University of Windsor

Load Calculation of 2-bedroom house with garage using OpenStudio.

MECH 8290-4-R-2023S-AIR CONDITIONING

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Submitted by

Ramachandran Nagarajan - 110103239

Hari Raghav Muruganandam - 110102585

Submitted To

Dr. Monsif Shineeb

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1. Introduction

There is a growing urgency to reduce global emissions in every sector due to the drastically rising global temperatures. This change is also emphasized in the HVAC industry, since 3.94% of the global greenhouse gas emission is due to air conditioning [1].

The objective of this project is the creation of an accurate and efficient Building Energy Model and Load Calculations using OpenStudio. OpenStudio is an open-source BEM software with a community where users can share their knowledge. The software also utilizes FloorSpaceJS and EnergyPlus. This is done using Building Component Library (BCL) that can be used to access components and Measures [2].

The project building, we have chosen, is a 2-bedroom hip roof house with a hobby room and one bathroom. The exterior of the house consists of a 38 x 39 Patio and a detached garage. The garage consists of a separate storage space

The house is located in Windsor, ON and the calendar year is 1984. The house is occupied by a family of 3.

The air conditioning system for this house will use a baseboard system, instead of a conventional heat pump system. Baseboard systems are ductless, easy to install, have lower upfront costs and provide zonal temperature control. Another reason for this decision is the house is approximately 1500 sq. ft in area and is only occupied by 3 people, hence, a system with zonal temperature control will be more efficient.

The home is powered by a solar panel located in the colony; hence the home is air-conditioned by renewable energy.

2. Roles and Responsibilities

The design team consists of 2 members, the roles and responsibilities are listed below:

Roles and Responsibilities	Hari Raghav Muruganandam	Ramachandran Nagarajan
Research on OpenStudio Software features	✓	✓
Organizing Meetings	✓	

Project report grammar and spell check		✓
3D Modelling		✓
Building Component Library	✓	
Load Calculations	✓	✓

Table 1. Roles and Responsibilities

The first step was researching the software and the fundamentals of Building Energy Modeling. After that, the load calculation Modeling was completed in turns. The report writing was the final step.

In order to obtain the best results, each one of us ran several iterations of the model with ideal air loads, HVAC equipment and baseboard electric heaters.

3. Environmental conditions

The house is located in Windsor, ON, and the year is 1984. The home is powered by a solar panel located in the colony; hence the home is air conditioned by renewable energy.

The detached garage is equipped with an EV charger, despite the year allotted being 1984. This is done so that the values of load calculation will have more relevance in a modern context, since Electric vehicles are becoming more and more prevalent.

The plans of the house do not consist of a laundry room, therefore the loads for a washing machine and dryer are not included in the design loads. The consideration is the family does their laundry in a nearby self-service laundry.

The daylights savings time is also considered from March 12 to November 5, same as that of 2023, for the purpose of simplicity.

The year of 1984 had a lowest temperature of -27.2 C, which is the record second-lowest day in the history of Windsor, ON [3].

4. OpenStudio Modeling and Load Calculation

4.1. Weather File

As mentioned above the weather file is selected location is Windsor, ON, in 1984 although the daylights savings time is the same as that of the year 2023.

4.2. Geometric Modeling

The House is modelled using floor space JS. The unknown elevation dimensions, were estimated using PowerPoint, with the known dimensions as reference.

