University of Victoria

Student Union Building Energy Review

March 11, 2020
Grant Sim

University of Victoria

1. Executive Summary

A review of the energy use of the Student Union Building (SUB) was completed in March, 2019. The most recent three years (2017-2019) indicate that absolute energy consumption has decreased year-over-year. The three primary sources of energy include electricity, natural gas, and district energy. The latter, used to provide space heating, has the most significant correlation with outdoor air temperature. Normalization was performed on the district energy consumption using a ten year average of heating degree days. The results determined that the relative district energy consumption has decreased in the past three years after accounting for weather. There is a concern with the calibration of the energy meters on the district loop and the values reported have an unquantified amount of inaccuracy.

The SUB Energy Use Intensity (EUI) was compared with statistics from the Building Owners and Managers Association (BOMA) and no concerning abnormalities were found. The differences between occupant patterns must be considered when comparisons between the BOMA office statistics and the SUB are made. A ranking of UVic campus building EUIs indicates that the SUB EUI of 384 kWh/m^2 is below the average across all UVic buildings of 428 kWh/m^2, however, caution must be exercised when comparing the SUB to other buildings due to occupancy differences.

Avalon Energy Management conducted a study of the Student Union Building in 2012. Many of the recommendations have previously been implemented, but a few remain, including air sealing, lighting upgrades, and a heat pump from AH-7 to the domestic hot water tank. Three additional opportunities were reviewed including a CO_2 sensor for the Vertigo area, heat pump replacement of AH-1, and installation of high-performance windows. However, the payback periods for these options are excessive at 39, 167 and 133 years, respectively.

2. Scope

The intent of this report was to conduct an overview of the energy use of the Student Union Building (SUB) to identify any high yield or low payback opportunities. The following steps were completed:

- Reviewed building history, including:
  - Previous energy studies
  - Construction drawings
- Compiled previous three year energy use
- Reviewed current DDC information, including:
  - Set points
  - Schedules
  - CO_2 monitors
- Consulted with maintenance personnel

In addition to identifying low cost measures, a specific request to provide an estimate for the installation of high performance windows was completed.

3. Building and System Description

3.1 General Building Description

The SUB (Building #117) was one of the first permanent structures constructed on campus in 1963, seen below in Figure 1.

Figure 1: SUB Original Construction Photo c. 1963

Major renovations/additions were completed in 1974 and 1996, and the complex currently contains a mixture of administration, services, food outlets, and retail. The building has a total floor area of 69,966 ft^2 (6,500 m^2) and consists of three main structural systems, as shown in Table 1, next page.

Table 1: Structural Characteristics of SUB

Date of Construction	Structure Type
1963	Reinforced concrete
1974	Steel floor and roof assemblies on solid masonry walls
1996	Predominantly steel framed structure; portions framed with steel on steel roof assemblies on load bearing masonry walls.

The current window systems are comprised of three different combinations:

1. Tubular aluminum windows with insulating glass
2. Extruded aluminum windows with insulating glass
3. Aluminum windows with non-insulating glass

3.2 Mechanical Systems Description

Space heating and domestic hot water (DHW) for the complex is provided through heat exchange from the district energy loop. Furthermore, there is electric standby/backup for the DHW.

A total of 14 air handling units (AHUs), ranging in capacity from approximately 1500 cfm to 9300 cfm, comprise the overall building air systems (see Appendix 1 for layout). In addition, there are numerous point exhaust fans. Cooling is provided to multiple areas with separate direct expansion (DX) systems.

Optimal start programming has been implemented through the building direct digital control (DDC) to help achieve energy savings and occupant comfort during morning shift starts. Figure 2, below, shows a typical AHU DDC graphic. The optimal start programming is currently being monitored and optimized.

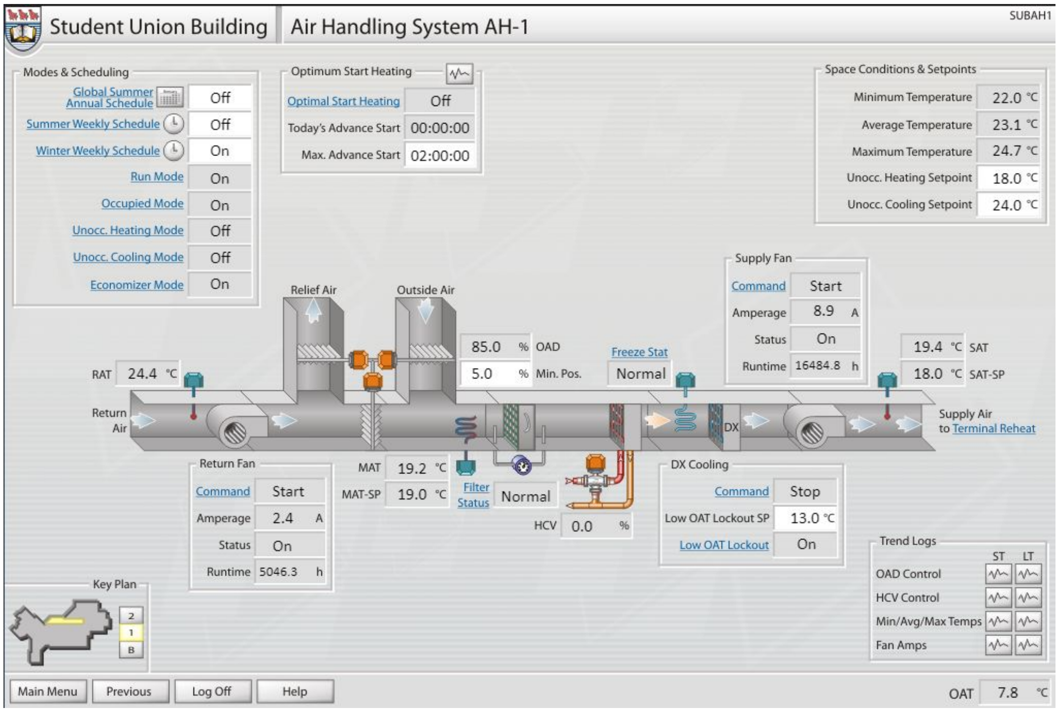

Figure 2: DDC Graphic of AH-1 (typical of other systems)

3.3 Lighting Systems Description

The SUB lighting systems consist of the following:

- Interior
  - T8 lamps and electronic ballasts
    - 600 x 1200 mm & 300 x 1200 mm recessed fluorescent fixtures
    - 600 x 600 mm & 300 x 1200 mm surface mount fluorescent fixtures
    - 1200 mm fluorescent strip-lights
  - Stage lighting – Room A134
- Exterior
  - Surface mounted high-intensity discharge
  - Surface mounted mini-fluorescent
  - Recessed mini-fluorescent

3.4 Building Occupancy and Use

The fourteen AHUs have varied operation schedules to accommodate different occupancy patterns and “free cooling” in the summer. Upon review, a couple of minor items were identified and fixed. The current air handling equipment schedule is shown below in Table 2.

