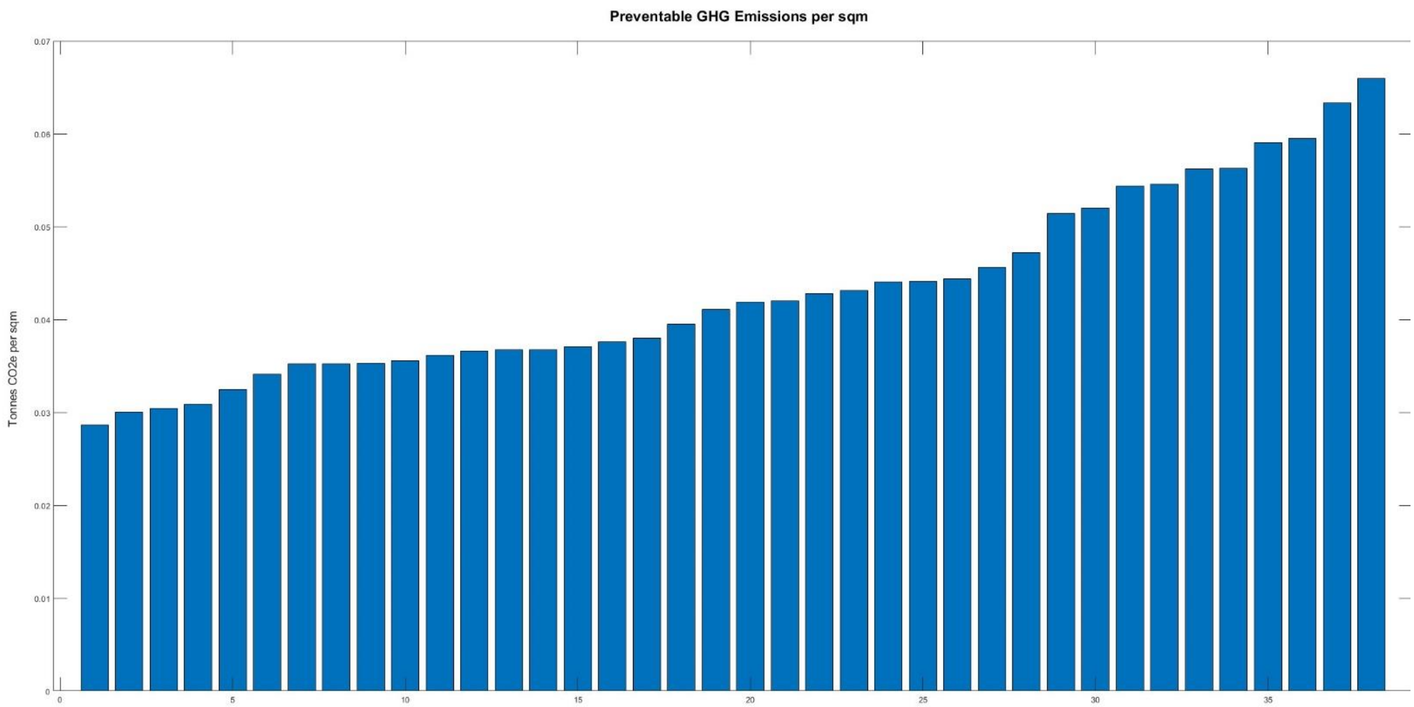
From all the buildings in the dataset, 38 of them had been selected for additional analysis on a single façade of the buildings including area measurements. With the area measurements known, preventable greenhouse gas (GHG) emissions could be calculated for that façade. Using the information from a single façade, the results were extrapolated to estimate the total preventable GHG emissions on the entire building. With these assumptions, the preventable GHG emissions from the 38 buildings range from 68 to 1,123 tonnes CO_2e per year.

The method of heating/cooling for the properties was not known and it is assumed that all heating is with gas. As a result, a single conversion factor of 49 $kgCO_2e/GJ$ from the GHG equivalencies calculator from Energy Star Performance Manager (ESPM) Emission Factors for natural gas was used for the calculations. No assumptions have been made regarding the buildings energy consumption as this information was not available for any of the buildings under investigation. The numbers reported in this section are solely the preventable GHG emissions based on the preventable energy loss calculations in the previous section 5.5.

The graph below illustrates the distribution of total preventable GHG emissions from the 38 buildings under consideration:



The following graph shows the distribution of preventable GHG emissions normalized to the total area of each of the 38 buildings:



For the remaining buildings, preventable GHG values are estimated per square metre of different building elements since no area measurements were performed on these buildings. Table 6 summarizes the average potential GHG savings per building element in each catchment zone.

Table 6: Total potential GHG savings:

Building Envelope Element	Potential GHG Savings ($kgCO_2e/m^2$)	
	Downtown	Kanata
Wall	0.0334	0.0380
Window	0.0327	0.0198
Door	0.0355	0.0370
Roof	0.0206	0.0214

6 Conclusions

The building envelope performance for both regions were generally performing below expectations. Out of all the buildings in the dataset, no building has any elements that meet building code (Ontario Building Code 2017) requirements. In general, buildings in Kanata perform slightly better than the buildings in Downtown Ottawa.

The average building envelope was observed to be performing 75% worse than current building code (based on the walls which are most of the envelope), all of which are significantly worse than current building code (Ontario Building Code 2017). It is notable that the Kanata buildings also were built typically between 1996 - 2002 while Downtown buildings were built between 1950 - 1975.

Every building observed had some instance of a building envelope issue. These issues included connections between different materials, thermal bridging, inconsistent or decay of insulation, heat loss through doors and frames, and moisture accumulation.

With regards to water ingress, a total of 122 buildings (64%) showed signs of water ingress. Water ingress issues were found to be more common in downtown buildings. In downtown Ottawa, moisture issues were found to be more common with increased building age.

Most building envelopes were performing below Ottawa's Energy Evolution Expectations (EEP). It was found that only 2 buildings had wall U-values within Ottawa's EEP and only 3 buildings had roof U-values within Ottawa's EEP.

Due to the limited scope of the activities and time, the data capture for every building were limited. In addition, several assumptions had to be made when calculating the U-values and overall thermal performance of the building envelopes. Lessons learned from this project include extending the time of data collection and capturing a higher volume of thermal images per building, inside temperatures per building, and spot surface temperature measurements.