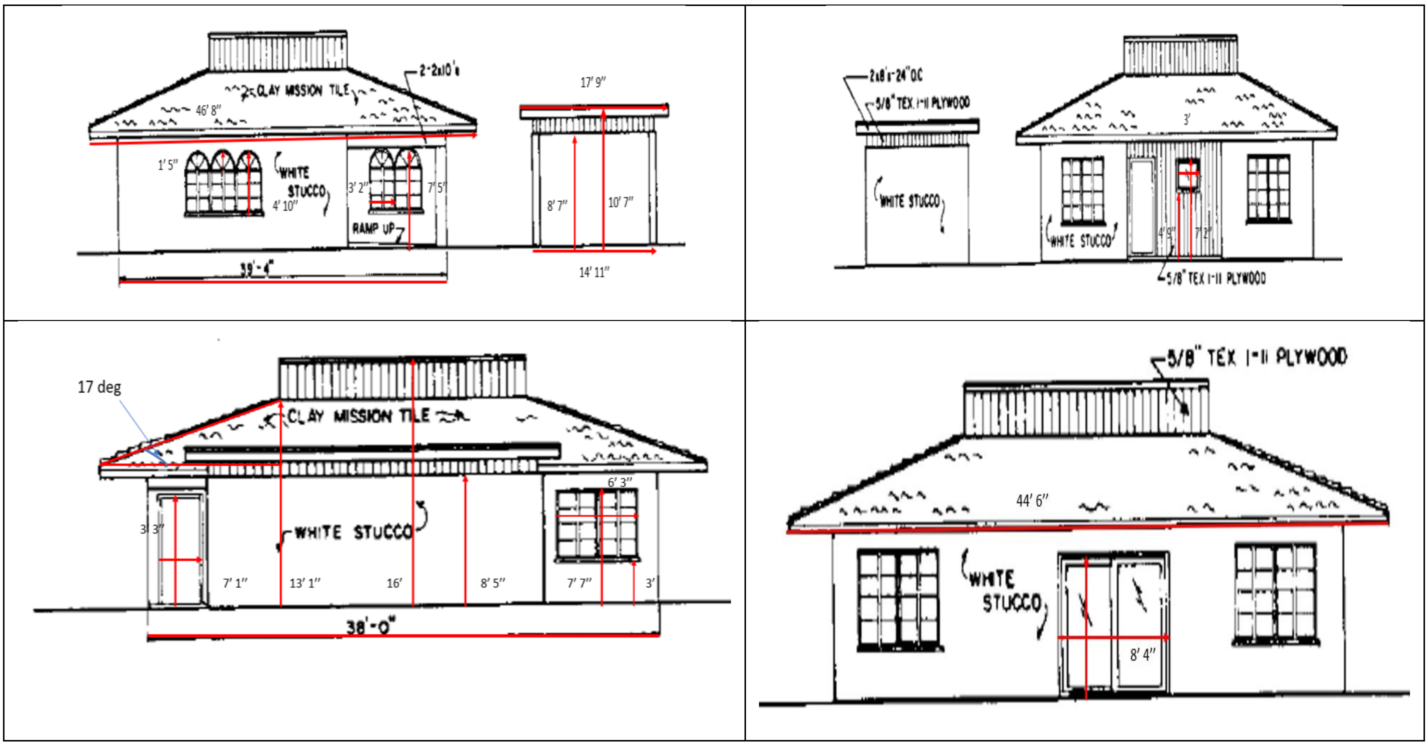


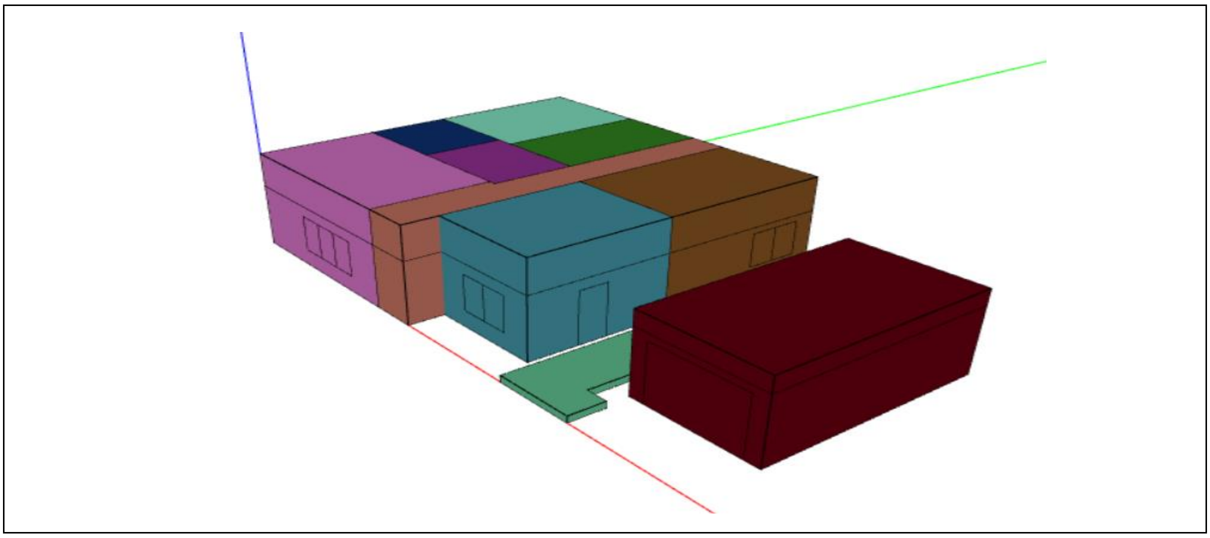
Fig 1. Elevation views

The 2-D floor plan Geometry in FloorSpace JS is shown below:

Fig 2. Floorspace JS Floorplan

The Thermal Zones are chosen such that each separate space type and the respective plenum has the same thermal zone.