Table 2: Current SUB Air Systems Schedule of Operation

Unit	Area		Mon	Tue	Wed	Thu	Fri	Sat	Sun
AHU-1	Retail	Summer	06:00 → 20:00	06:00 → 20:00	06:00 → 20:00	06:00 → 20:00	06:00 → 20:00	06:00 → 20:00	06:00 → 20:00
		Winter	06:30 → 20:00	06:30 → 20:00	06:30 → 20:00	06:30 → 20:00	06:30 → 20:00	08:00 → 20:00	08:00 → 18:30
AHU-2	Multi-purpose Area	Summer	06:00 → 21:00	06:00 → 21:00	06:00 → 21:00	06:00 → 21:00	06:00 → 21:00	08:00 → 21:00	08:00 → 21:00
		Winter	07:00 → 20:00	07:00 → 20:00	07:00 → 20:00	07:00 → 20:00	07:00 → 20:00	07:00 → 20:00	07:00 → 20:00
AHU-3	Entrance Lounge	Summer	10:00 → 20:00	10:00 → 20:00	10:00 → 20:00	10:00 → 20:00	10:00 → 20:00	10:00 → 20:00	10:00 → 20:00
		Winter	10:00 → 20:00	10:00 → 20:00	10:00 → 20:00	10:00 → 20:00	10:00 → 20:00	10:00 → 18:00	07:00 → 18:00
AHU-4	Pub	Summer	04:00 → 09:00 11:30 → 23:59	04:00 → 09:00 11:30 → 23:59	04:00 → 09:00 11:30 → 23:59	04:00 → 09:00 11:30 → 23:59	04:00 → 09:00 11:30 → 23:59	04:00 → 09:00 11:30 → 23:59	
		Winter	10:00 → 01:00	10:00 → 01:00	10:00 → 01:00	10:00 → 01:00	10:00 → 01:00	10:00 → 01:00	10:00 → 18:30
AHU-5	W. & S. Concourse	Summer	07:00 → 20:00	07:00 → 20:00	07:00 → 20:00	07:00 → 20:00	07:00 → 20:00	07:00 → 20:00	
		Winter	07:00 → 20:00	07:00 → 20:00	07:00 → 20:00	07:00 → 20:00	07:00 → 20:00	07:00 → 20:00	
AHU-6	E. Concourse	Summer	03:00 → 22:30	03:00 → 22:30	03:00 → 22:30	03:00 → 22:30	03:00 → 22:30	03:00 → 22:30	
		Winter	05:30 → 22:30	05:30 → 22:30	05:30 → 22:30	05:30 → 22:30	05:30 → 22:30	08:00 → 22:30	
SF-7	Radio Station	Summer	24 Hrs.	24 Hrs.	24 Hrs.	24 Hrs.	24 Hrs.	24 Hrs.	24 Hrs.
		Winter	24 Hrs.	24 Hrs.	24 Hrs.	24 Hrs.	24 Hrs.	24 Hrs.	24 Hrs.
SF-8	Newspaper	Summer	09:00 → 16:00	09:00 → 16:00	09:00 → 16:00	09:00 → 16:00	09:00 → 16:00		
		Winter	10:00 → 17:00	10:00 → 17:00	10:00 → 17:00	10:00 → 17:00	10:00 → 17:00		
SF-9	N. Wing Lower	Summer	07:00 → 22:00	07:00 → 22:00	07:00 → 22:00	07:00 → 22:00	07:00 → 22:00	07:00 → 22:00	
		Winter	07:00 → 20:00	07:00 → 20:00	07:00 → 20:00	07:00 → 20:00	07:00 → 20:00	07:00 → 20:00	07:00 → 20:00
SF-10	Multi-purpose Area	Summer	05:00 → 21:00	05:00 → 21:00	05:00 → 21:00	05:00 → 21:00	05:00 → 21:00	06:00 → 20:00	06:00 → 20:00
		Winter	06:00 → 20:00	06:00 → 20:00	06:00 → 20:00	06:00 → 20:00	06:00 → 20:00	06:00 → 20:00	06:00 → 20:00
SF-11	N. Wing Offices	Summer	07:00 → 20:00	07:00 → 20:00	07:00 → 20:00	07:00 → 20:00	07:00 → 20:00	07:00 → 20:00	
		Winter	07:00 → 20:00	07:00 → 20:00	07:00 → 20:00	07:00 → 20:00	07:00 → 20:00	07:00 → 20:00	
SF-12	Upper Floor	Summer	08:00 → 18:00	08:00 → 18:00	08:00 → 18:00	08:00 → 18:00	08:00 → 18:00		
		Winter	08:00 → 18:00	08:00 → 18:00	08:00 → 18:00	08:00 → 18:00	08:00 → 18:00		
EXSF-13	Theatre	Summer	03:00 → 06:00 17:00 → 23:50	03:00 → 06:00 17:00 → 23:50	03:00 → 06:00 17:00 → 23:50	03:00 → 06:00 17:00 → 23:50	03:00 → 06:00 17:00 → 23:50	03:00 → 06:00 17:00 → 23:50	03:00 → 06:00 13:00 → 20:00
		Winter	08:00 → 23:50	08:00 → 23:50	08:00 → 23:50	08:00 → 23:50	08:00 → 23:50	08:00 → 23:50	10:00 → 23:50
AH-14	Pharm./Dental	Summer	06:00 → 20:00	06:00 → 20:00	06:00 → 20:00	06:00 → 20:00	06:00 → 20:00	08:00 → 20:00	08:00 → 20:00
		Winter	03:00 → 20:00	03:00 → 20:00	03:00 → 20:00	03:00 → 20:00	03:00 → 20:00	03:00 → 20:00	06:00 → 20:00

4. Energy Performance

4.1 Natural Gas Rates

The SUB direct natural gas consumption for the previous three years was compiled as per Table 3, below.