Appendix A – Potential GHG Savings Per Envelope Element

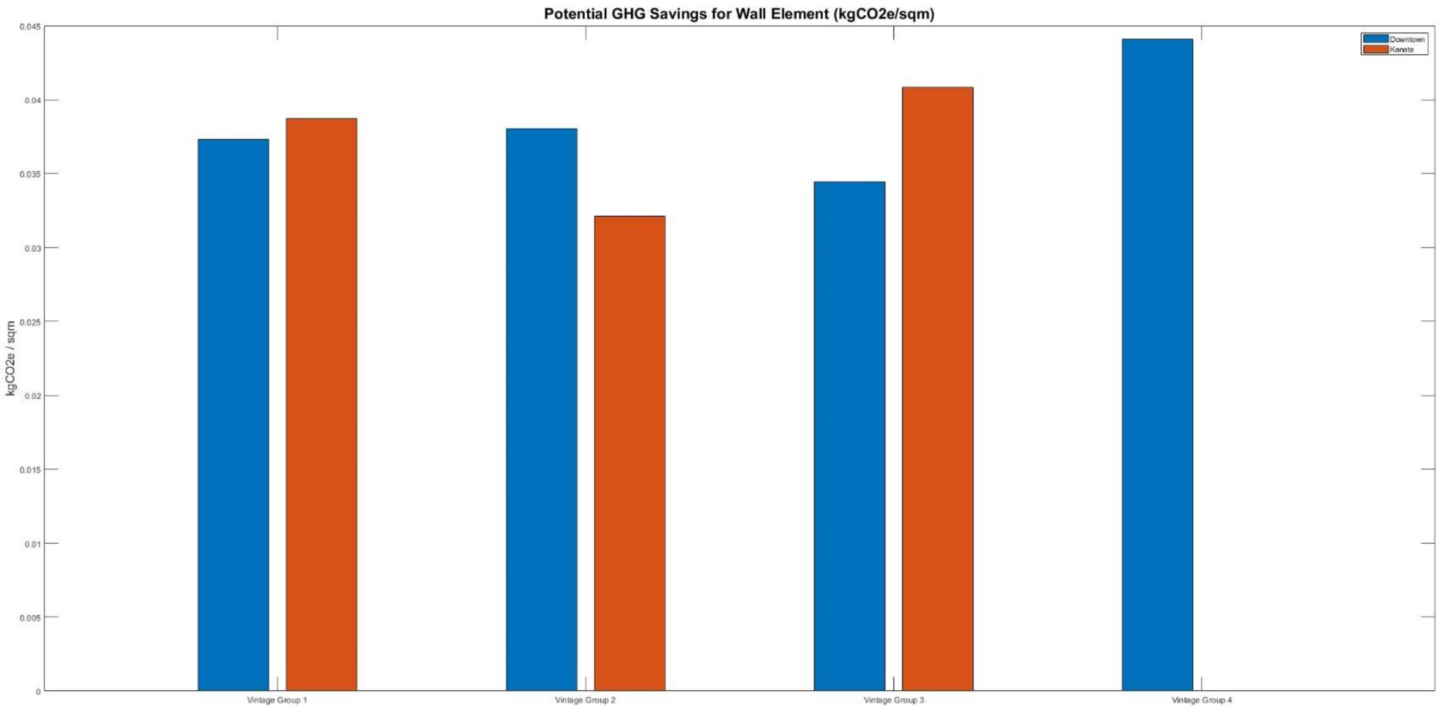


Figure 11: Potential GHG Savings for Wall Element

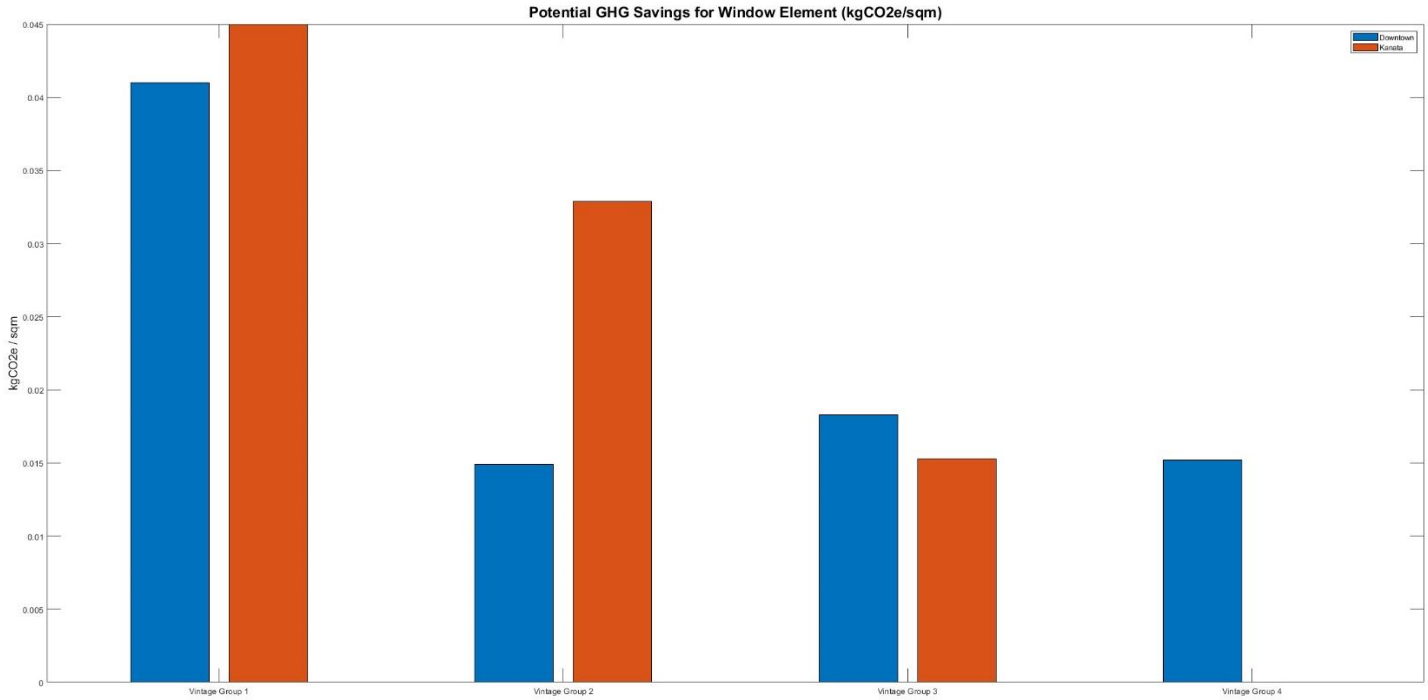


Figure 12: Potential GHG Savings for Window Element

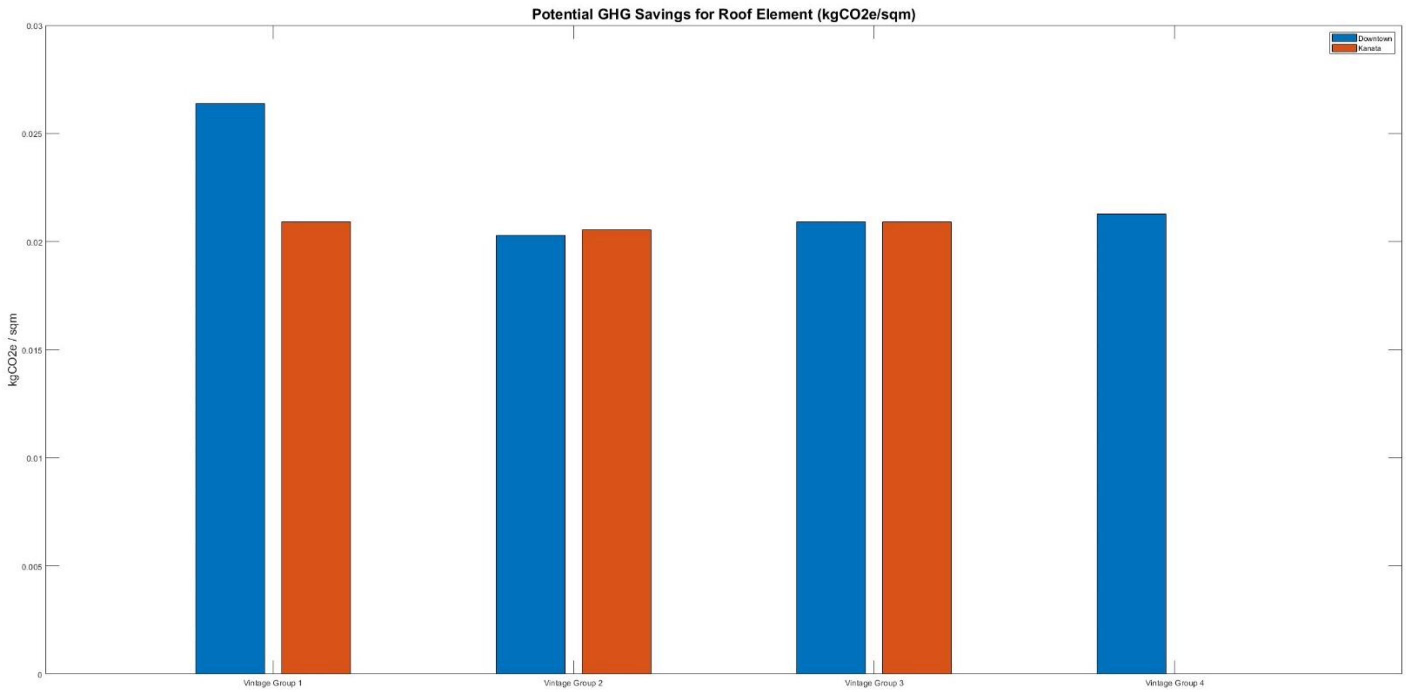


Figure 13: Potential GHG Savings for Window Element

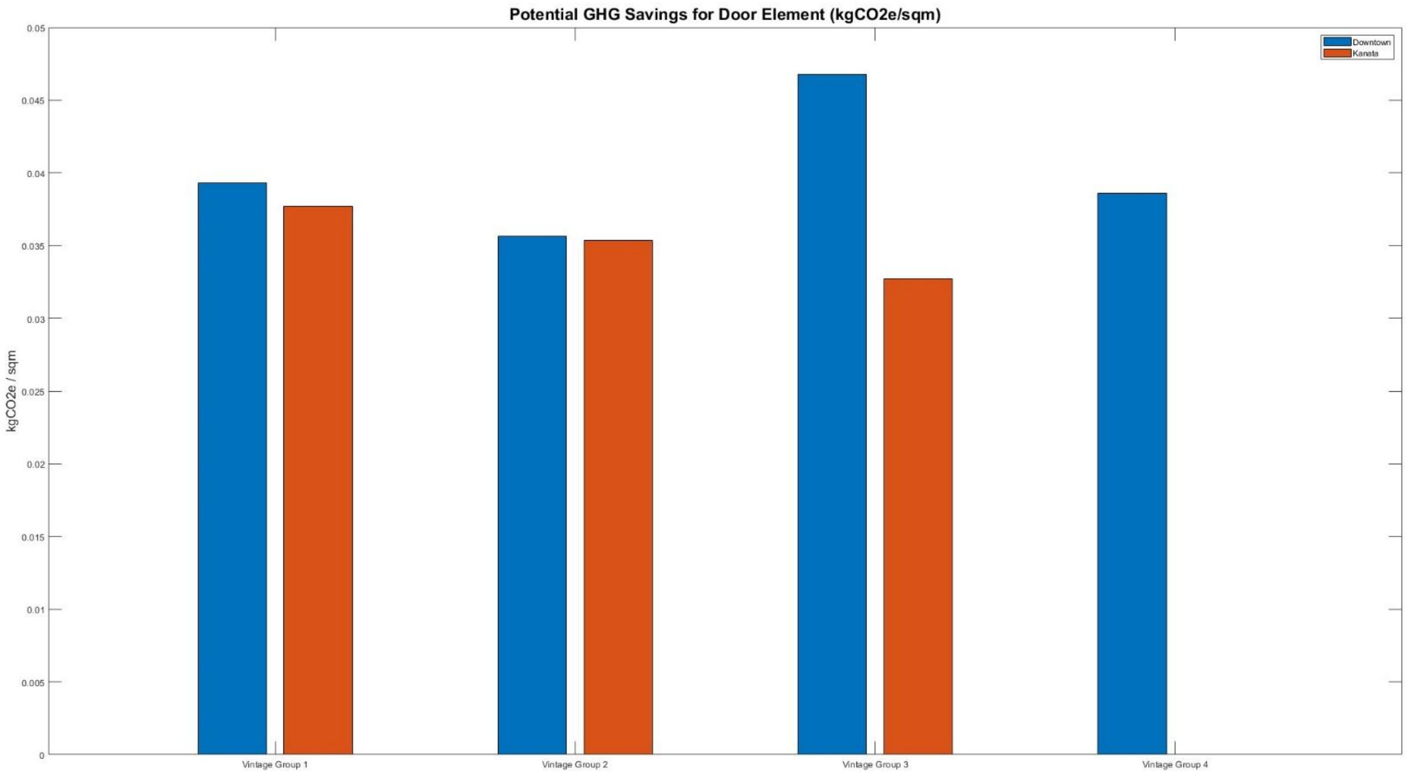
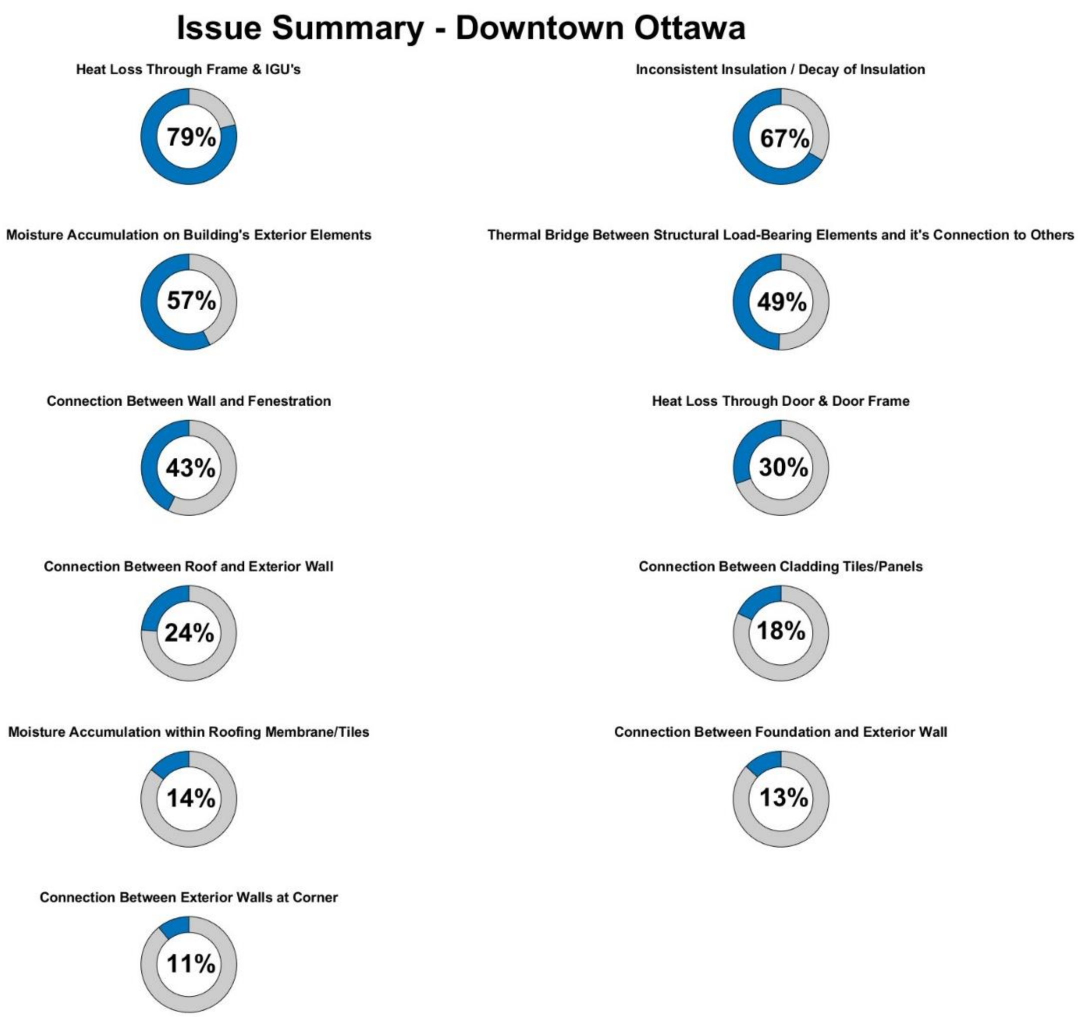