The Flat roofed 3-D model are shown below:



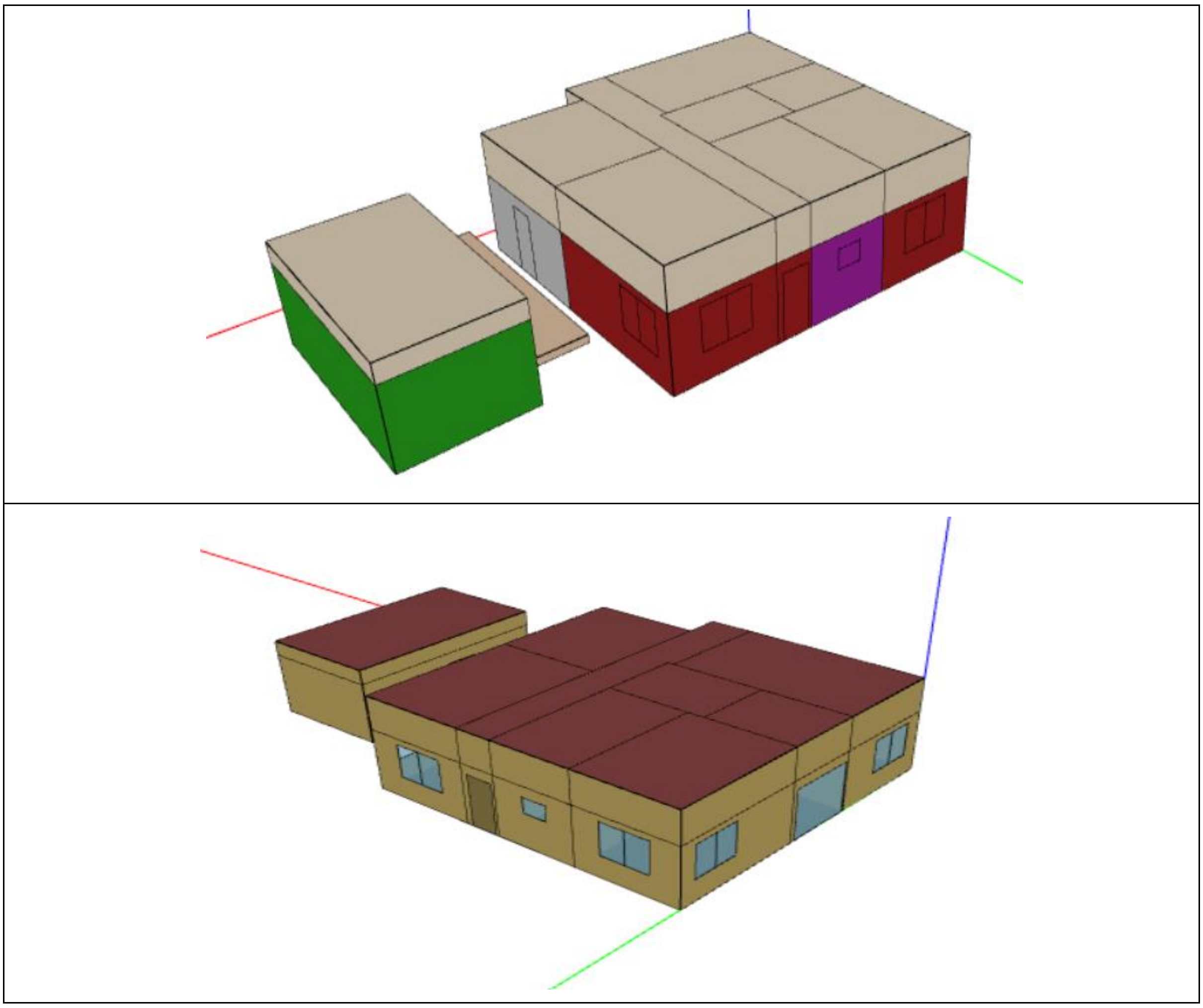


Fig 3. Flat roof 3D model

The door and Window schedule for the house a garage is attached below:

DOOR SCHEDULE			
MARK	SIZE	TYPE	QTY
1	3' x 6' - 8''	WOOD SOLID CORE EXTERIOR	3
2	3' x 6' - 8''	WOOD HOLLOW CORE EXTERIOR	4
3	2' x 6' - 8''	WOOD FOLDING	2
4	2' - 2'' x 6' - 8''	WOOD FOLDING	2
5	4' x 6' - 8''	WOOD FOLDING	2
6	10' x 6' - 8''	WOOD SLIDING (4 PANELS)	1
7	7' - 6'' x 6' - 8''	WOOD SLIDING (3 PANELS)	1
8	7' - 6'' x 6' - 8''	GLASS SLIDING	1
9	4' - 6'' x 6' - 8''	WOOD FOLDING	2

Table 2. Door Schedule

WINDOW SCHEDULE			
MARK	SIZE	TYPE	QTY

A	3' x 3'	WOOD SOLID CORE EXTERIOR	3
B	3' x 1' - 6''	WOOD HOLLOW CORE EXTERIOR	4
C	2' x 4' - 6''	WOOD FOLDING	2
D	3' x 2'	WOOD FOLDING	2