Table 3: Three Year Direct Natural Gas Consumption

2017	2018	2019	3-Year Average
1221.3 GJ	1214.6 GJ	1180.5 GJ	1205.5 GJ

The SUB's current Fortis gas rate is *Rate 2 Small Commercial,* with pricing as per Table 4, below.

Table 4: Current Rate 2 Charges

Basic charge per day	$0.9485/day
Delivery charge per GJ	$3.569/GJ
Storage and transport charges per GJ	$1.043/GJ
Cost of gas per GJ	$1.549/GJ

Of the various rate structures, shown in Table 5 below, Rate 2 is the most applicable.

Table 5: Fortis Rate Structure Descriptions

Rate	Fortis Description
2	You are a commercial, institutional or small industrial operation and use less than 2,000 GJ annually (e.g. restaurants, apartment buildings).
3	You are a commercial, institutional or small industrial operation and use more than 2,000 GJ annually (e.g. schools, offices).
4	You are a large commercial operation or institution that uses natural gas only in the warmer months between April 1 and November 1 (e.g. municipal swimming pools, summer agricultural crops).
5	You are a large-volume commercial, institutional, multi-family or other customer that uses about 5,000 GJ or more annually. Rate 5 is authorized by written contract only and specific terms and conditions may apply.
6	You are a company with a fleet of natural gas vehicles or one that retails natural gas to customers with natural gas vehicles.
7	You are a large-volume customer with the ability to switch to an alternative energy source. Rate 7 is authorized by written contract only and specific terms and conditions may apply.

4.2 Energy Analysis

Energy consumption from 2017 through 2019 was collected on a monthly basis and is summarized in Figures 3, 4, and 5, below. The energy is on an absolute basis and has not been normalized to account for weather. It can be seen that, of electricity, natural gas, and district energy, that the latter form is most closely correlated with weather (i.e. consumption of district energy is much greater in winter months than summer months).