Figure 14: Potential GHG Savings for Door Element

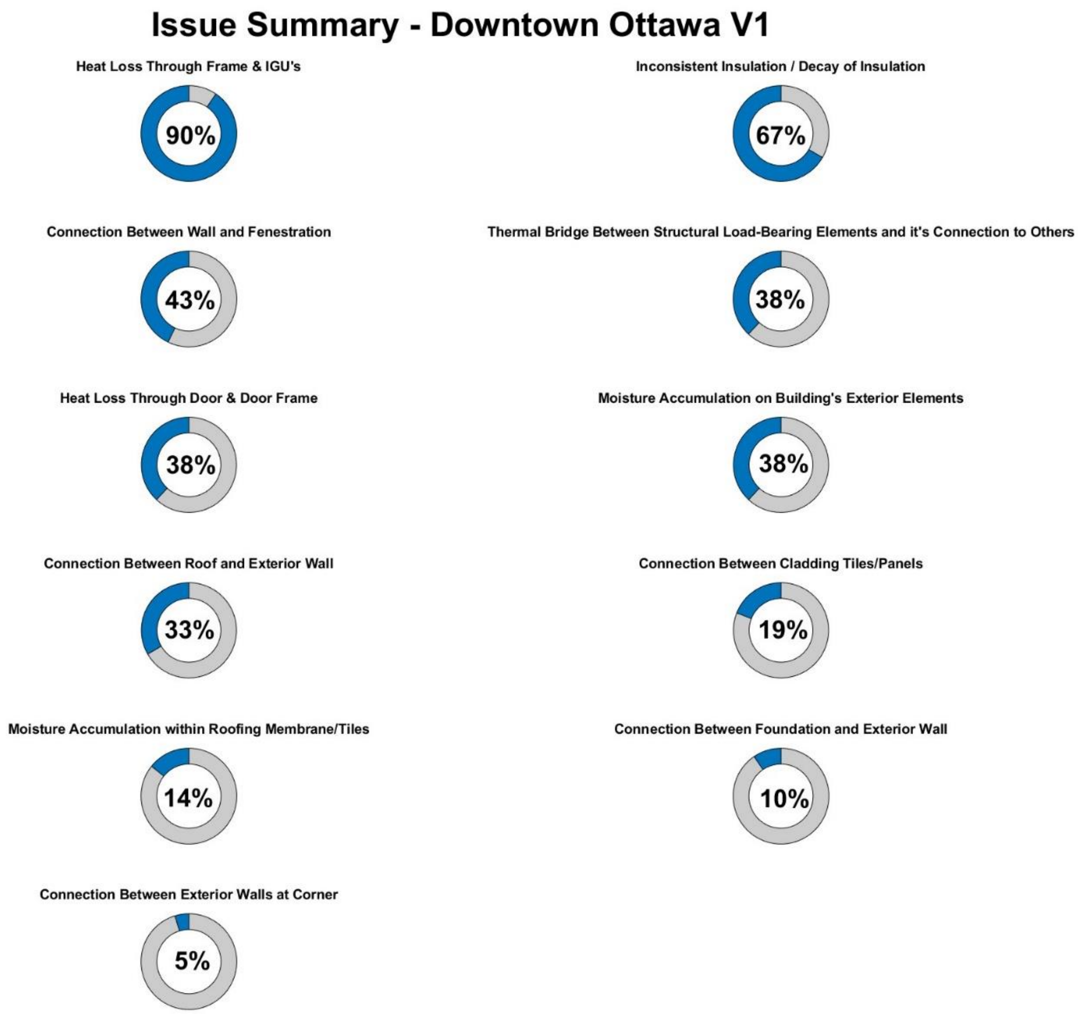
Appendix B – Issue Details by Catchment and Vintage Group



Issue Type	Number of Buildings Found	Number of Occurences
"Heat Loss Through Frame & IGU's"	109	199
"Inconsistent Insulation / Decay of Insulation"	92	176
"Moisture Accumulation on Building's Exterior Elements"	79	233
"Thermal Bridge Between Structural Load-Bearing Elements and it's Connection to Others"	68	114
"Connection Between Wall and Fenestration"	59	107
"Heat Loss Through Door & Door Frame"	42	51
"Connection Between Roof and Exterior Wall"	33	45
"Connection Between Cladding Tiles/Panels"	25	37
"Moisture Accumulation within Roofing Membrane/Tiles"	20	27
"Connection Between Foundation and Exterior Wall"	18	18
"Connection Between Exterior Walls at Corner"	15	17

Figure 15: Summary of Issues in Downtown Catchment

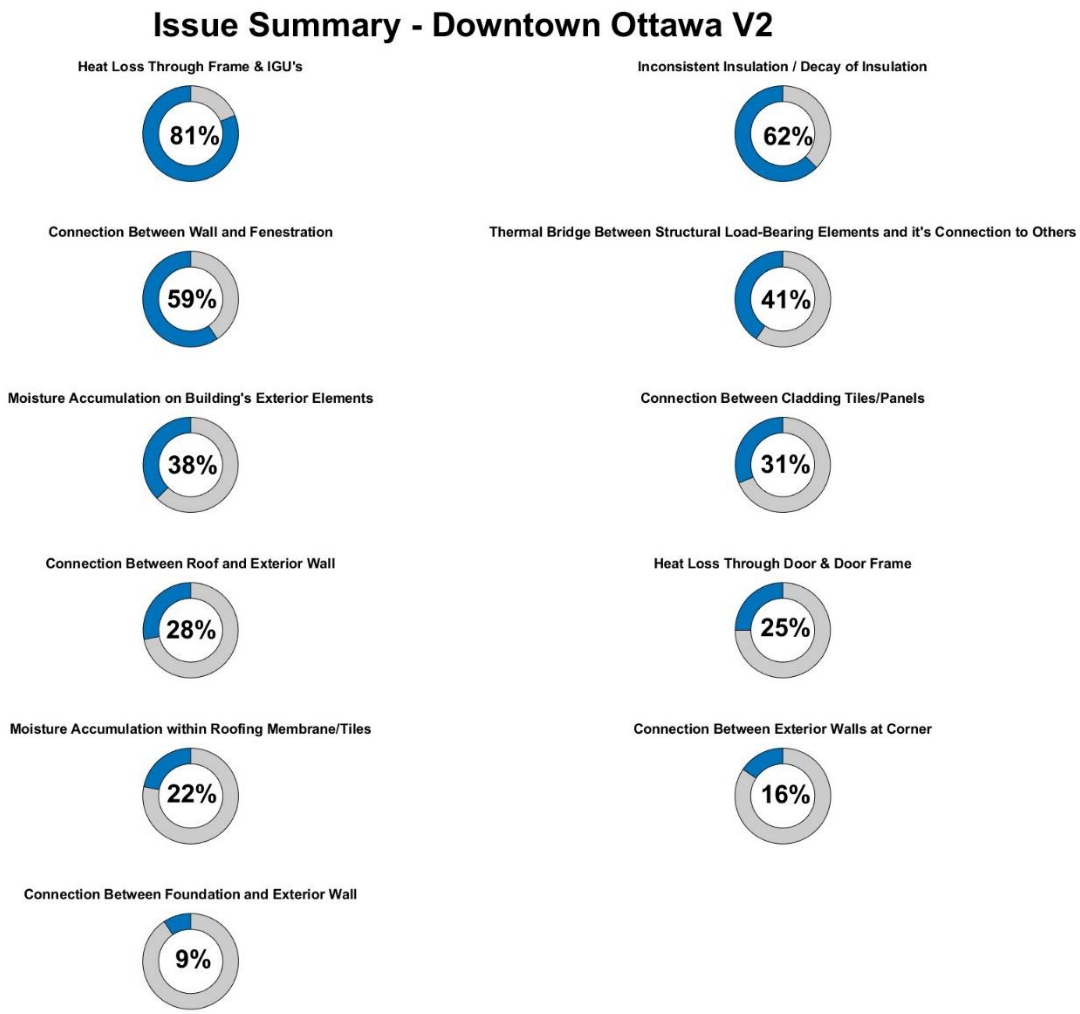
Issue Summary – Downtown Ottawa 2005-Present (Vintage 1)



Issue Type	Number of Buildings Found	Number of Occurences
"Heat Loss Through Frame & IGU's"	19	52
"Inconsistent Insulation / Decay of Insulation"	14	25
"Connection Between Wall and Fenestration"	9	13
"Thermal Bridge Between Structural Load-Bearing Elements and it's Connection to Others"	8	12
"Heat Loss Through Door & Door Frame"	8	10
"Moisture Accumulation on Building's Exterior Elements"	8	22
"Connection Between Roof and Exterior Wall"	7	11
"Connection Between Cladding Tiles/Panels"	4	9
"Moisture Accumulation within Roofing Membrane/Tiles"	3	4
"Connection Between Foundation and Exterior Wall"	2	2
"Connection Between Exterior Walls at Corner"	1	1