Table 3. Window Schedule

4.3. Construction

The construction chosen is that of a small hotel, since we have assumed they are made up of similar materials and are also closest to a house from the available library. The patio is made up of a separate Construction set as seen below in

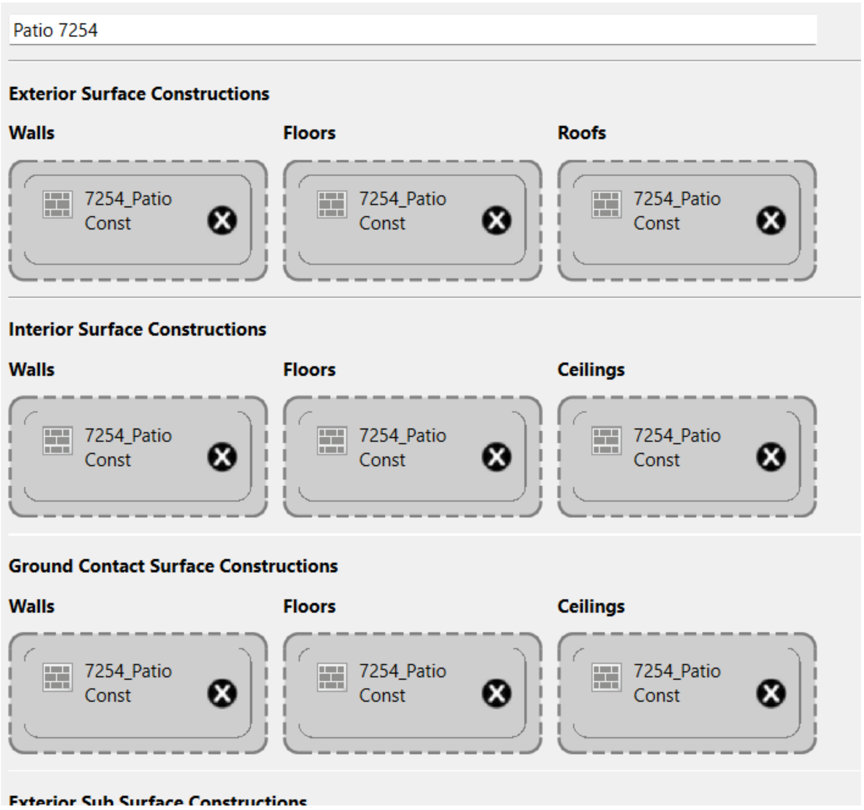


Fig 4. Patio Construction

As seen above, the construction only consists of a construction: 7254_Patio Const, which is made up of concrete to emulate a concrete patio.

4.4. Lighting and Electric Loads

The lighting loads for the various sections of the house are depicted in the table below:

Section of the house	Lighting Load per sq. ft (W/sq. ft)
Bathroom	0.5
Bedroom - 1	0.24
Bedroom - 2	0.22
Corridor	0.32
Garage	0.84
Hobby Room	0.32
Kitchen + Dining Room	1.5

Table 4. Lighting Load

The kitchen and Dining Room Lighting loads are combined, since there are no partition walls separating the two. The Garage has a high Wattage per sq. ft because high visibility is a priority. The bedrooms have a lower value, since it is easier on the eye and more relaxing.

The Electric load and the Electric Equipment considered are listed below:

Section of the House	Electric Equipment	Electric Load per sq. ft (W/sq. ft)
Bathroom	Hair Dryer, Hair Straightener	1.61
Bedroom - 1	Mobile/Laptop Charger x 3	2.34
Bedroom - 2	Mobile/Laptop Charger x 3	3.3
Corridor	None	
Garage	EV Charger	14
Hobby Room	Flat Screen TV	4.82
Kitchen + Dining Room	Microwave, Oven, Electric Stove	15

Table 5. Electric Load

The kitchen and Dining Room appliances are combined since there are no partition walls. The Kitchen and the Garage have the highest wattage per sq. ft. The values of Electric Load are slightly higher than the listed appliances in case a new device is used for a short period of time.

4.5. Facilities Tab

The north axis of the 3D – Geometry is set to 0 degree and there are no default construction/ schedule sets or space types assigned, since they all are added for the individual sections.

4.6. Spaces Tab

The Spaces tab consists of the Loads, multiplier, Definition, equipment, and activity schedules as seen below in Fig. The schedules for the equipment are done for the entire rooms instead of for a single appliance for greater simplicity. This also covers the entire house and garage.

