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Abstract

This report evaluates the energy consumption of the Toronto Metropolitan University Architecture Building located at 325 Church St in downtown Toronto which was constructed over 40 years ago. The buildings out-dated insulation, coupled with its poor thermal performance and air infiltration issues cause significant energy loss. Using data we have collected from an on-site survey, building plans, and an excel model we have developed, we identify key aspects of the building which contribute to these inefficiencies. With all that data, we produced a comprehensive retrofit proposal. Our recommendations including installing a green wall and roof, upgrading the aged windows, and the addition of new high quality EPS insulation, proved to be correct as our life cycle analysis confirms. We found that the proposed green wall also significantly improved the exterior aesthetic of the building.

User Manual

Welcome to this brief explanation of how to use the Excel sheet, here is the list of the options that you can use on the sheet:

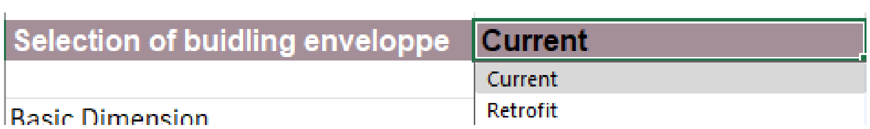
Information of the parameters:

You can see the current parameters in the sheet Calculation in the cells B2:C3.

Screenshot of the cells showing the parameters for the current building envelope for the city of Toronto

Choosing between the current and new building envelope:

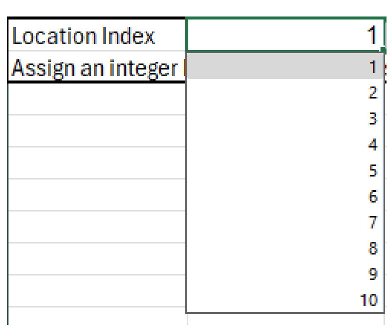
You can set the building envelope by going into the sheet bldg cell B4 and choosing between the Current and Retrofit in the dropdown list. When the current building envelope is selected, the LCA on the sheet Calculation will show "no calculation" because no life cycle analysis can be made using the old material.



Screenshot of the cell showing the dropdown, with the selection on the Current building envelope

Choosing the site location:

You can set the building envelope by going into the sheet ClimaticCondition cell D2 and choosing the number corresponding to the wanted city index in the dropdown list.



Screenshot of the cell showing the dropdown, with the selection on the city with index 1 (Toronto)

On-Site Survey

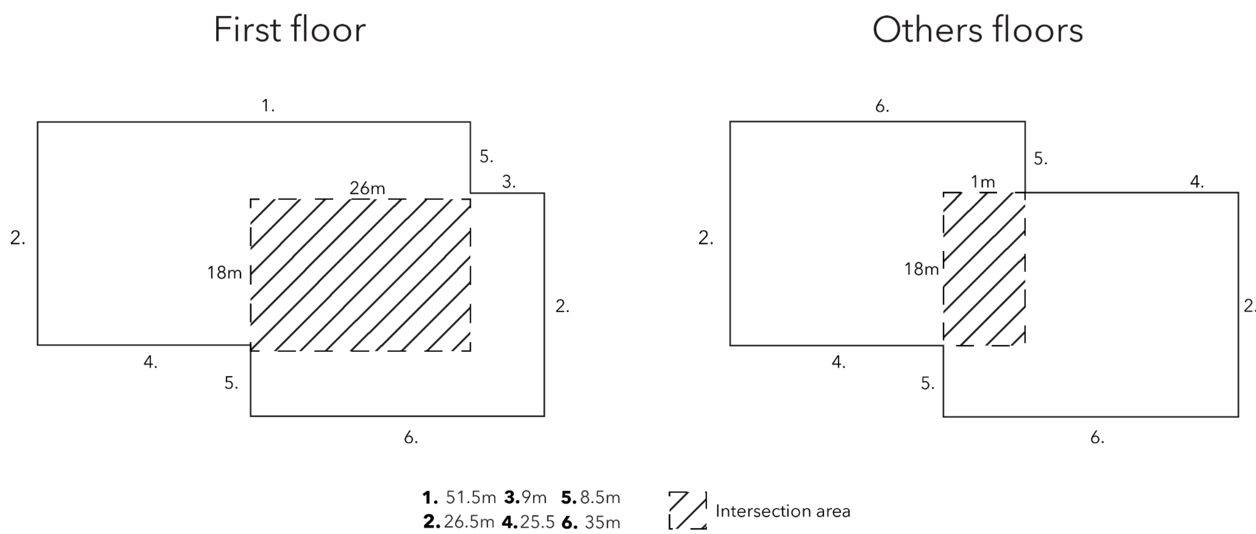
Based on the building dimensions, HDD values of ten different cities in Canada, and estimations for the R-value and ACH value of a 40-year-old building, we have applied this relevant data in the Excel tool to estimate the monthly and yearly heating energy consumption (GJ/yr) and intensity (MJ/m2.yr). Now, we have conducted a survey highlighting the current condition of the ARC building of TMU and collected the needed information amongst a group of different architecture building staff.