Figure 16: Summary of Issues in Downtown Catchment - Vintage Group 1

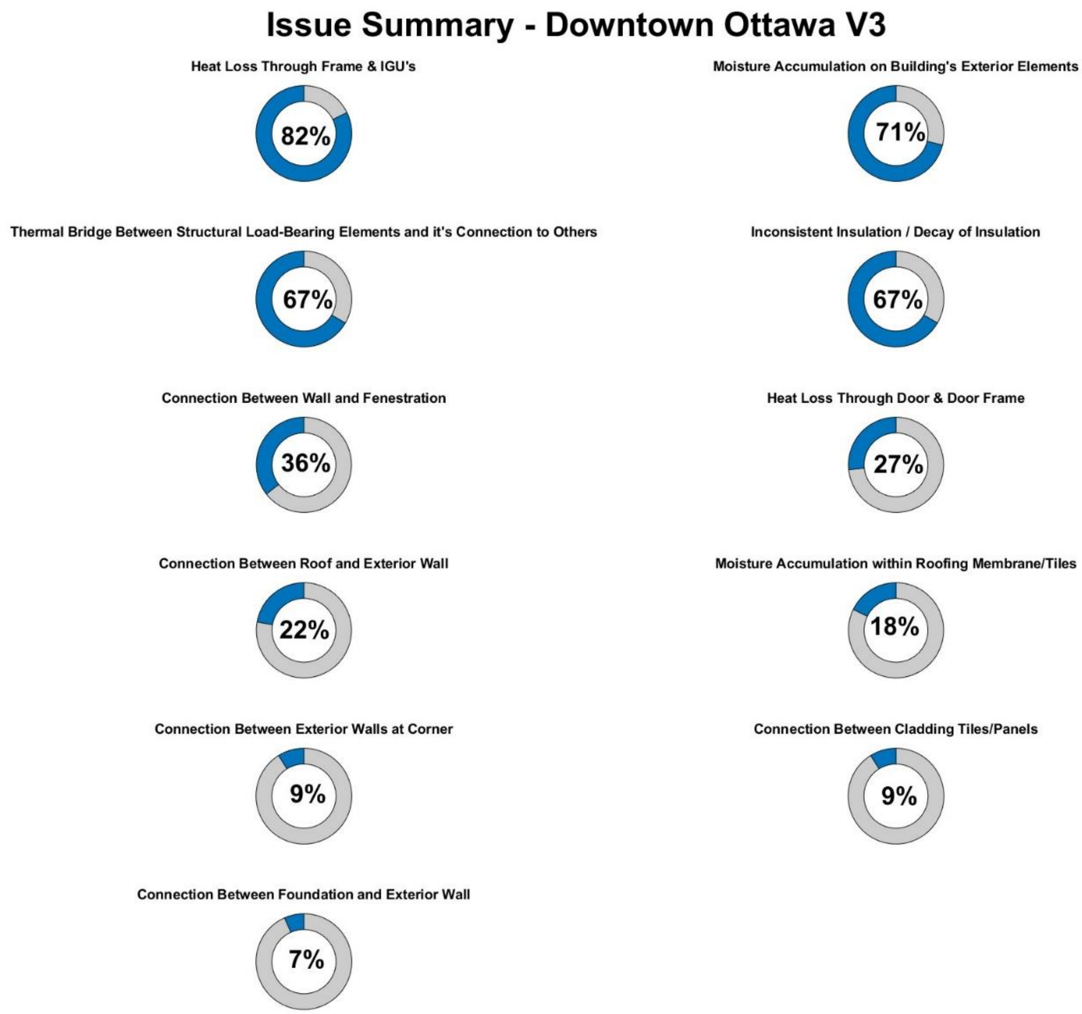
Issue Summary – Downtown Ottawa 1980-2004 (Vintage 2)



Issue Type	Number of Buildings Found	Number of Occurences
"Heat Loss Through Frame & IGU's"	26	45
"Inconsistent Insulation / Decay of Insulation"	20	30
"Connection Between Wall and Fenestration"	19	30
"Thermal Bridge Between Structural Load-Bearing Elements and it's Connection to Others"	13	27
"Moisture Accumulation on Building's Exterior Elements"	12	27
"Connection Between Cladding Tiles/Panels"	10	12
"Connection Between Roof and Exterior Wall"	9	13
"Heat Loss Through Door & Door Frame"	8	10
"Moisture Accumulation within Roofing Membrane/Tiles"	7	11
"Connection Between Exterior Walls at Corner"	5	5
"Connection Between Foundation and Exterior Wall"	3	3

Figure 17: Summary of Issues in Downtown Catchment - Vintage Group 2

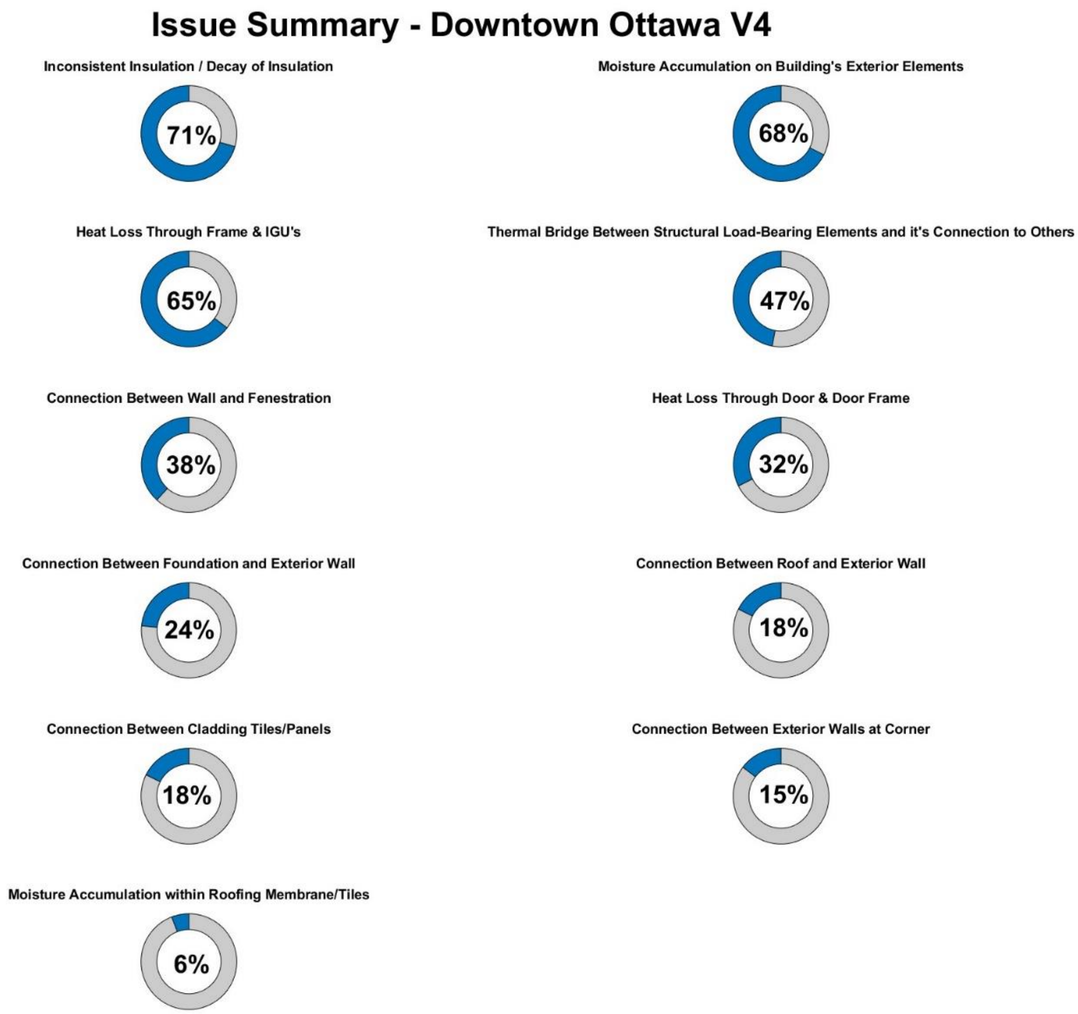
Issue Summary – Downtown Ottawa 1961-1979 (Vintage 3)



Issue Type	Number of Buildings Found	Number of Occurences
"Heat Loss Through Frame & IGU's"	37	60
"Moisture Accumulation on Building's Exterior Elements"	32	109
"Thermal Bridge Between Structural Load-Bearing Elements and it's Connection to Others"	30	53
"Inconsistent Insulation / Decay of Insulation"	30	63
"Connection Between Wall and Fenestration"	16	35
"Heat Loss Through Door & Door Frame"	12	14
"Connection Between Roof and Exterior Wall"	10	11
"Moisture Accumulation within Roofing Membrane/Tiles"	8	10
"Connection Between Exterior Walls at Corner"	4	4
"Connection Between Cladding Tiles/Panels"	4	6
"Connection Between Foundation and Exterior Wall"	3	3

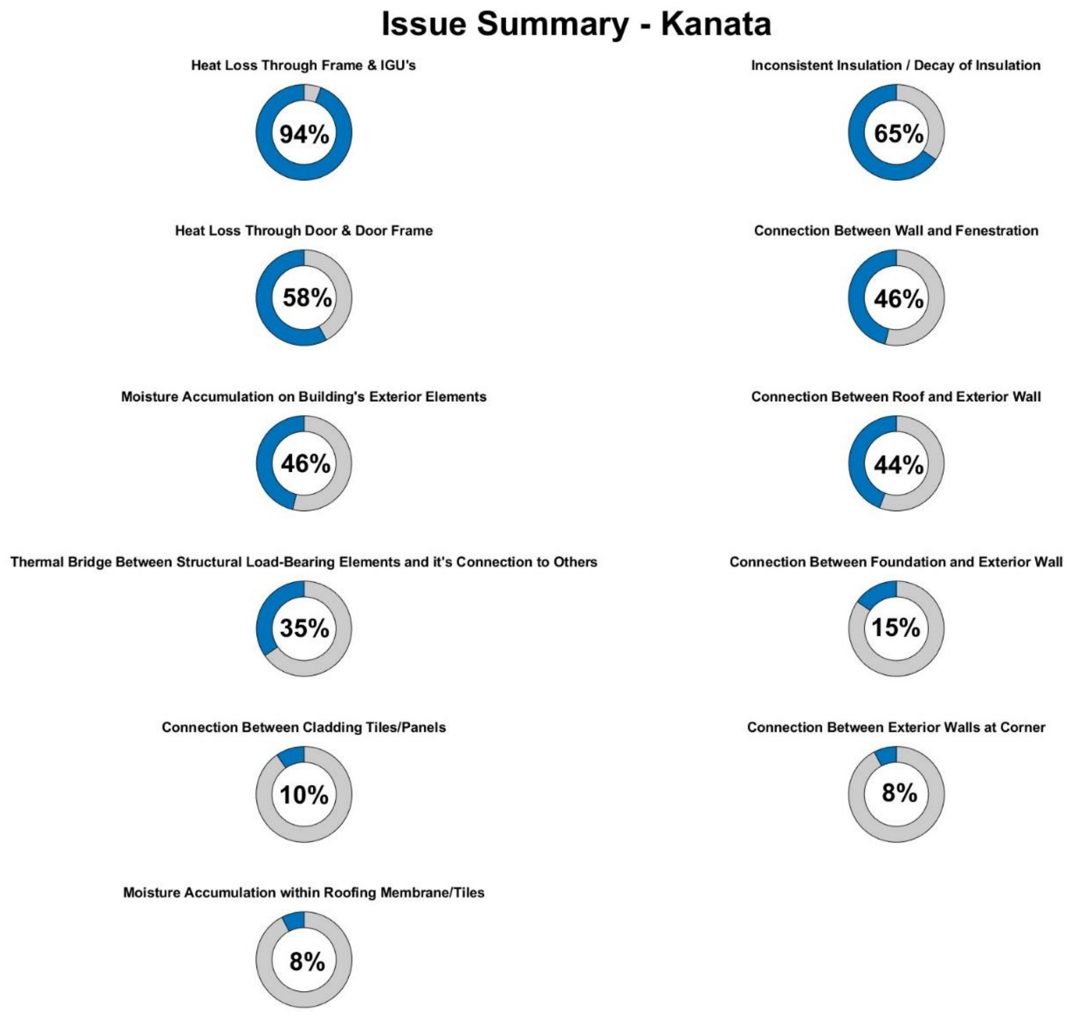
Figure 18: Summary of Issues in Downtown Catchment - Vintage Group 3