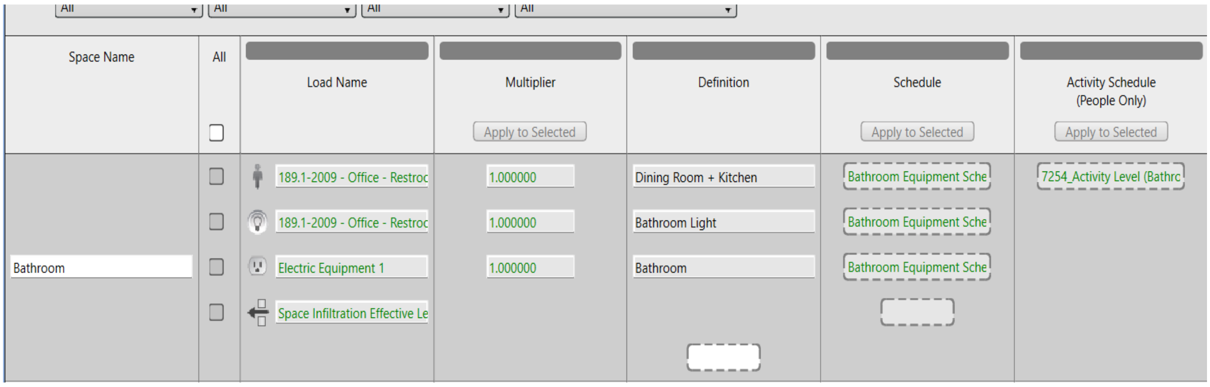


Fig 5. Spaces Tab

4.7. HVAC Systems tab

A hot water system is created for the entire building. A hot water loop is created with a constant speed pump, a 12-kW water heater and a setpoint manager, as shown below in Fig 6.

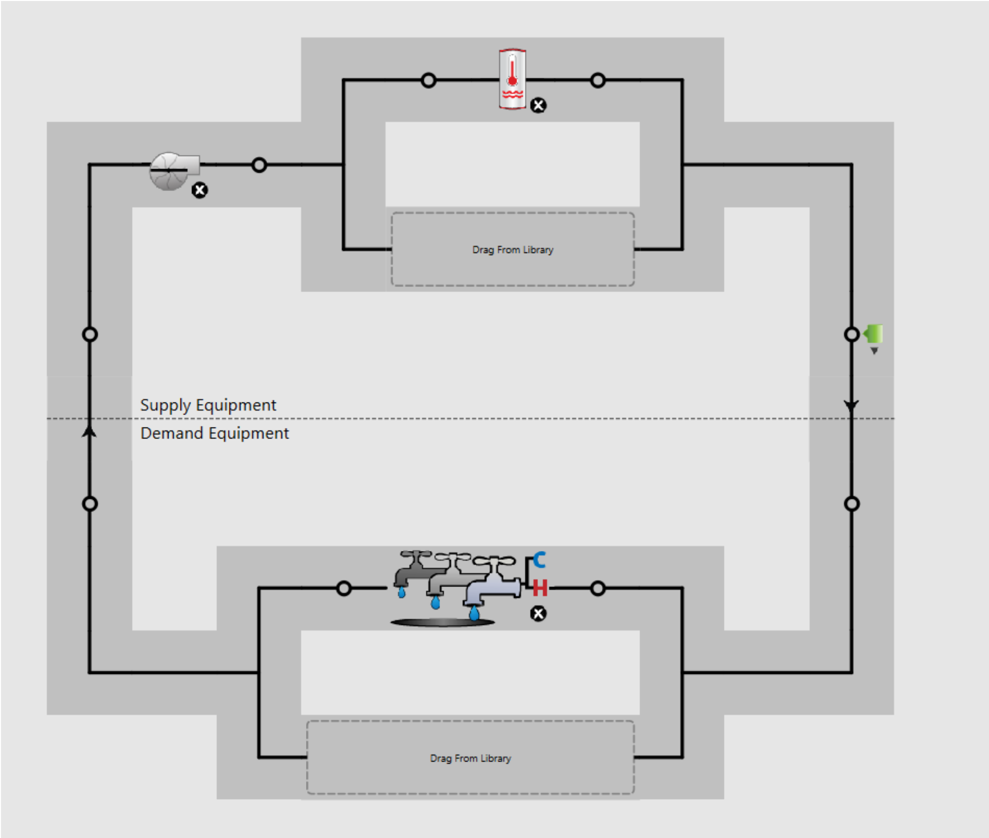


Fig 6. Hot water loop

4.8. <u>Thermal Zones</u>

The thermal zones consist of the cooling and heating schedule previously mentioned under the schedules section. The house is air conditioned by a set of electric baseboard heaters due to a high sq. ft per occupant value. The baseboard heating system also provides better zonal temperature control, lower upfront costs and are ductless.

The garage also consists of an exhaust fan for better ventilation and can be used to make minor repairs on the occupant vehicles.

4.9. <u>Settings Tab</u>

The number of timesteps are set to 4 to produce more accurate results

5. Results

5.1. Electricity Consumption

The electricity consumption of the various equipment in the house is seen below in Fig 7.