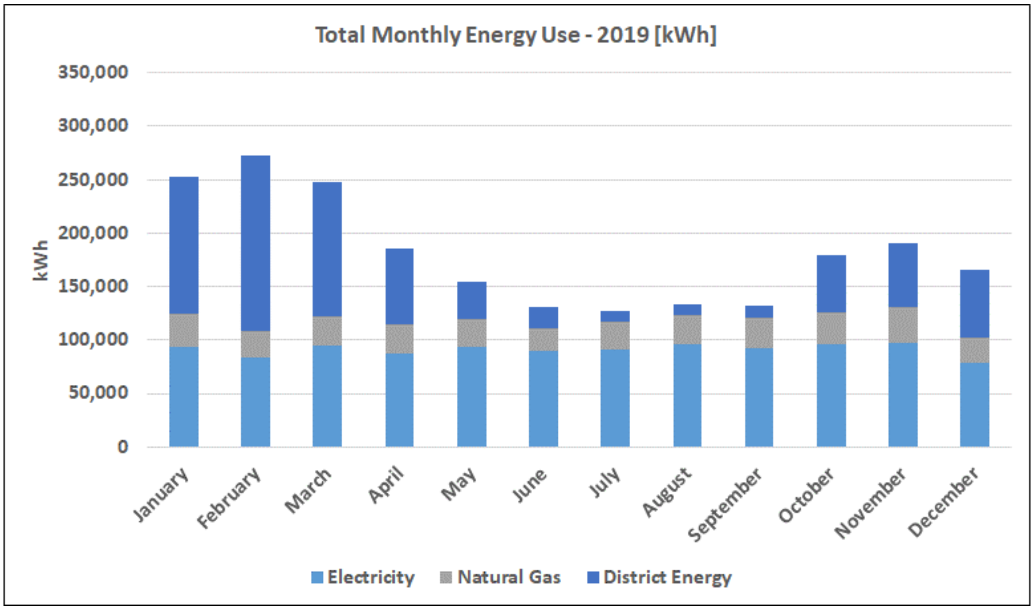

Figure 3: 2019 SUB Energy Use

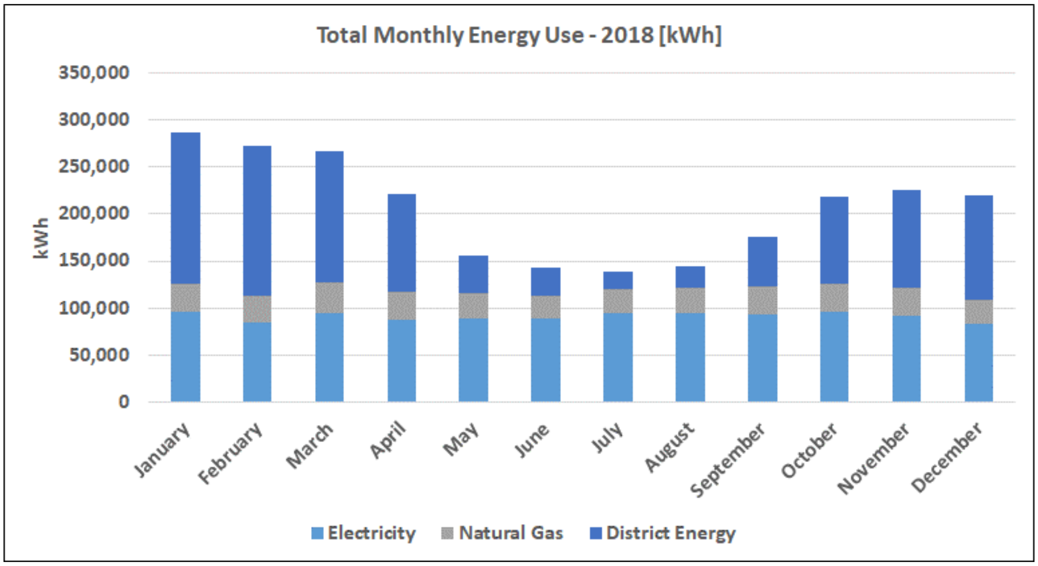

Figure 4: 2018 SUB Energy Use

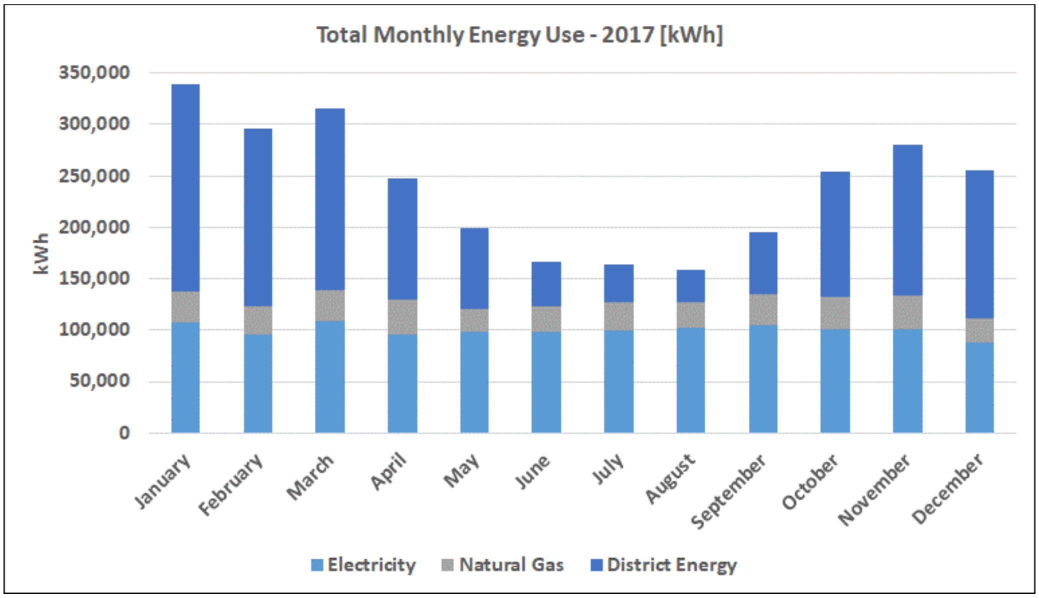

Figure 5: 2017 SUB Energy Use

When the non-normalized total monthly energy use is compared across the three years, a reduction in consumption can be visualized as indicated in Figure 6, below.

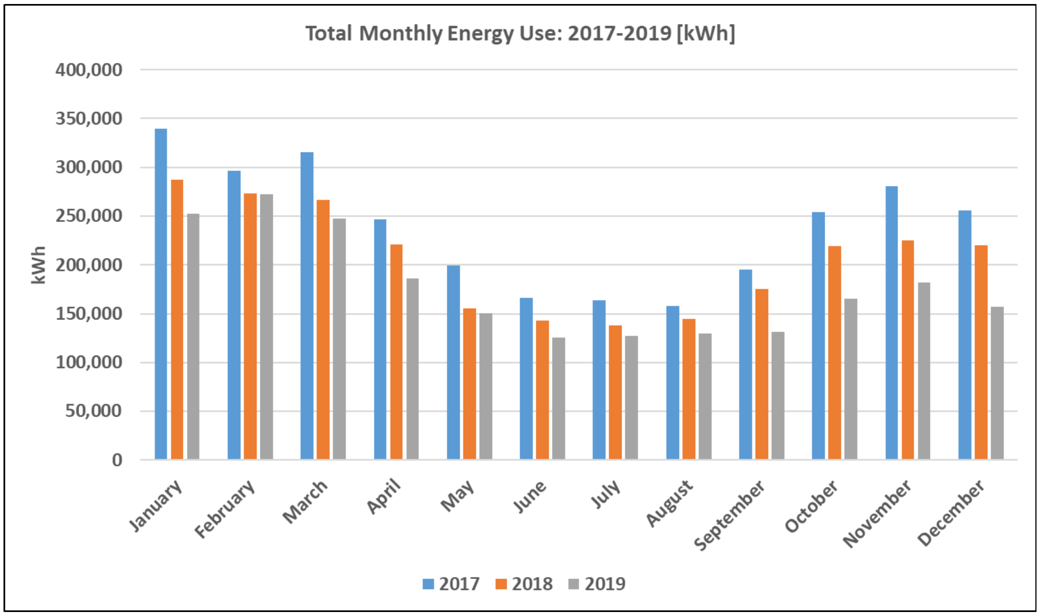

Figure 6: SUB Energy Use 2017-2019

In order to compare the three years data to account for temperature dependency, the district energy was normalized based on a ten year average of heating degree days, shown in Figure 7, below.

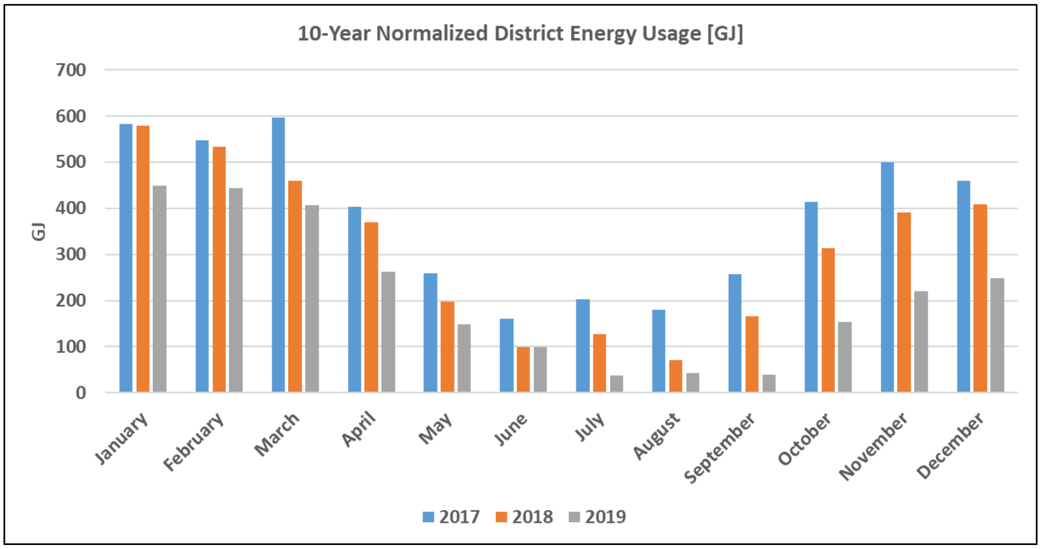

Figure 7: Normalized SUB District Energy Use 2017-2019

After accounting for outdoor air temperature, a reduction in district energy use year-over-year is indicated. However, it must be noted that there are concerns with the calibration of the district energy meters and the data collected does contain inaccuracies.