Issue Summary – Downtown Ottawa Before 1960 (Vintage 4)



Issue Type	Number of Buildings Found	Number of Occurences
"Inconsistent Insulation / Decay of Insulation"	24	45
"Moisture Accumulation on Building's Exterior Elements"	23	67
"Heat Loss Through Frame & IGU's"	22	35
"Thermal Bridge Between Structural Load-Bearing Elements and it's Connection to Others"	16	21
"Connection Between Wall and Fenestration"	13	25
"Heat Loss Through Door & Door Frame"	11	14
"Connection Between Foundation and Exterior Wall"	8	8
"Connection Between Roof and Exterior Wall"	6	9
"Connection Between Cladding Tiles/Panels"	6	9
"Connection Between Exterior Walls at Corner"	5	7
"Moisture Accumulation within Roofing Membrane/Tiles"	2	2

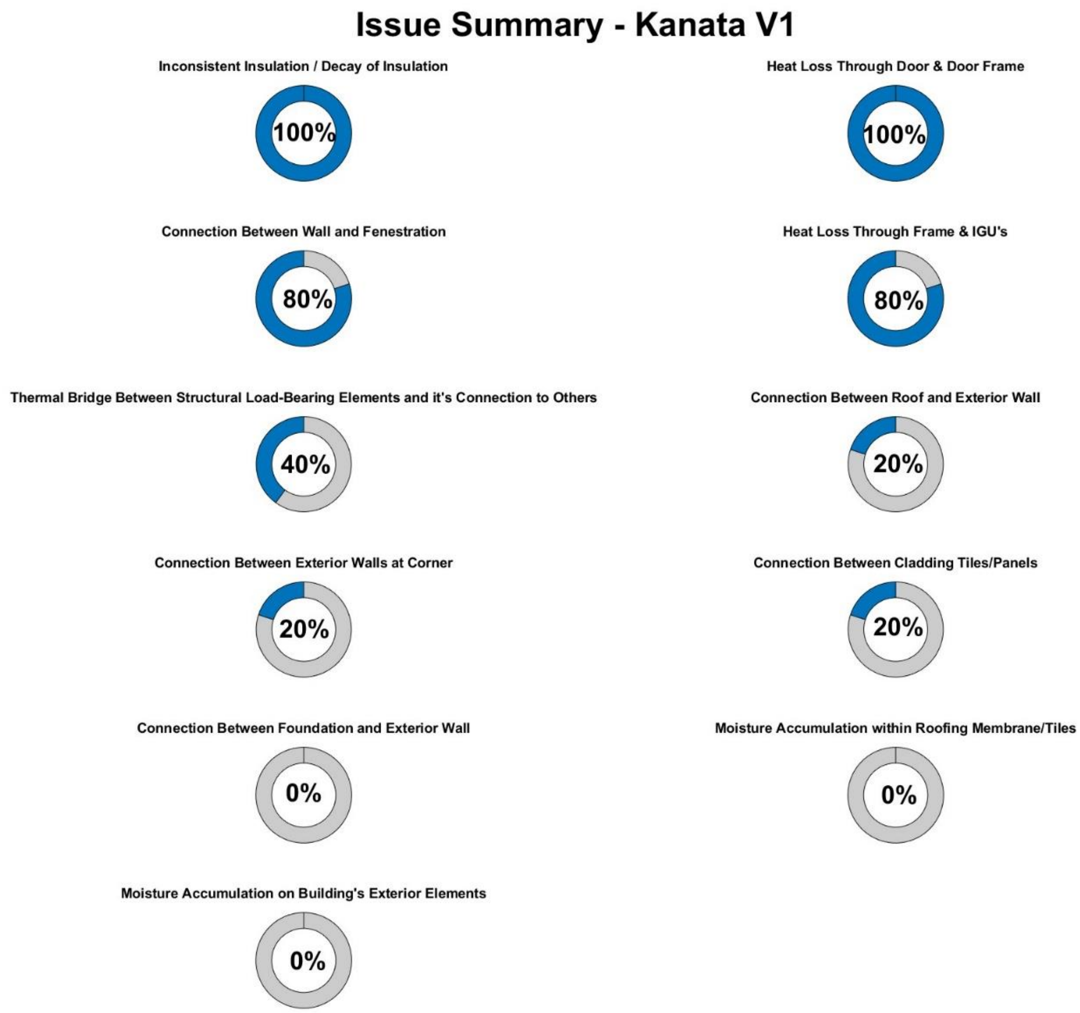
Figure 19: Summary of Issues in Downtown Catchment - Vintage Group 4



Issue Type	Number of Buildings Found	Number of Occurences
"Heat Loss Through Frame & IGU's"	49	121
"Inconsistent Insulation / Decay of Insulation"	34	90
"Heat Loss Through Door & Door Frame"	30	39
"Connection Between Wall and Fenestration"	24	30
"Moisture Accumulation on Building's Exterior Elements"	24	43
"Connection Between Roof and Exterior Wall"	23	25
"Thermal Bridge Between Structural Load-Bearing Elements and it's Connection to Others"	18	30
"Connection Between Foundation and Exterior Wall"	8	8
"Connection Between Cladding Tiles/Panels"	5	11
"Connection Between Exterior Walls at Corner"	4	4
"Moisture Accumulation within Roofing Membrane/Tiles"	4	4

Figure 20: Summary of Issues in Kanata Catchment

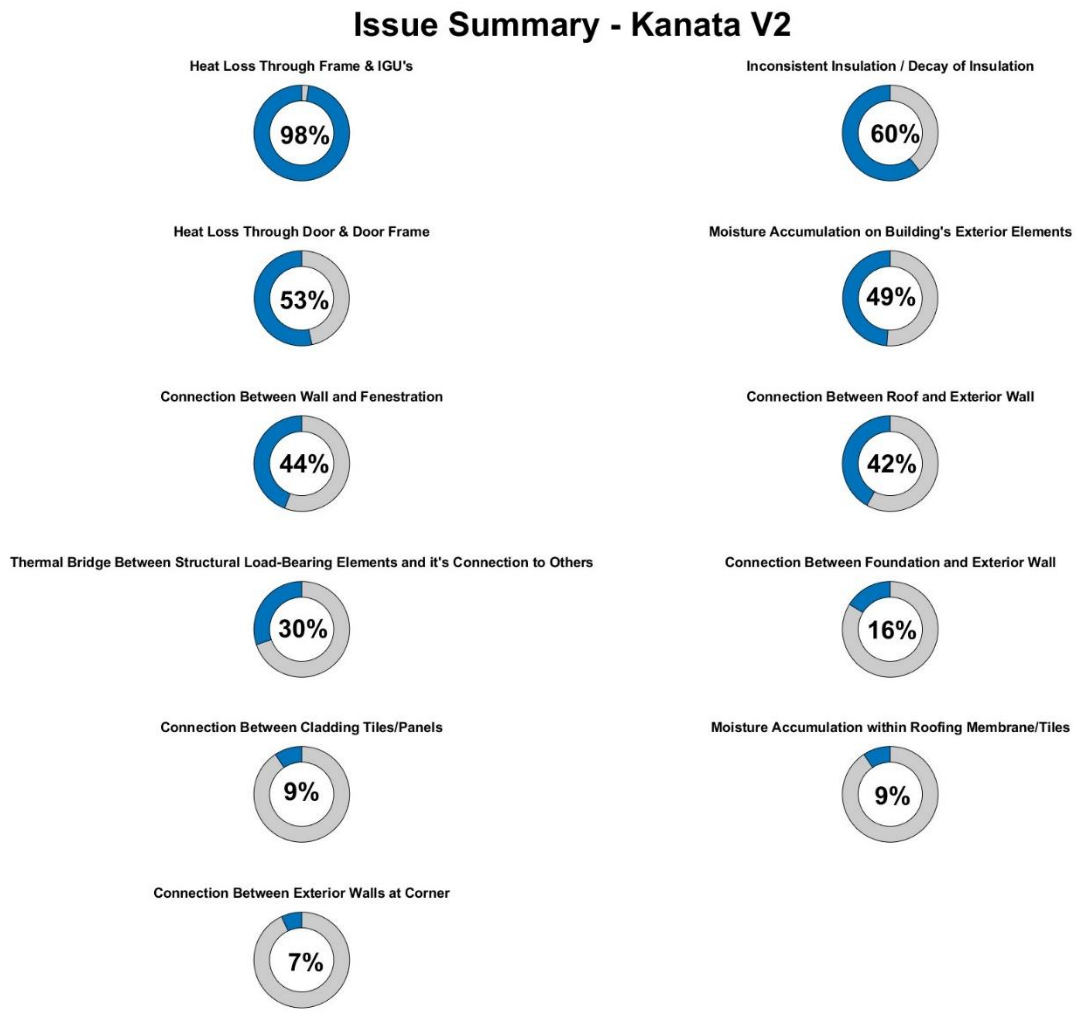
Issue Summary – Kanata 2005-Present (Vintage 1)



Issue Type	Number of Buildings Found	Number of Occurences
"Inconsistent Insulation / Decay of Insulation"	5	18
"Heat Loss Through Door & Door Frame"	5	9
"Connection Between Wall and Fenestration"	4	5
"Heat Loss Through Frame & IGU's"	4	10
"Thermal Bridge Between Structural Load-Bearing Elements and it's Connection to Others"	2	10
"Connection Between Roof and Exterior Wall"	1	1
"Connection Between Exterior Walls at Corner"	1	1
"Connection Between Cladding Tiles/Panels"	1	3
"Connection Between Foundation and Exterior Wall"	0	0
"Moisture Accumulation within Roofing Membrane/Tiles"	0	0
"Moisture Accumulation on Building's Exterior Elements"	0	0