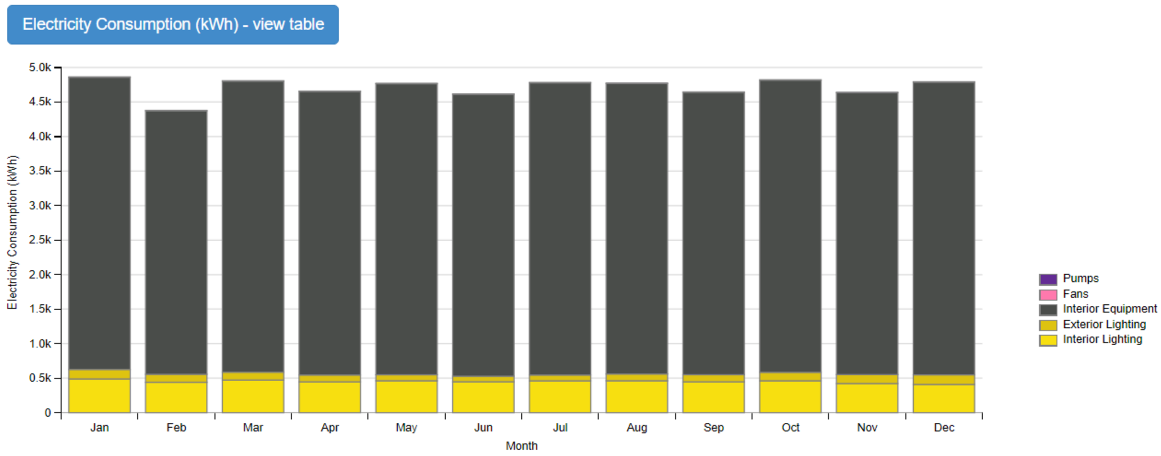


Fig 7. Electricity Consumption

The interior equipment of the house consumes the most of the electricity.

The annual overview pie chart is listed below in Fig 6

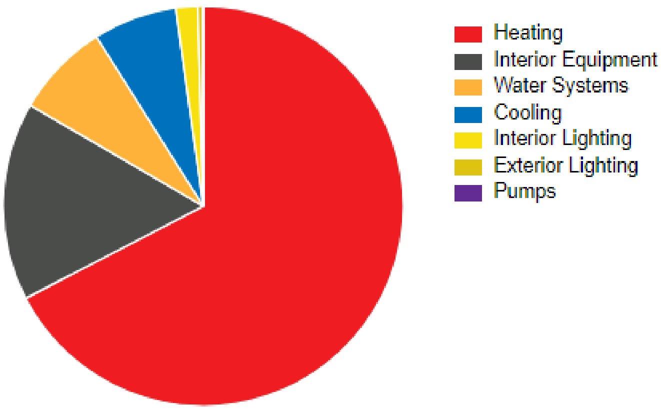
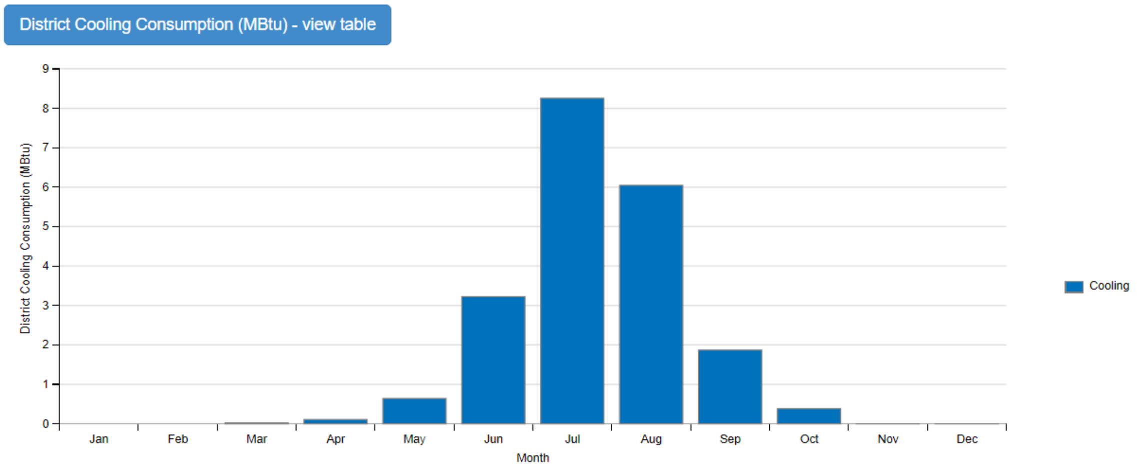