4.3 Benchmarking

In order to compare the energy performance of the SUB to other buildings the Energy Use Intensity (EUI) factor was calculated. This factor represents energy use on a floor area basis to allow for direct comparison to other buildings of a different footprint.

The SUB does not have a single occupancy class as it contains a wide variety of occupants (i.e. office space, theatre, conference rooms, fast food, pub, retail, etc.). It is therefore difficult to compare to other building databases as this unique subset has not been separately categorized. However, a relative comparison can be made to the Building Owners and Managers Association (BOMA) statistics[1], Figure 8, right, keeping in mind that the SUB most likely has a higher intrinsic energy use than an office setting.

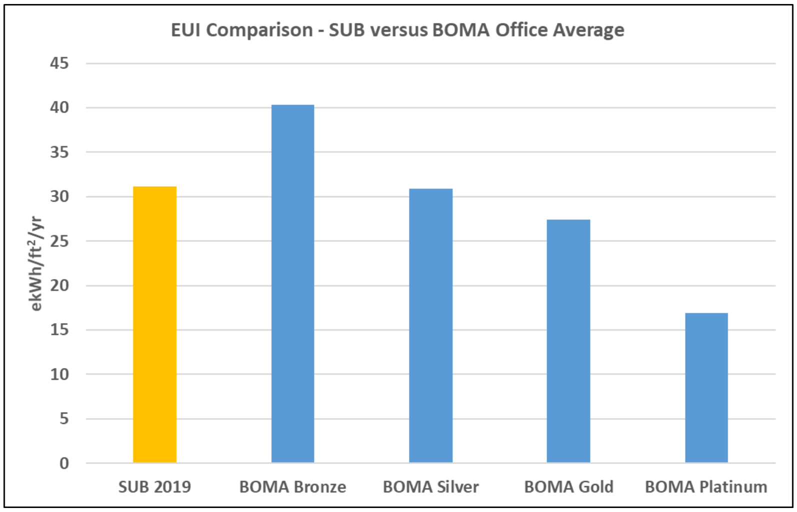

Figure 8: EUI Comparison – SUB versus BOMA

[1] – BOMA 2017, *BEST National Green Building Report*, BOMA Canada, accessed 20 February 2020, <http://bomacanada.ca/wp-content/uploads/2017/05/2017-NGBR-Full-Report.pdf>

Figure 9, below, illustrates the dependency of BOMA statistics on location due to differing climatic conditions. The SUB is located in Climate Zone A and, with a more temperate climate, has less requirements for space heating compared to other locations.

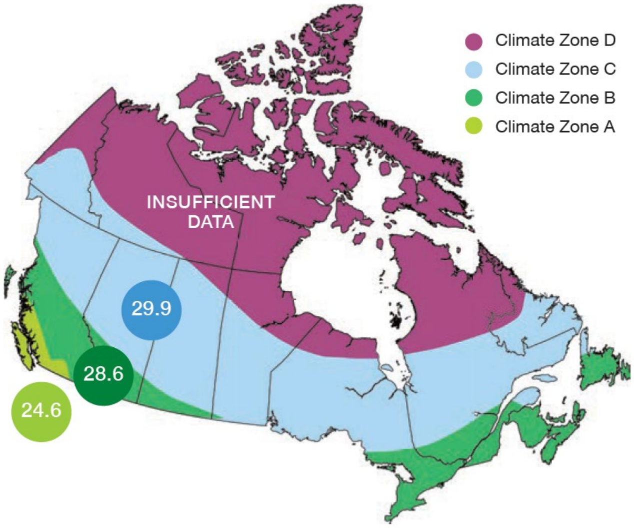

Figure 9: BOMA Canada Statistics[2]

The EUI for the Student Union Building has shown a steady decrease in the past three years as shown in Figure 10, below.

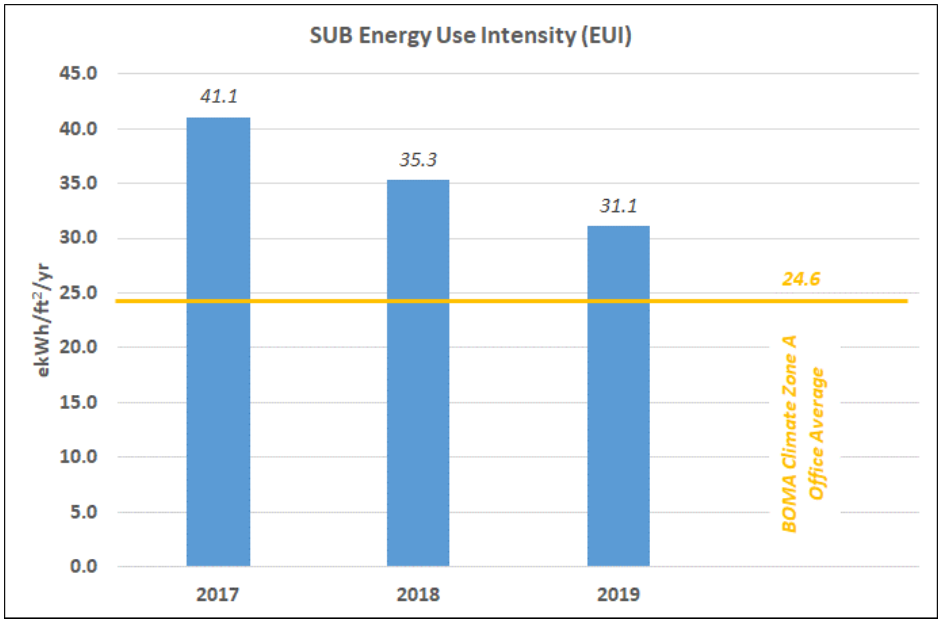

Figure 10: SUB 3-Year EUI

[2] – Ibid.

A comparison of Energy Use Intensity factors, campus-wide, at the University of Victoria is illustrated in Figure 11, below.