Figure 21: Summary of Issues in Kanata Catchment – Vintage Group 1

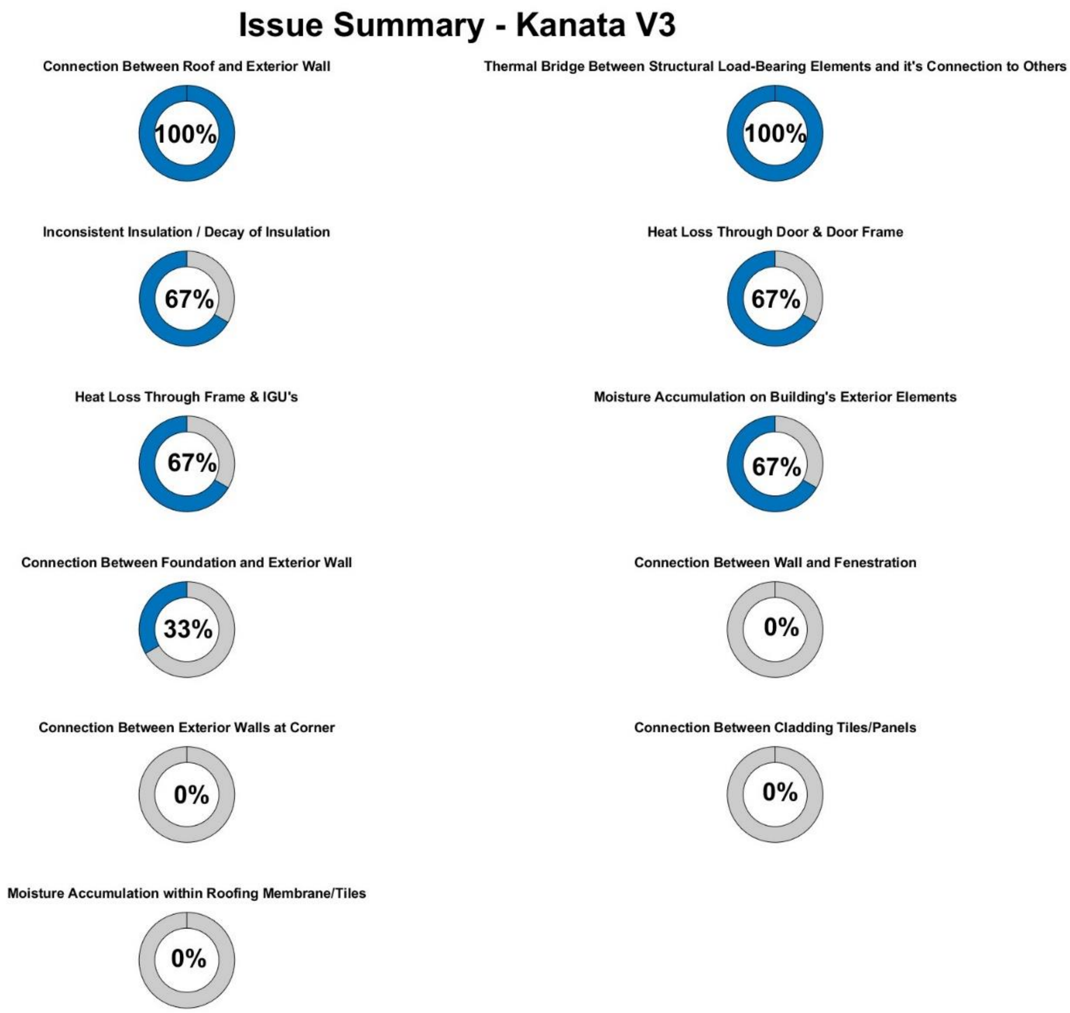
Issue Summary – Kanata 1980-2004 (Vintage 2)



Issue Type	Number of Buildings Found	Number of Occurences
"Heat Loss Through Frame & IGU's"	42	106
"Inconsistent Insulation / Decay of Insulation"	26	62
"Heat Loss Through Door & Door Frame"	23	26
"Moisture Accumulation on Building's Exterior Elements"	21	38
"Connection Between Wall and Fenestration"	19	24
"Connection Between Roof and Exterior Wall"	18	20
"Thermal Bridge Between Structural Load-Bearing Elements and it's Connection to Others"	13	17
"Connection Between Foundation and Exterior Wall"	7	7
"Connection Between Cladding Tiles/Panels"	4	8
"Moisture Accumulation within Roofing Membrane/Tiles"	4	4
"Connection Between Exterior Walls at Corner"	3	3

Figure 22: Summary of Issues in Kanata Catchment – Vintage Group 2

Issue Summary – Kanata 1961-1979 (Vintage 3)



Issue Type	Number of Buildings Found	Number of Occurences
"Connection Between Roof and Exterior Wall"	3	3
"Thermal Bridge Between Structural Load-Bearing Elements and it's Connection to Others"	3	3
"Inconsistent Insulation / Decay of Insulation"	2	7
"Heat Loss Through Door & Door Frame"	2	4
"Heat Loss Through Frame & IGU's"	2	2
"Moisture Accumulation on Building's Exterior Elements"	2	4
"Connection Between Foundation and Exterior Wall"	1	1
"Connection Between Wall and Fenestration"	0	0
"Connection Between Exterior Walls at Corner"	0	0
"Connection Between Cladding Tiles/Panels"	0	0
"Moisture Accumulation within Roofing Membrane/Tiles"	0	0