Fig 8. Annual Overview



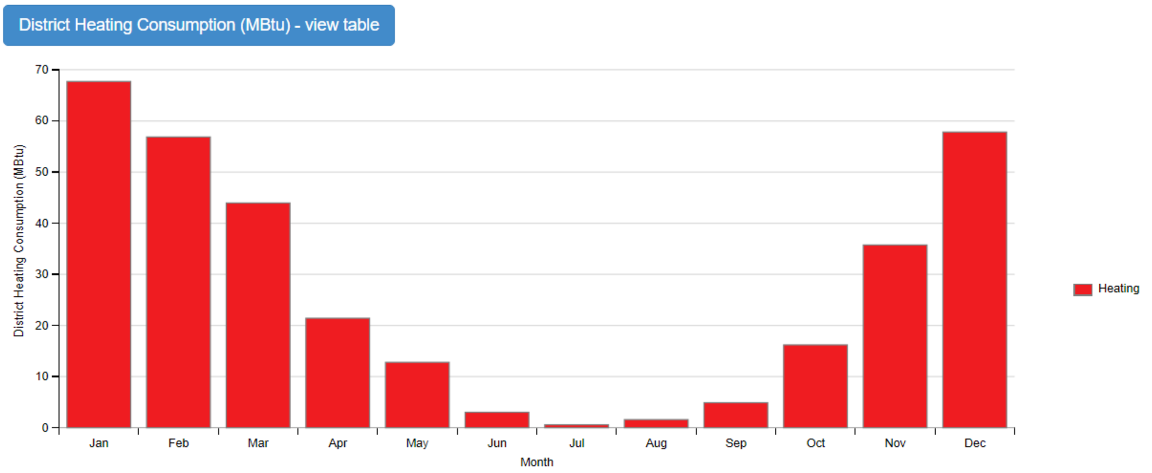


Fig 9. Month wise heating and cooling consumption

The heating load is lowest during Summer and early fall and the cooling is highest during the same time period.

5.2. HVAC Load Profiles

The HVAC heating and cooling Loads are shown below:

HVAC Load Profiles

Monthly Load Profiles - view table

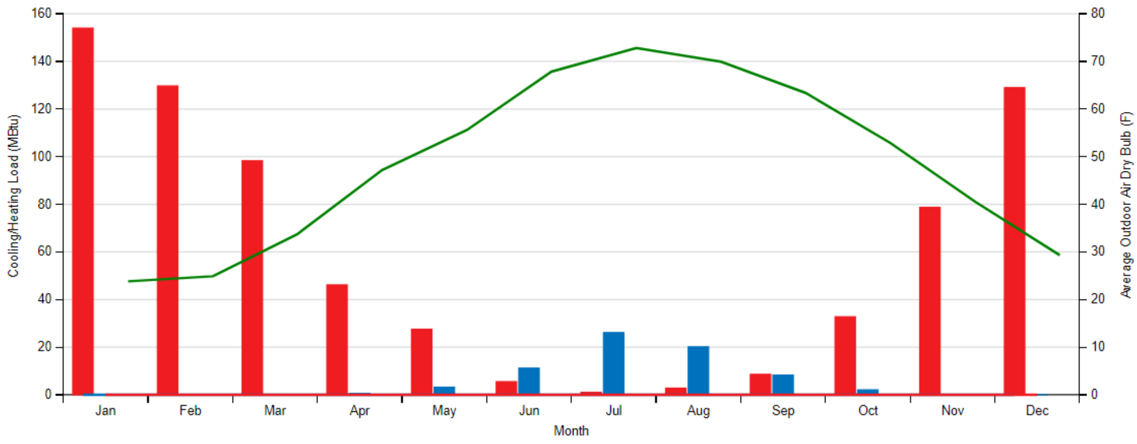


Fig 10. HVAC Load Profiles

As mentioned above the cooling Load tends to be highest during summer and Early fall.

5.3. Zone Conditions

The zone conditions are displayed below in Fig 9.

The average temperature is within 60 F – 70 F inside the house and the Garage is on average maintained ate 58.5 F. The combined Unmet Occupied heating and Cooling hours is 109 hours.

The average humidity is between 35 and 43 except the garage and patio.

Temperature (Table values represent hours spent in each temperature range)