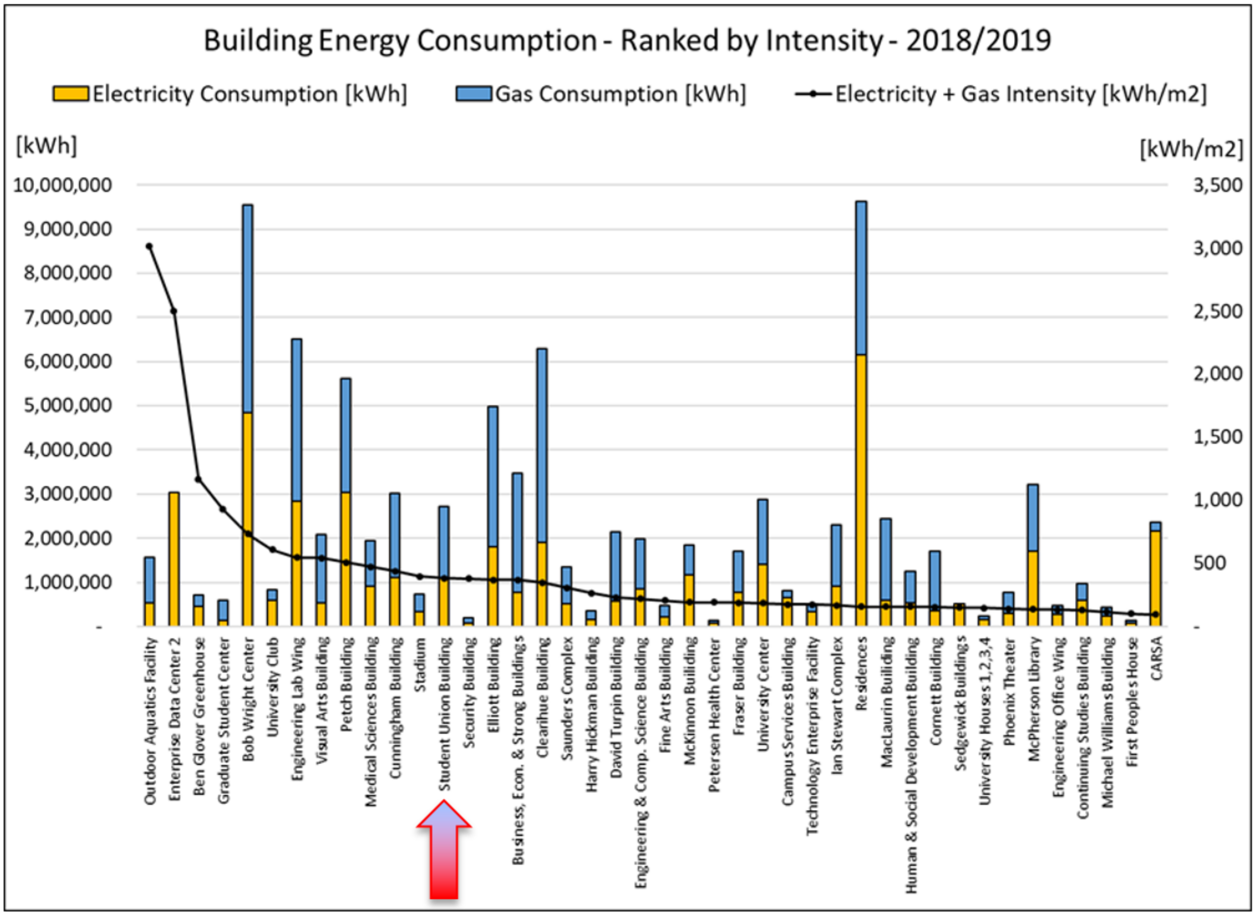

Figure 11: UVIC Campus Building EUI

The SUB EUI of 384 kWh/m^2 is below the average across all UVic buildings of 428 kWh/m^2. However, direct comparisons to other buildings on campus must be made with caution. Due to the unique characteristics of the SUB, it may be possible that the only other building on campus that would represent a meaningful comparison is the University Centre. As indicated in Figure 11, the SUB has a larger EUI than the University Centre, but the building occupancy differences must be considered (e.g. auditorium, office space, foyer, etc.).

5. Retrofit Options

Building retrofits, regarding energy consumption, can be categorized into shallow, moderate, and deep as show in Table 6, below.

Table 6: Retrofit Types[3]

Retrofit Depth	Shallow	Moderate	Deep
Typical energy conservation measures	• Lighting • Smart controls • HVAC motors and fans • Caulking and sealing • Optimization	• Boiler, furnace, or AHU replacement • Steam to hot/low-temp water • Heat pumps • Drain/waste heat recovery • Heat recovery ventilation • Roof/cavity insulation	*As previous, plus:* • Window replacement • Wall and foundation reinsulating • Shading • Envelope replacement • Conversion to renewable district energy
Energy savings range	10-20%	30-50%	40-80%
Typical payback period and costs	1-3 year payback <$2/ft^2	3-6 year payback $2-$5/ft^2	6+ year payback $20-$50/ft^2
Advantages	• Short payback • Cost-effective • Incentivized by current program and policy structure	• Attractive balance of energy savings and payback • Can be performed with minimal disruption to tenants	• Holistic approach optimizes components • Large and lasting energy and emissions reductions
Disadvantages	• Small energy savings • Weakens business case for deeper retrofits in the future • Missed synergies between building components	• Higher energy reductions difficult to achieve without envelope upgrade • May result in larger/more complex mechanical systems than would be required with a deep envelope retrofit	• Complex • Longer payback period • Disruption to tenants/owners

To be discussed in subsequent sections, most of the shallow options have already been implemented within the SUB.

In order to achieve more substantial savings, “deeper” retrofit options will need to completed, which have longer payback periods.

[3] – Pembina Institute 2016, *Building Energy Retrofit Potential in British Columbia*, Pembina Institute, accessed 2 March 2020, <https://www.pembina.org/docs/event/netzeroforum-backgrounder-2016.pdf>

6. Previously Identified Opportunities

Avalon Energy Management conducted an Energy Study of the SUB in 2012 (Report and Spreadsheet attached) and identified numerous savings opportunities as listed in Table 7, below.