Figure 23: Summary of Issues in Kanata Catchment – Vintage Group 3

Appendix C – U Values Details

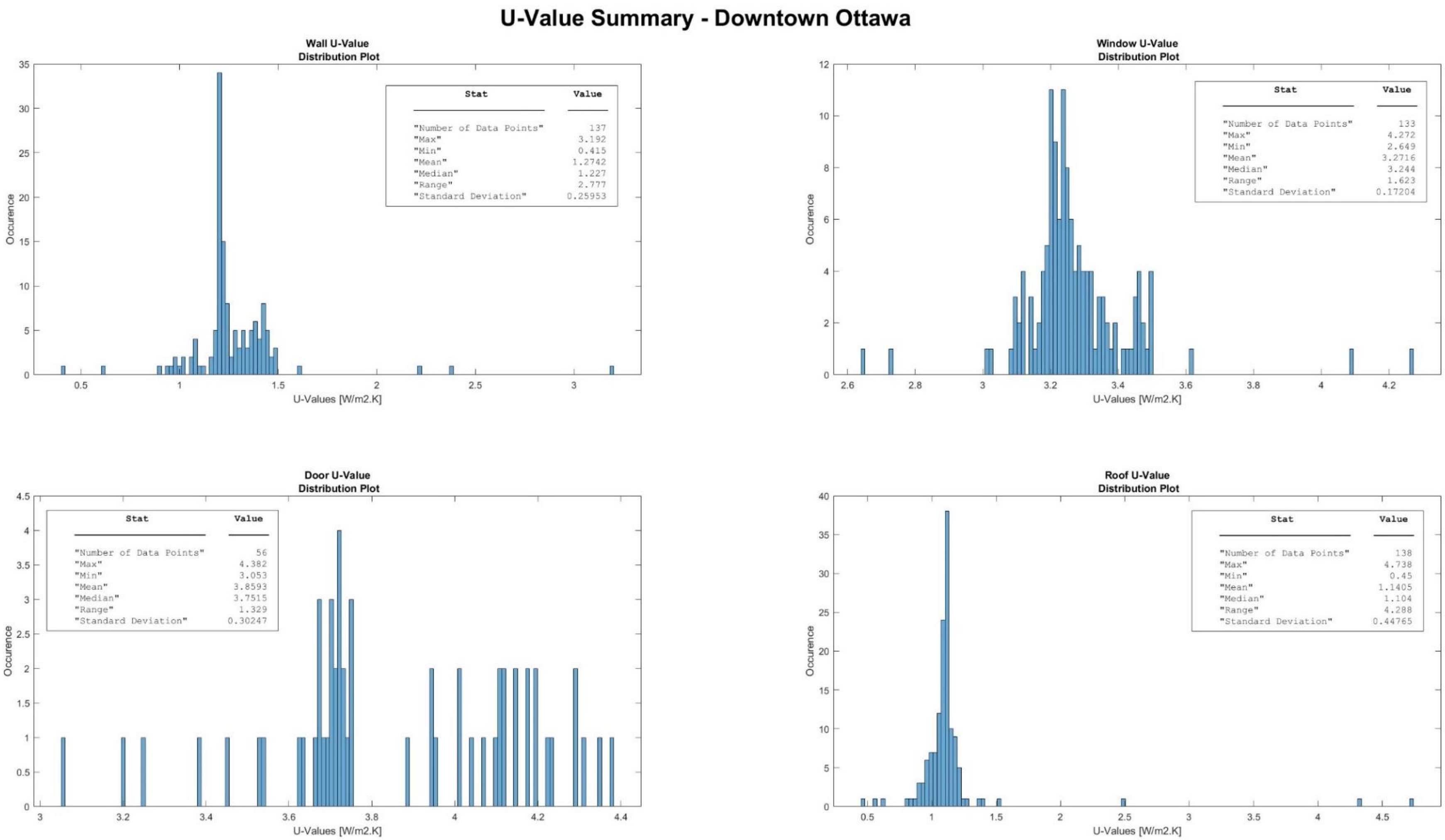


Figure 24: Summary of U-Values in Downtown Ottawa Buildings

Figure 25: Summary of U-Values in Downtown Ottawa Buildings – Vintage Group 1

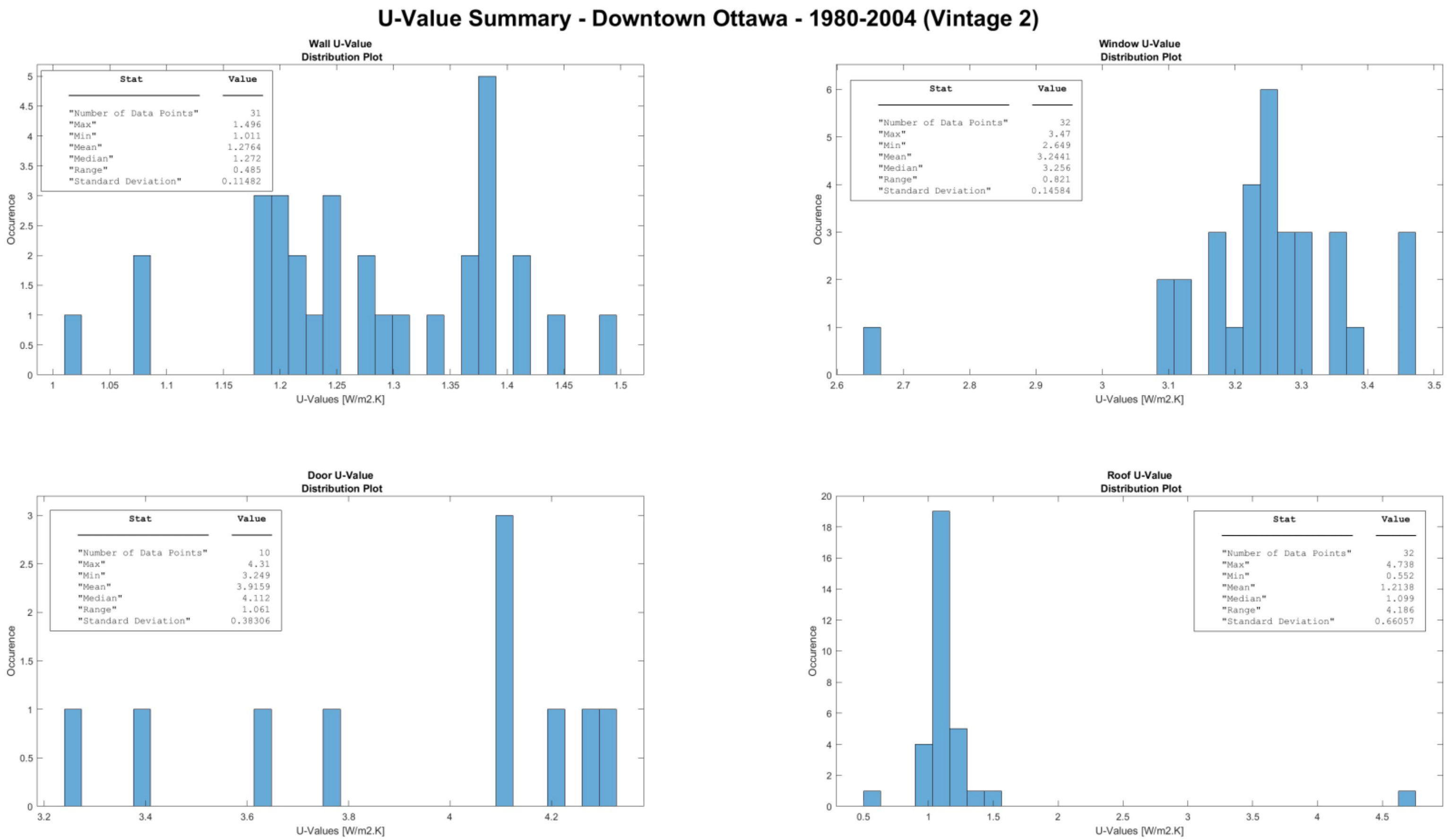


Figure 26: Summary of U-Values in Downtown Ottawa Buildings – Vintage Group 2

Figure 27: Summary of U-Values in Downtown Ottawa Buildings – Vintage Group 3

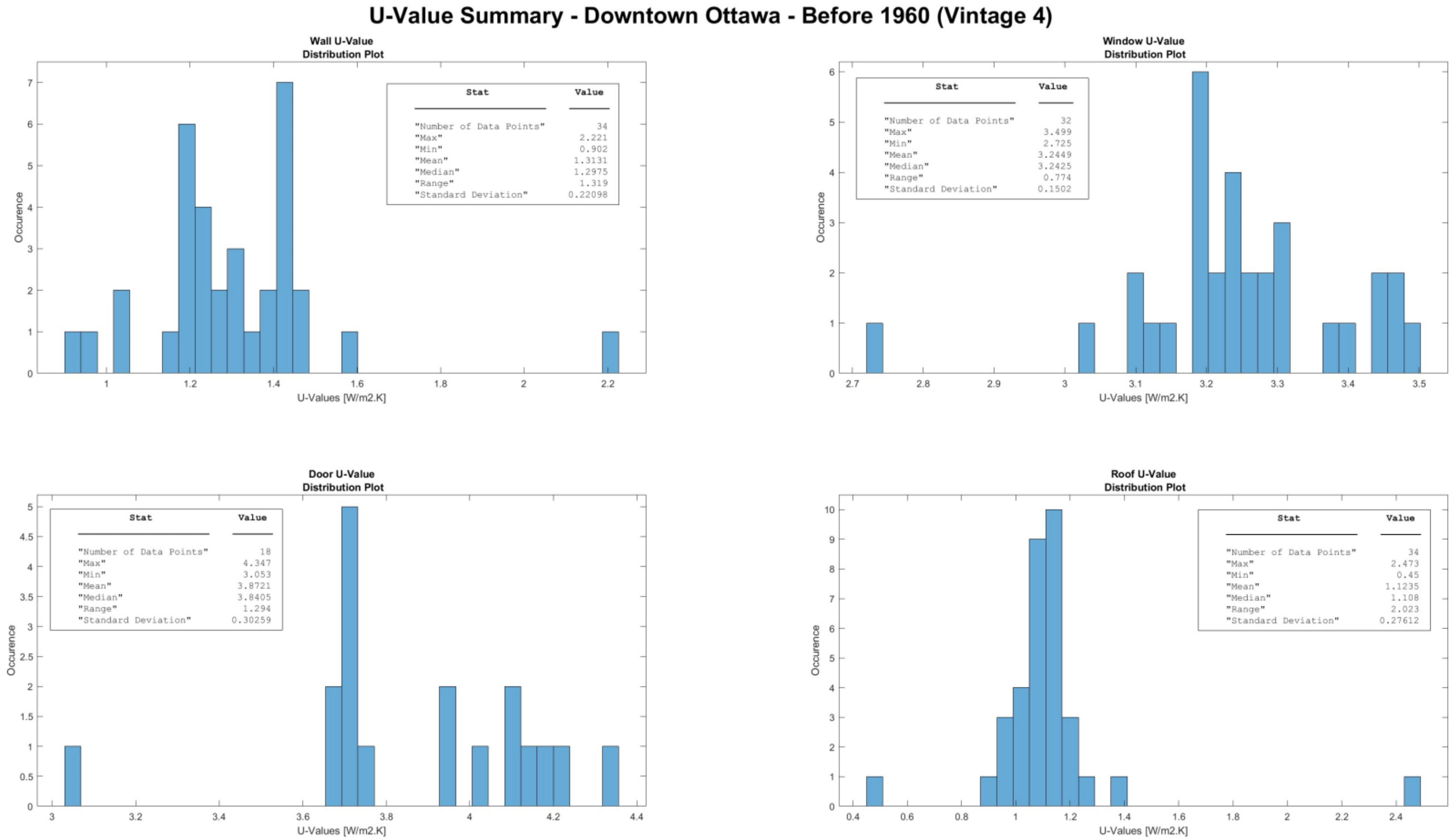