Built more than 40 years ago, the ARC building follows the standard construction and style of its time. They use precast walls that have little thermal insulation and are mostly composed of masonry and reinforced concrete. Despite their longevity, these materials' low thermal resistance permits substantial heat transmission through the walls. The building's inability to retain heat during the colder months due to outdated insulation raises the energy requirements for heating.

Although it has a significant impact on the building's energy efficiency, the roof may have several issues. Staff comments and observations point to the roof's poor insulation, which results in significant energy loss. Furthermore, wear indicators and possible leaks were found, which worsened thermal inefficiencies in addition to raising structural issues. These disclosures may enable heat to escape and cold air to enter, which raises the need for heating even more. Another significant issue with the ARC building is the windows and doors. The rate of heat loss is increased by the large number of single-glazed windows that are inadequately sealed. According to employees, drafts around windows and doors are a symptom of major air leaks that compromise the building's thermal envelope. The building's heating energy usage is significantly influenced by these problems, which include air leakage, inadequate insulation, and thermal bridging. We were able to improve our calculations and provide a thorough estimate of the monthly and annual heating energy use by incorporating this data specific to the ARC building into the Excel sheet.

Current Building

Today's report concerns the consumption of the ARC building on the TMU campus. During this study, the first floor will be considered as one full floor as it is now, and by extension, we will neglect the part of the first floor that is half under the ground because the construction calculation for this scenario hasn’t been studied in class. The 5th floor will be neglected being only an access point for the roof. Furthermore, the actual consumption calculation will be based on the building envelope from the original drawing, and so will not consider the new roof's insulation that is currently installed, and will consider a good aging of the insulation for 40 years. Finally, the ACH of the building will be based on averages for a building 40 years old. The dimensions and other building calculations will be based on the sections of the original drawings and the updated plans, we will consider the 3rd and 4th floors as the same, and the 1st and 2nd will have a consideration of respectively the additional space under the entry stairs and the Pit room. All information regarding the current building envelope and dimensions comes from the original building drawing.



For the facade, we will calculate the area of the 6 different sizes of the external walls that can be seen in the plan. For the calculation of the floor area, we’ll calculate the area of the two rectangles and subtract the overlapping area which is cross-hatched in the plan. For the volume, we’ll simply multiply the floor area by the height. Based on the original section drawings and the updated plan, we can see that the windows represent the height of the insert number for a total height of 3.5m and represent the total length of the insert windows for the perimeter of the insert floor. This calculation will be made for each floor as described in the introduction and then will be summed to simplify the data in one table.

Here is the current building envelope. You can read the details and the thicknesses of all the layers on the left.