Table 7: Avalon Savings Opportunities

		Electricity Consumption		Electricity Demand		Total Est.		Estim.	Estim	GHG	Estim.		Estim.	Simple	Pay back	Comments
	OPTION	Estim Savings kWh/yr	Estim Savings $/YR	Estim. Savings kW	Estim. Savings $	Electrical Savings $	Heating Penalty GJ	Fuel GJ Savings	Gas Saving $	tonne CO2 reduced	Other Savings $	Total Savings	Capital Cost $	Pay-Back (YR)	w/ Part 2 Saving	
5.1	Air sealing throughout	0	$0	0	$0	$0	0	170	$2,406	8	$0	$2,406	**$10,000**	4.2	**4.2**	
5.2	Wall-mount CO2 sensors for dampers	3,764	$325	0	$0	$325	0	9	$124	1	$0	$449	**$3,750**	8.4	**7.3**	AHU-2,10 & 13, see EF26 rec
5.3	S/A Duct CO2 sensors for dampers	0	$0	0	$0	$0	0	323	$4,578	16	$0	$4,578	**$20,000**	4.4	**4.4**	AHU-4,8,9,11,12
5.4	Shorten run times/optimum start	121,780	$10,514	0	$0	$10,514	0	593	$8,416	32	$0	$18,930	**$7,950**	0.4	**immed**	
5.4	Re-Cx SAT SWT Setpoints	0	$0	0	$0	$0	0	108	$1,532	5	$0	$1,532	**$4,000**	2.6	**2.6**	not req'd if Con.Op. to be done
5.4	Override timers for periods of low occupancy	0	$0	0	$0	$0	0	0	$0	0	$0	$0	**$1,500**	0.0	**na**	AHU-8,9,12/ No saving; supports schedules
5.5	Aerco upgrade of Kitchen exhaust / make-up	3,067	$265	0	$0	$265	0	459	$6,520	23	$0	$6,785	**$19,500**	2.9	**2.8**	EF9 plus bldg press sensor for AH6
5.6	Lighting	188,225	$16,251	35	$0	$16,251	-68	0	-$962	4	$3,790	$19,080	**$214,000**	11.2	**10.0**	
5.8	Upgrade theater exhaust fan to reduce SF hours	921	$80	0	$0	$80	0	283	$4,018	14	$0	$4,097	**$7,500**	1.8	**1.8**	EF26 noise reduces free cool
5.9	Local Mech Rm DHW Heat Pump	719	$62	-1	-$121	-$59	0	22	$310	1	-$25	$226	**$1,900**	8.4	**8.0**	Phase 1 - AH7 mech room
5.10	HP to replace AHU 1 10 ton AC	-25,692	-$2,218	-10	-$605	-$2,823	9	302	$4,411	14	$0	$1,587	**$20,000**	12.6	**14.6**	Incremental cost payback ~4yr
	Design Proj Management												**$29,900**			
	GRAND TOTALS	**292,784**	**$25,279**	**24**	**-$726**	**$24,552**	**-59**	**2,268**	**$31,353**	**119**	**$3,765**	**$59,671**	**$340,000**	**5.7**	**5.1**	

Within the same study, a recommended change to the equipment operation schedule was noted as shown in Table 8, below.

Table 8: Avalon Recommended Schedule

	AREA	MAY 1 to AUG 31	SEP 1 to APR 30
AHU-1	Retail	800 to 2000 Mon to Fri	800 to 2000 Mon to Sat
AHU-2	Multi-purpose Area	notify Facilities each week	notify
AHU-3	Entrance Lounge	unocc mode w CO2	1000 to 2000 Mon to Fri; notify for weekend
AHU-4	Pub Supply	1100 to 100 Mon to Fri	1100 to 100 Mon to Sat
AHU-5	Concourse West and South	700 to 2200 Mon to Sat	700 to 2200 - 7 day/wk
AHU-6	Concourse East	600 to 2100 Mon to Fri	600 to 2100 Mon to Fri
SF-7	Radio Station	600 to 2100 7d/wk	600 to 2100 7d/wk
SF-8	Student Newspaper	900 to 1600 Mon to Fri	100 to 1700, Mon to Fri
SF-9	Lower Floor N. Wing	700 to 2200 Mon to Sat	700 to 2200 7 day/wk
SF-10	Multi-purpose Area	notify Facilities each week	notify
SF-11	N. Wing Offices	700 to 2100 Mon to Sat	700 to 2100 Mon to Sat
SF-12	Upper Floor	800 to 1800 Mon to Fri	800 to 1800 Mon to Fri
EXSF-13	Theartre	1800 to 2400 7d/wk	1800 to 2400 7d/wk (notify for events)

7. Savings Opportunities

Sections 7.1-7.4, to follow, summarize the findings of the 2012 Avalon Study that have not been implemented to-date.

Section 7.5 has been added to provide an estimate for an additional CO_2 sensor in the Vertigo area if deemed appropriate by further engineering analysis.

Section 7.6 has been included, by specific request, to provide budgetary numbers for the installation of high-performance windows.

Fortis BC does not currently have any rebates that apply to these measures. Other incentive sources, including BC Hydro may exist, but were not investigated.

7.1 Air sealing

Table 9, below, provides an updated summary of the Avalon 2012 Study (see attachments for details).

Table 9: Updated Avalon Air Sealing Summary

Electricity Savings		District Energy Savings		Total Savings	Estimated Cost	Simple Pay-Back
[kWh/yr]	[$/yr]	[GJ]	[$/yr]	[$/yr]	[$]	[years]
0*	0**	170*	1,340**	1,340**	10,000*	7.5

NOTES: * Based on 2012 Avalon Energy Study
** Based on recent utility rates (Electricity = $0.088/kWh; District Energy = 7.88/GJ)

7.2 Lighting

Table 10, below, provides an updated summary of the Avalon 2012 Study (see attachments for details).

Table 10: Updated Avalon Lighting Summary

Electricity Savings		District Energy Savings		Total Savings	Estimated Cost	Simple Pay-Back
[kWh/yr]	[$/yr]	[GJ]	[$/yr]	[$/yr]	[$]	[years]
188,225*	16,500**	-68*	-535**	15,965**	214,000*	13.4

NOTES: * Based on 2012 Avalon Energy Study
** Based on recent utility rates (Electricity = $0.088/kWh; District Energy = 7.88/GJ)

For more information, and/or an updated study, the following should be contacted:

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Senior Lighting Designer & Project Manager

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Office: 604-526-7717
Fax: 604-526-7795

7.3 DHW Heat Pump

Table 11, below, provides an updated summary of the Avalon 2012 Study (see attachments for details).

Table 11: Updated Avalon DHW Heat Pump Summary

Electricity Savings		District Energy Savings		Total Savings	Estimated Cost	Simple Pay-Back
[kWh/yr]	[$/yr]	[GJ]	[$/yr]	[$/yr]	[$]	[years]
719*	63**	22*	173**	236**	1,900*	8

NOTES: * Based on 2012 Avalon Energy Study
** Based on recent utility rates (Electricity = $0.088/kWh; District Energy = 7.88/GJ)

7.4 Heat pump replacement of AHU-1

Table 12, below, provides an updated summary of the Avalon 2012 Study (see attachments for details).