Figure 28: Summary of U-Values in Downtown Ottawa Buildings – Vintage Group 4

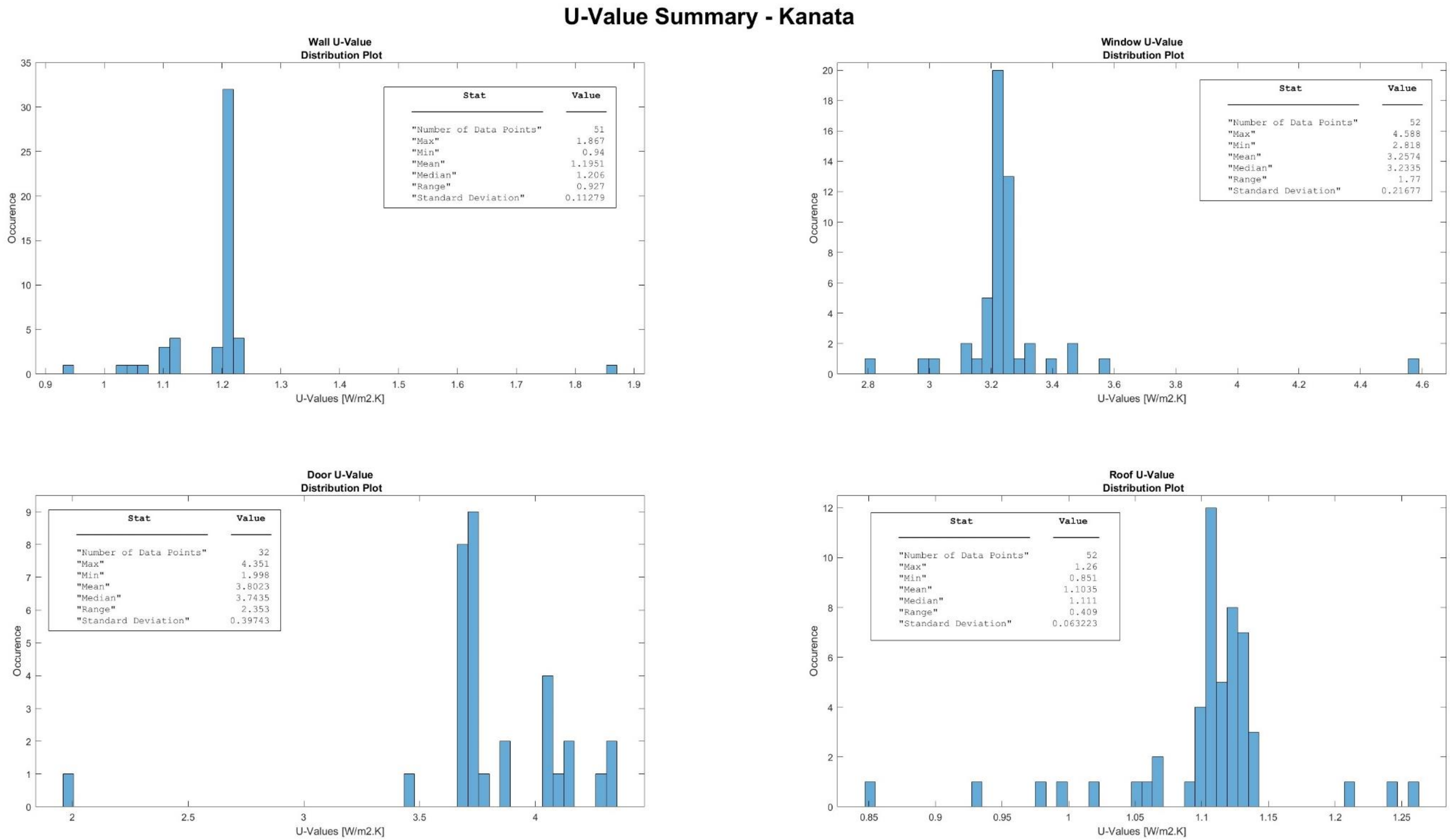


Figure 29: Summary of U-Values in Kanata Buildings

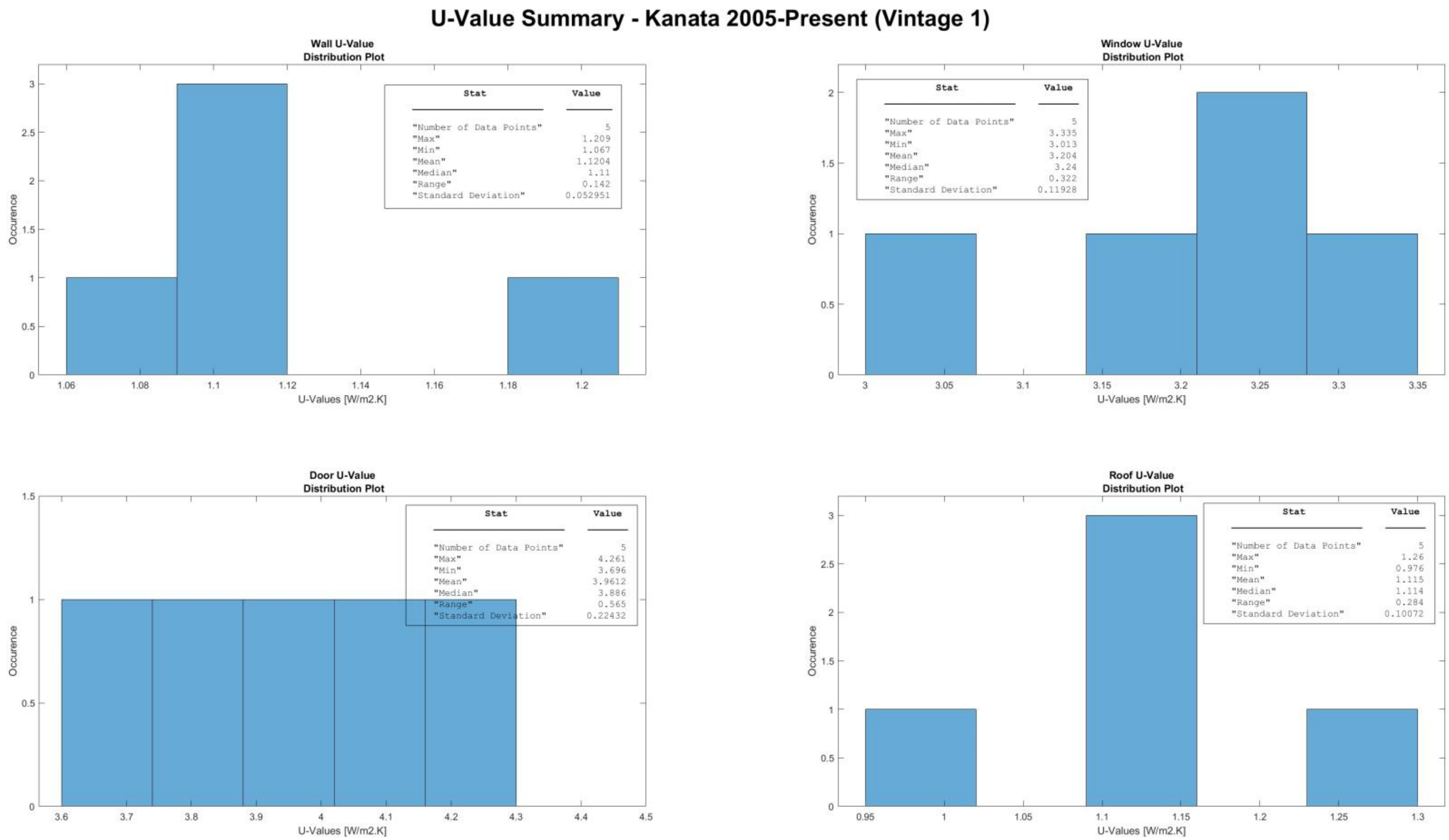


Figure 30: Summary of U-Values in Kanata Buildings – Vintage Group 1

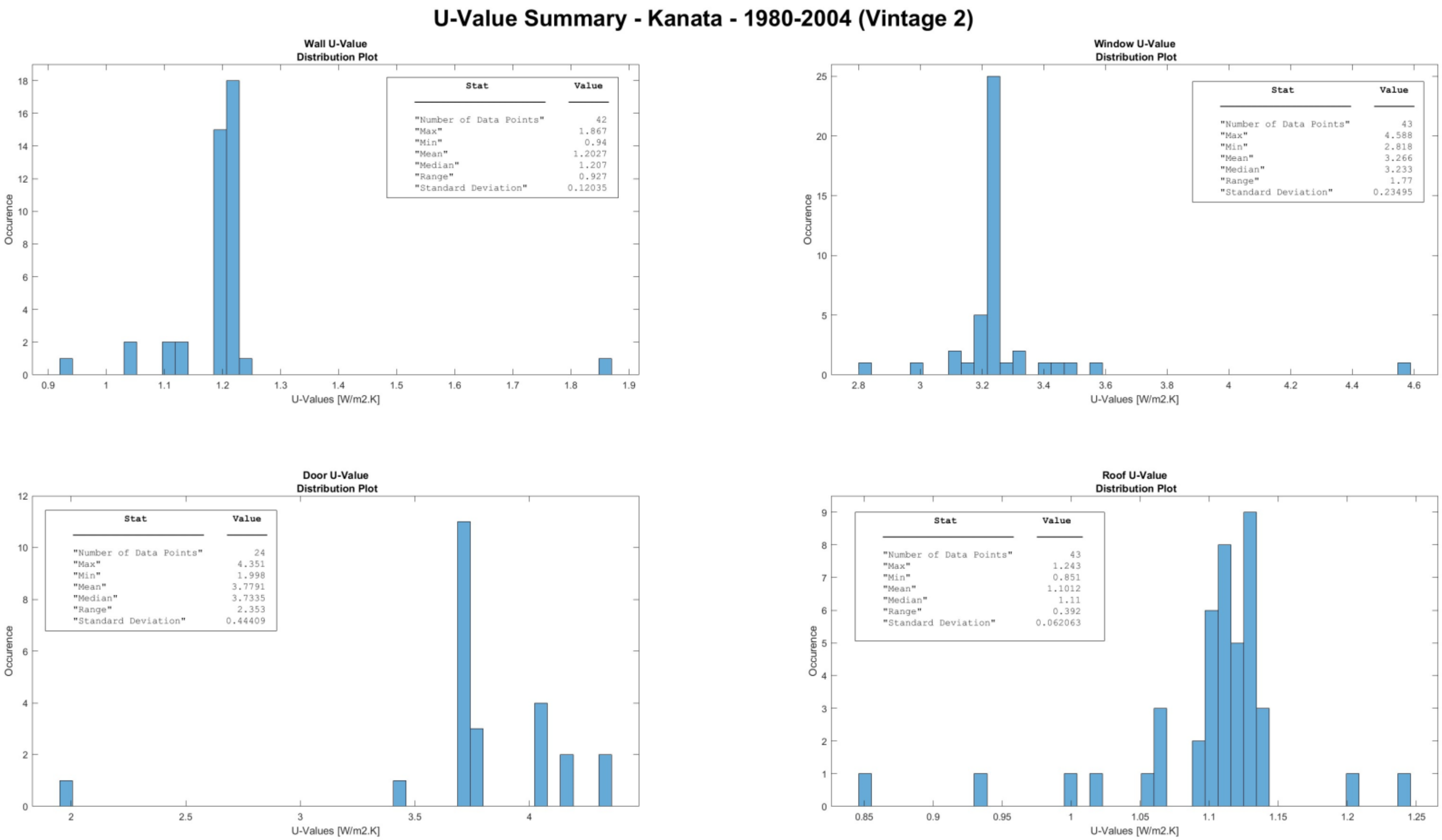


Figure 31: Summary of U-Values in Kanata Buildings – Vintage Group 2

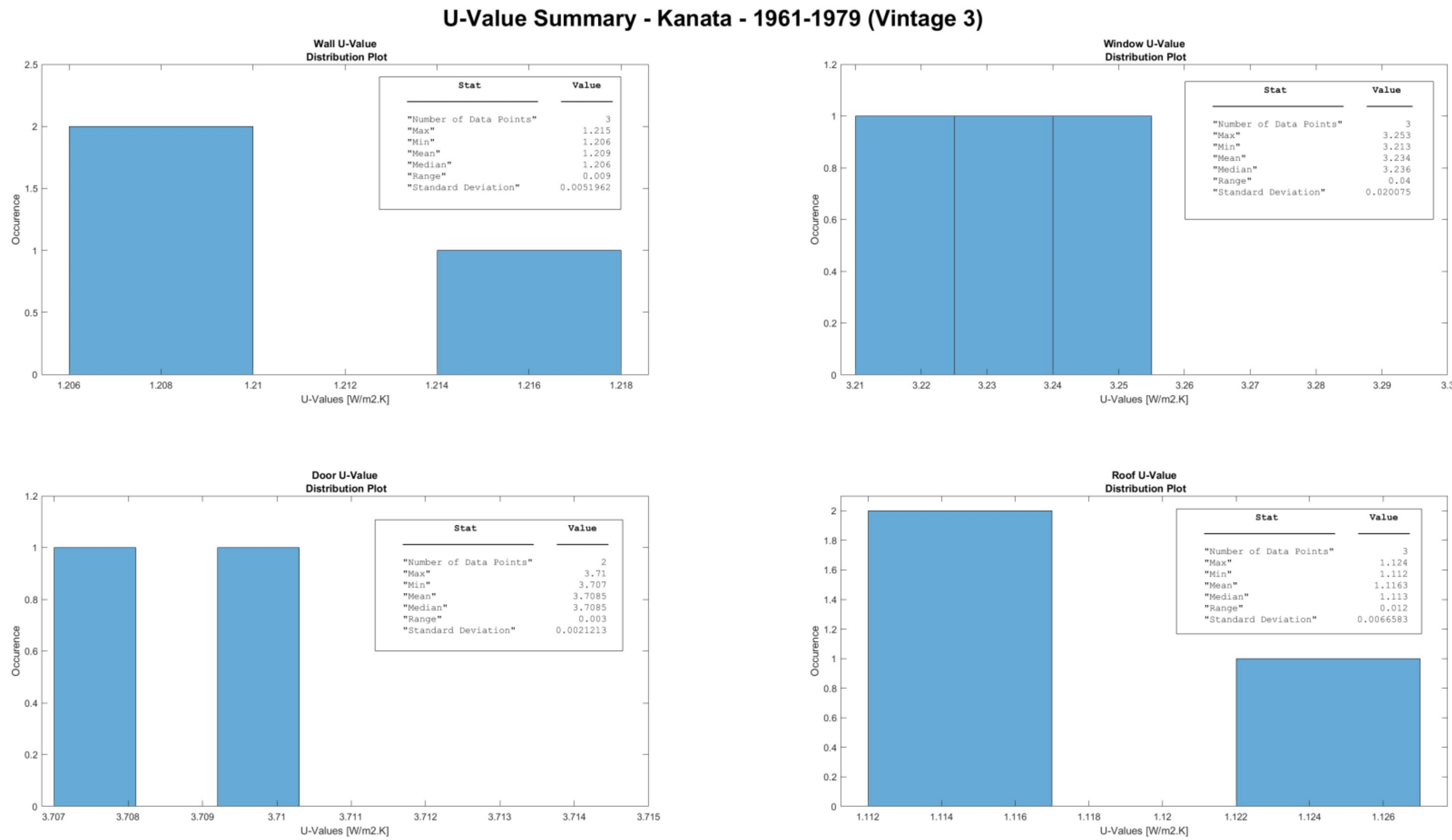


Figure 32: Summary of U-Values in Kanata Buildings – Vintage Group 3