Index	Name					Mass per m2 of wall area (kg/m2)	Embedded Energy per m2 surface area (MJ/m2)	Embedded Carbon Emission per m2 surface area (kg CO2/m2)
Current								
			XPS efficiency reduced in 40 years	10%				
2	**ARC Wall**							
		Layer	**Material**	**Width (m)**	**R value (m2.oC/W)**			
		1	Precast Facing Panel	0,024	0,012	62,4	156	62,4
		2	Air Gap (25mm)		0,2			
					0	0	0	0
		3	Rigid Insulation (XPS)	0,1	2,571428571	3,2	480	19,2
		4	Inside conrete HD	0,15	0,075	390	975	390
							0	0
			Total		**2,858428571**		**0**	**0**
3	**ARC Roof**						0	0
		Layer	**Materials**	**Width (m)**	**R value (m2.oC/W)**		0	0
		1	Concrete HD slab	0,25	0,125	650	1625	650
		2	Rigid Insulation (XPS)	0,075	1,928571429	2,4	360	14,4
		3	Crushed stone	0,075	8,82353E-05	120	60	7,2
			Total		**2,053659664**			

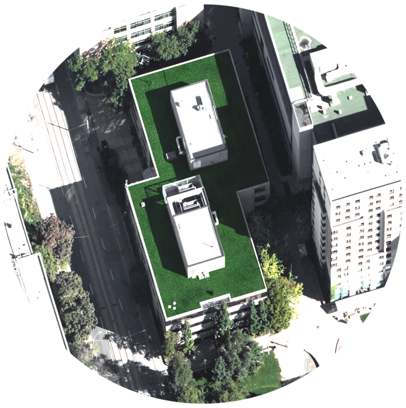
This table here shows the current building envelope and the layers it consists of along with the R-Values and the width of the layers. This information is very important when modelling the building's energy consumption in Excel. The proposed building envelope in the retrofit proposal must use the current building envelope as a basis for any redesign. The embedded energy of the current building envelope will not be considered later for the life cycle analysis. The wall and the roof are currently using XPS and according to our research, XPS's thermal performance declines 10% after 40 years.

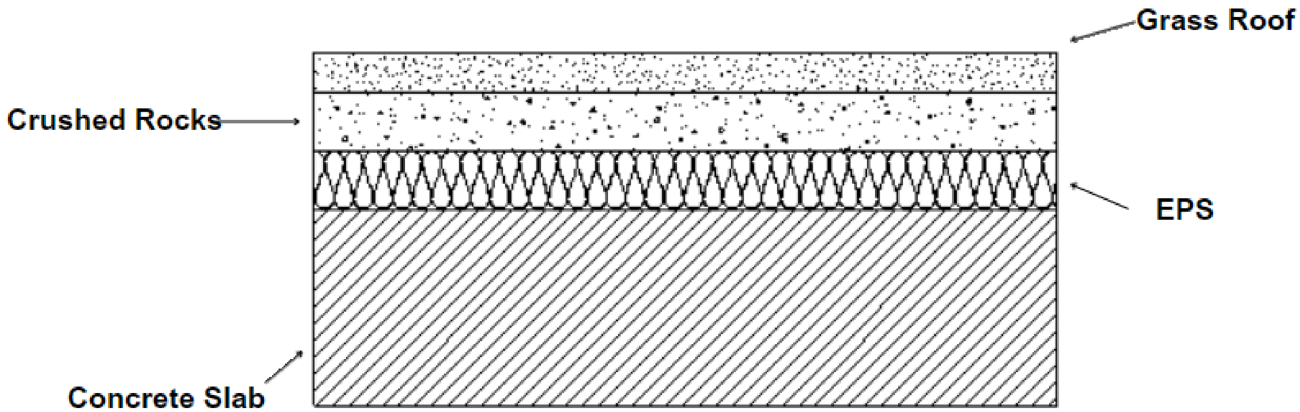
Retrofit Proposal

For our retrofit proposal, we have decided to cover the building in one large green wall which will extend across the facade. This will help insulate the building in both the summer and the winter. The image above shows what our proposal would look like from Church St. The green wall will provide an aesthetic enhancement as well which is an extra advantage.