Table 12: Updated Avalon AHU-1 Heat Pump

Electricity Savings		District Energy Savings		Total Savings	Estimated Cost	Simple Pay-Back
[kWh/yr]	[$/yr]	[GJ]	[$/yr]	[$/yr]	[$]	[years]
-25,692*	-2,260**	302*	2,380**	120**	20,000*	167

NOTES: * Based on 2012 Avalon Energy Study
** Based on recent utility rates (Electricity = $0.088/kWh; District Energy = 7.88/GJ)

7.5 CO_2 sensor for Vertigo space (AH3)

Table 13, below, provides a summary for an optional installation of a CO_2 sensor in the Vertigo area. This is based on similar areas detailed in the Avalon 2012 Study. An engineering study would need to be conducted in order to determine the feasibility of this option.

Table 13: Optional CO_2 Sensor for Vertigo Area

Electricity Savings		**District Energy Savings**		**Total Savings**	**Estimated Cost**	**Simple Pay-Back**
[kWh/yr]	[$/yr]	[GJ]	[$/yr]	[$/yr]	[$]	[years]
0*	0**	13*	102**	102**	4,000*	39

NOTES: * Based on 2012 Avalon Energy Study
** Based on recent utility rates (Electricity = $0.088/kWh; District Energy = 7.88/GJ)

7.6 High performance windows

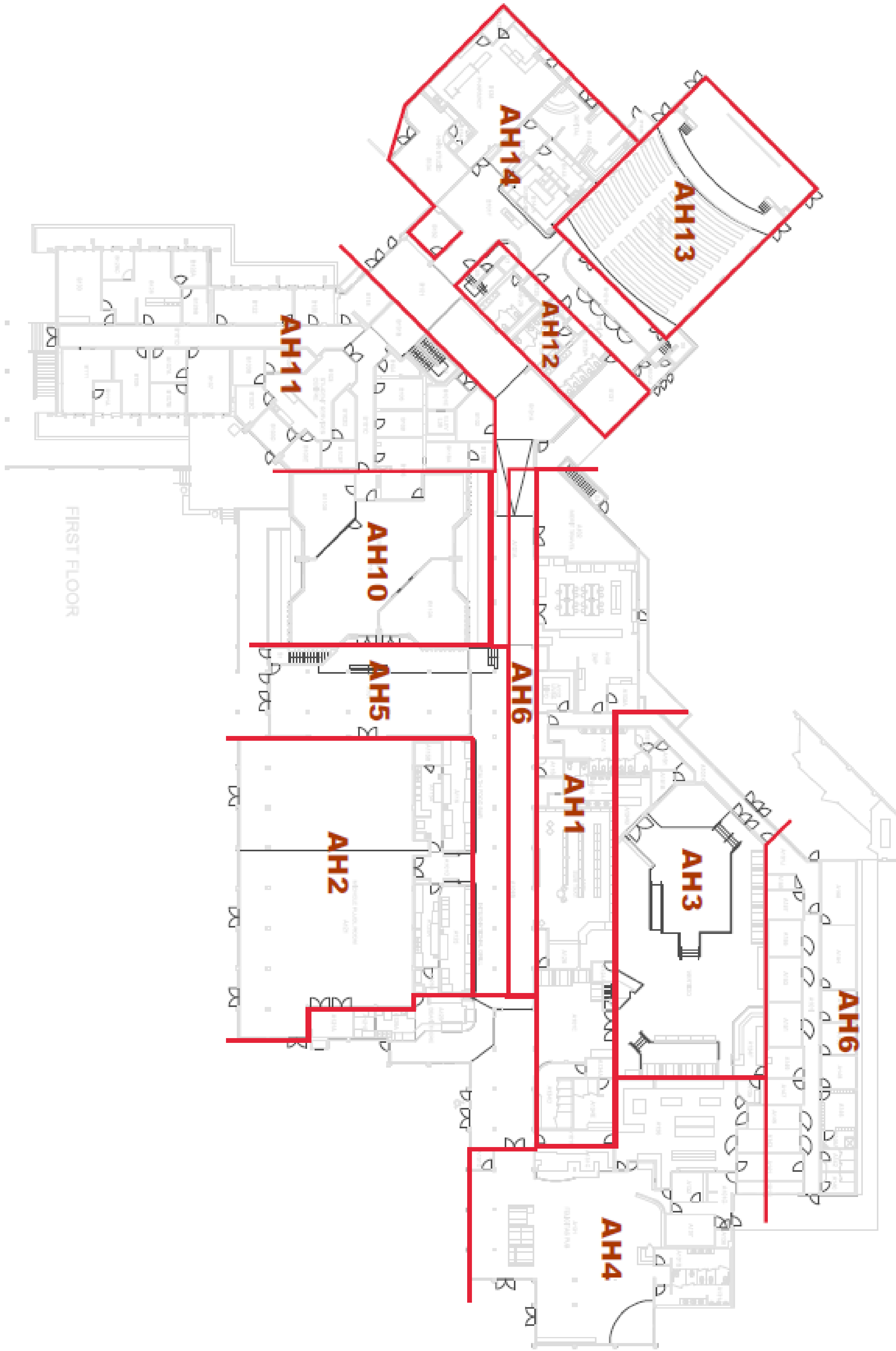
The installation of high performance windows is a major retrofit and if it were to be completed as a separate project, Table 14, below, provides budgetary numbers. If the windows were replaced as part of a larger retrofit project (e.g. roof replacement or envelope upgrades), then there would be cost synergies and the payback period would be reduced.

Table 14: High Performance Window Installation

Item	Value	Units
Window area	748.7	m^2
Existing U-Value	3.2	$W/m^2 \cdot K$
Existing UA Energy Loss	2,396	W/K
Existing Energy Loss Through Windows	807	GJ/year
High Performance U-Value	1.8	$W/m^2 \cdot K$
High Performance Energy Loss	1,348	W/K
Estimated Energy Loss Through High Performance Windows	454	GJ/year
Estimated Energy Savings per year	353	GJ
Estimated Cost Savings per year	3,000	$/year
Estimated Cost of High Performance Windows	400,000	$
Simple Pay-Back Period for High-Performance Windows	133	years

Appendix 1 – Basement AHUs

APPENDIX 1 CONT'D – GROUND FLOOR AHUS



Appendix 1 cont'd – Second Floor AHUs