Since the building is 40+ years old, there has been a significant decrease in the quality of the building's insulations.

Furthermore, we have decided to add a green roof on top of the building as well which will provide added insulation. Green roofs are easy and cheap to install and a quick retrofit solution is implemented frequently.



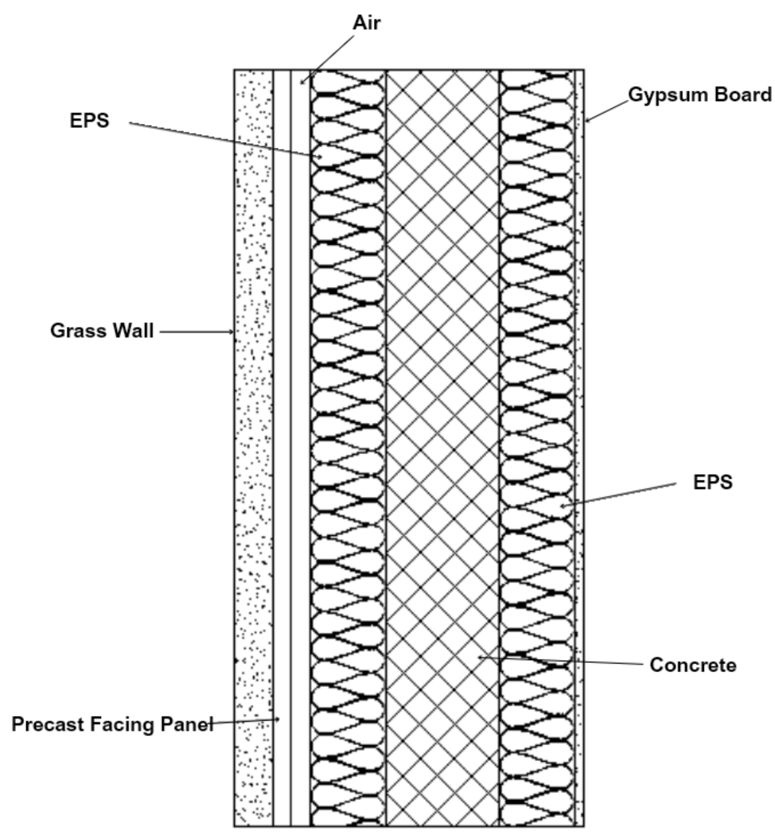


Retrofit Roof

As this diagram shows, the added grass roof will sit on top of the crushed rock layer that is already present. The grass roof can be made of real grass or it can be astroturf, both will add a different amount of insulation while an astro-turf layer will be cheaper.

Below, is a section cut of our proposed wall. The grass wall will be way thicker than the grass roof meaning that it will provide even more insulation. The grass wall will have to be maintained during the winter (when it is most important) as the current vines that cover the architectural building die in the winter. Measures must be taken to maintain them and keep them alive during winter. Perhaps, a water dripping system that will keep watering the vines daily could work.

Furthermore, we have decided to add new double-glazed windows. Since the seals have decayed in the last 40 years, the windows' R-value has worsened.



Retrofit Wall

Life Cycle Analysis of The Retrofit Proposal

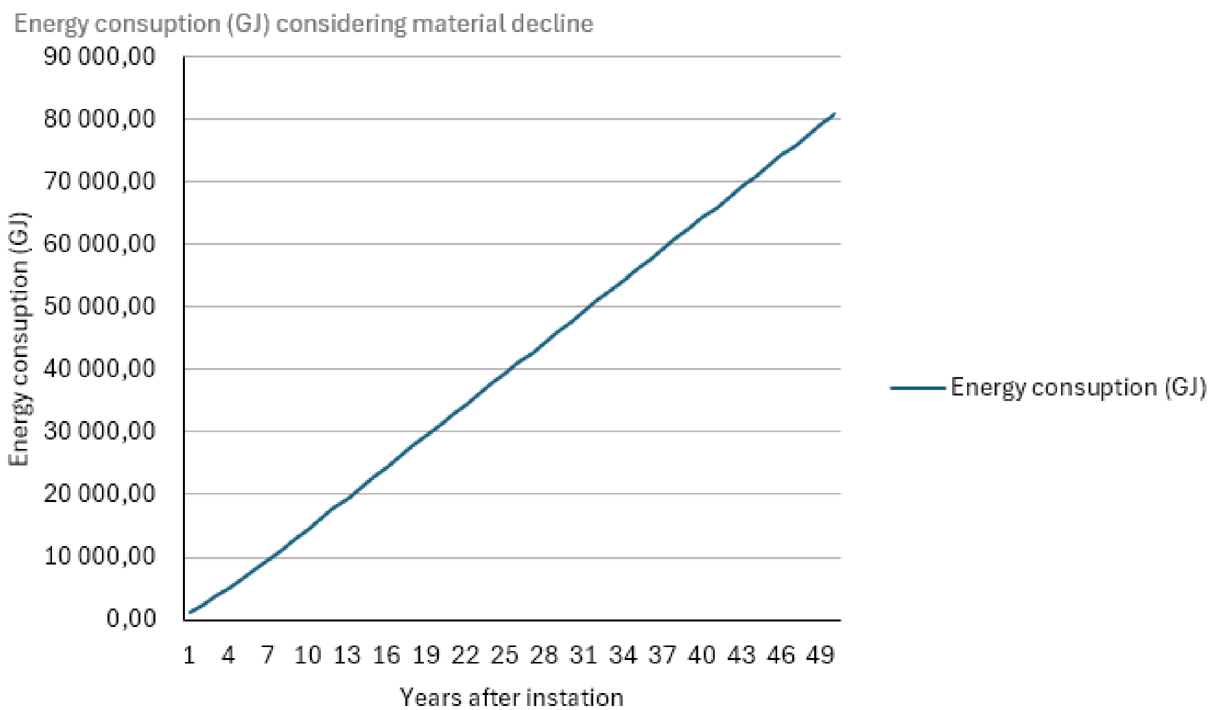
Here is our retrofit proposal's building envelope. You can read the details and the thicknesses of all the layers on the left.

Index	Name						Mass per m2 of wall area (kg/m2)	Embedded Energy per m2 surface area (MJ/m2)	Embedded Carbon Emission per m2 surface area (kg CO2/m2)
Retrofit Proposal									
4	**ARC Wall**			**Targeted R-Value**	6				
		Layer	**Material**	**Width (m)**	R value (m2.oC/W)				
		1	Green wall	0,05	0,25		65,00	32,50	162,50
		2	Precast Facing Panel	0,024	0,012		60,00	150,00	60,00
		3	Air Gap (25mm)	0,025	0,2				
		4	EPS	0,1	2,857142857		4,5	661,5	10,8
		5	Inside conrete HD	0,15	0,075		375,00	937,50	375,00
		6	EPS	0,090505	2,585857143		4,072725	598,690575	9,77454
		7	Gyspum board	0,01	0,02		8,00	16,00	3,20
				Total without EPS	3,414142857				
				R-Value needed for EPS	2,585857143				
				Width of EPS	0,090505				
				Total	6	**Total for the new m**	**81,57**	**1308,69**	**186,27**
3	**ARC Roof**			**Targeted R-Value**	8				
		Layer	**Materials**	**Width (m)**	R value (m2.oC/W)				
		1	Concrete HD slab	0,25	0		0	0	0
		2	EPS	0,258897059	7,397058824		11,6503676	1712,60404	27,96088235
		3	Crushed stone	0,6	0,352941176		960	480	57,6
		4	Green roof	0,05	0,25		62,5	37,5	75
				Total without EPS	0,602941176				
				R-Value needed for EPS	7,397058824				
				Width of EPS	0,258897059				
				total	8	**Total for the new m**	**74,1503676**	**1750,10404**	**102,9608824**

We need to bear in mind that when it comes to the embedded energy here, we are only considering the new materials we have installed in the building. Furthermore, we are only considering the decline in R-value for the EPS layer. The double-glazed windows are assumed to have an R-Value of 0.55 m².°C/Win the current state of the building and after redoing insulation and joints, it has an increased R-Value of 1 m².°C/W.The original ACH has been assumed to be 2 1/h. Because this building has existed for 40 years, we find that the ACH has increased to 3.6 1/h according to our calculations in Excel. The image above outlines our new retrofitted building envelope which we have developed for both the roof and the external walls. The thicknesses and R-Values are presented on the left side along with the names of the layers.

Year after Installation	R Retention %	ACH compare with original	ACH (1/hr)	Yearly Energy (GJ)
1	99%	1,1	0,275	**1 189,43**
2	98%	1,2	0,3	**1 256,02**
3	97%	1,3	0,325	**1 322,63**
4	96%	1,4	0,35	**1 389,26**
5	95%	1,5	0,375	**1 455,91**
6	94,20%	1,6	0,4	**1 522,36**
7	93,40%	1,65	0,4125	**1 556,04**
8	92,60%	1,7	0,425	**1 589,74**
9	91,80%	1,75	0,4375	**1 623,45**
10	91%	1,8	0,45	**1 657,18**
11-50	90%	1,8	0,45	**1 658,39**
Original ACH	0,25			
			Total in 20yrs	**31 145,90**
			Total in 35yrs	**56 021,75**
			Total in 50 yrs	**80 897,60**

This image shows the life-cycle analysis for the retrofit proposal. As you can see, high-quality EPS is used which retains about 90% of its R-Value 10+ years after installation. The change in ACH has also been factored in as you can see in the second rightmost column. The graph below shows the correlation between energy consumption and time after installation of the EPS layer.



Difference In Energy Consumption Between The Current And Proposed Building Envelope

Heating Energy And Intensity / Transfer By Transmission:

Current:

Monthly	HDD (oC.Day)	Window	External Wall	Roof	Total
January	598,3	132 050,54	22 949,53	45 918,60	**200 918,68**
Febuary	477,7	105 432,97	18 323,57	36 662,74	**160 419,28**
March	419,8	92 653,88	16 102,65	32 219,00	**140 975,53**
April	267,4	59 017,74	10 256,90	20 522,54	**89 797,18**
May	76,2	16 818,07	2 922,87	5 848,23	**25 589,17**
June	24,7	5 451,53	947,44	1 895,69	**8 294,65**
July	4,1	904,91	157,27	314,67	**1 376,85**
August	10,6	2 339,52	406,59	813,53	**3 559,65**
September	31,7	6 996,49	1 215,95	2 432,93	**10 645,37**
October	179,7	39 661,51	6 892,92	13 791,70	**60 346,12**
November	394,3	87 025,79	15 124,52	30 261,91	**132 412,23**
December	448	98 877,89	17 184,34	34 383,31	**150 445,54**
Yearly (MJ/Year)	2932,5	647 230,86	112 484,55	225 064,84	**984 780,25**
Intensity (MJ/Year.m2)		354,79	61,66	123,37	**539,83**

Retrofit:

Monthly	HDD (oC.Day)	Window	External Wall	Roof	Total
January	598,3	72 627,80	10 933,27	11 787,65	**95 348,71**
Febuary	477,7	57 988,13	8 729,44	9 411,60	**76 129,17**
March	419,8	50 959,64	7 671,38	8 270,86	**66 901,87**
April	267,4	32 459,76	4 886,44	5 268,29	**42 614,48**
May	76,2	9 249,94	1 392,47	1 501,28	**12 143,69**
June	24,7	2 998,34	451,37	486,64	**3 936,34**
July	4,1	497,70	74,92	80,78	**653,40**
August	10,6	1 286,74	193,70	208,84	**1 689,28**
September	31,7	3 848,07	579,28	624,55	**5 051,90**
October	179,7	21 813,83	3 283,82	3 540,43	**28 638,08**
November	394,3	47 864,18	7 205,39	7 768,46	**62 838,04**
December	448	54 382,84	8 186,70	8 826,45	**71 395,99**
Yearly (MJ/Year)	2932,5	355 976,97	53 588,18	57 775,82	**467 340,97**
Intensity (MJ/Year.m2)		195,14	29,38	31,67	**256,18**

Heating Energy And Intensity / Transfer By Infiltration:

Current:

Month	Energy Consumption (MJ)
January	1 925 863,72
Febuary	1 537 665,22
March	1 351 291,31
April	860 732,01
May	245 279,65
June	79 506,66
July	13 197,46
August	34 120,27
September	102 038,91
October	578 435,08
November	1 269 209,54
December	1 442 064,09
	9 439 403,91
	5 174,40

Retrofit:

Month	Energy Consumption (MJ)
January	133 740,54
Febuary	106 782,31
March	93 839,67
April	59 773,06
May	17 033,31
June	5 521,30
July	916,49
August	2 369,46
September	7 086,04
October	40 169,10
November	88 139,55
December	100 143,34
	655 514,16
	359,33

Total heating energy and intensity:

Current:

Mounth	Energy consuption
January	2 126 782,40
Febuary	1 698 084,49
March	1 492 266,84
April	950 529,19
May	270 868,83
June	87 801,31
July	14 574,31
August	37 679,92
September	112 684,28
October	638 781,21
November	1 401 621,76
December	1 592 509,63
	10 424 184,16
	5 714,23

Retrofit

Mounth	Energy consuption
January	229 089,25
Febuary	182 911,47
March	160 741,55
April	102 387,54
May	29 177,00
June	9 457,64
July	1 569,89
August	4 058,74
September	12 137,94
October	68 807,18
November	150 977,59
December	171 539,33
	1 122 855,13
	615,52

As the data above suggests, the retrofit solution decreases the energy consumption by 10x. The total energy consumption decreases from 10.4 million MJ annually to a mere 1.1 million MJ. This is a stark difference in energy consumption proving the success of the tactics that we employed in our retrofit proposal. Such as the green wall, the green roof, newly installed windows, and the new high grade EPS layer. The main deciding force in this comparison was the decrease in infiltration that happened as a result of our proposal. The energy lost to air infiltration decreased from 9 million MJ to a mere 655,000 MJ while the energy lost to the building envelope simply halved from almost a million MJ to 585,000 MJ. This shows that most of the energy was being lost to aerial infiltration and that our proposal dealt with it perfectly. All in all, this was a success.

Conclusion

In conclusion, this study shows the need for retrofitting the Toronto Metropolitan University Architecture Building to improve its energy performance, sustainability, and user experience. Currently, the building has outdated insulation, inefficient windows, and an aging HVAC system which all combine to cause significant energy losses and an increased heating demand. Our retrofit proposal, which includes the new green wall, green roof, installation of new double-glazed windows, and the use of new high-quality EPS insulation addresses these concerns effectively. By improving the building envelope and reducing the air infiltration rate, we significantly decrease the energy consumption of the building. Additionally, the green wall not only increases the energy efficiency of the building but also the aesthetic appeal from the outside. These tactics, backed by the life-cycle analysis, demonstrate a practical approach to building retrofitting in downtown Toronto.

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