Zone	Unmet Htg (hr)	Unmet Htg - Occ (hr)	< 56 (F)	56-61 (F)	61-66 (F)	66-68 (F)	68-70 (F)	70-72 (F)	72-74 (F)	74-76 (F)	76-78 (F)	78-83 (F)	83-88 (F)	>= 88 (F)	Unmet Clg (hr)	Unmet Clg - Occ (hr)	Mean Temp (F)
BATHROOM - TZ	16	0	598	1946	251	241	244	4591	168	143	278	193	93	14	2	0	67.0 (F)
BEDROOM -2 TZ	0	0	365	1303	371	298	185	4579	171	182	384	347	332	243	19	19	69.2 (F)
BEDROOM 1 - TZ	1	1	406	1458	395	305	205	4600	181	185	425	320	197	83	11	11	68.4 (F)
CORRIDOR - TZ	23	23	379	1374	445	316	287	4551	195	208	451	311	191	52	26	26	68.4 (F)
DINING ROOM -TZ	26	3	607	1939	231	249	247	4553	169	136	263	198	120	48	9	0	67.1 (F)
GARAGE -TZ	0	0	3818	833	455	505	271	271	333	348	634	528	347	417	0	0	58.5 (F)
HOBBY ROOM -TZ	1	0	371	1272	396	292	193	4598	174	175	404	343	309	233	19	0	69.2 (F)
KITCHEN - TZ	9	0	570	1876	270	258	234	4570	188	181	290	210	101	12	2	0	67.2 (F)
LIVING ROOM -TZ	0	0	258	1049	390	390	186	4623	196	182	409	421	375	281	46	29	70.0 (F)
PATIO -TZ	71	0	605	2003	280	301	328	4561	139	132	200	125	74	12	3	0	66.7 (F)

Humidity (Table values represent hours spent in each Humidity range)

Zone	< 30 (%)	30-35 (%)	35-40 (%)	40-45 (%)	45-50 (%)	50-55 (%)	55-60 (%)	60-65 (%)	65-70 (%)	70-75 (%)	75-80 (%)	>= 80 (%)	Mean Relative Humidity (%)
BATHROOM - TZ	3153	661	495	520	515	582	554	458	428	378	383	633	42.6 (%)
BEDROOM -2 TZ	3362	776	688	704	650	886	668	404	355	226	40	1	37.4 (%)
BEDROOM 1 - TZ	3269	723	618	642	636	850	704	483	411	306	105	13	38.6 (%)
CORRIDOR -TZ	3282	747	621	612	577	800	693	454	428	359	151	36	38.9 (%)
DINING ROOM - TZ	3162	681	503	526	525	576	545	453	440	355	370	624	42.4 (%)
GARAGE -TZ	1843	719	817	814	828	888	771	687	562	453	265	113	45.7 (%)
HOBBY ROOM - TZ	3485	788	671	665	644	865	608	393	338	235	64	4	36.9 (%)
KITCHEN - TZ	3165	671	514	534	524	686	598	480	456	451	345	336	41.5 (%)
LIVING ROOM - TZ	3638	798	701	670	645	1078	564	332	226	100	8	0	35.6 (%)
PATIO -TZ	3159	652	478	499	497	531	513	424	396	398	372	841	43.5 (%)

Fig 11. Zone Conditions

5.4. Building Summary

Building Summary

Data	Value
Building Name	2 bedroom_7254
Total Site Energy	1,132,300 kBtu
Total Building Area	3,938 ft^2
Total Site EUI	287.54 kBtu/ft^2
OpenStudio Standards Building Type	n/a

Fig 12. Building Summary

The Total Site Energy Use Intensity (EUI) is 287.54 kBtu/ft^2 = 84.27 kWh/ft^2.

6. Conclusion

From the monthly electricity consumption graph, we see that the electrical appliance consumes the most electricity, which is a logical result. A similar trend can also be seen in the peak demand consumption.

The annual overview pie chart shows that heating consumes 67% of the energy, while only 7% of the energy is spent in cooling. This correlates with the fact that the 2nd lowest temperature (-27.2 C) in the history of Windsor, ON was recorded in 1984.

The HVAC heating loads tend to be higher in the winter months and the cooling load higher in early fall and summer months.

From Zone Conditions results table we can infer that the house is maintained in the temperature range of 68-72 F for the maximum number of hours. ASHRAE recommends a temperature range of 68.5 F to 75 F. This suggests that the load calculation model has resulted in favourable results [4].

The garage is however maintained below 56 F for 3818 hours. This is because garages in general are maintained at a lower temperature and for the most part is unoccupied [4].

The desirable humidity value for a house between 30 % and 40 % which correlates with the average humidity values of the house (35% – 40%) except the garage and patio [4].

The occupied unmet hours for heating are 23 and for cooling is 85, a combined value is 108 hours. This value is significantly lower than the recommended maximum 300 hours according to ASHRAE standard 90.1 suggesting that the load calculation model yields accurate results.

The Total Site Energy Use Intensity is 84.27 kWh/ft^2. The average home in Ontario consumes about 9500 kWh per year with an average area of 1500 ft^2, Total Site EUI is approximately 6.33 kWh/ft^2 [5]. This value will however be higher for the average detached home in the state of Ontario. Another consideration is that our project home consists of an EV charger in the garage capable of charging the vehicle to full battery overnight with a W/ft ^2 of 9.15, which is the highest in the house and could result in the increase in the overall site EUI.

The results suggest that the load calculation model has produced mostly accurate and favourable results. The only value higher than average is the Site EUI, which is higher due to the use of an EV charger, which is not available in most homes. This suggests that for the most part the values are coherent and the use of custom space types, construction sets and the modeling of sloped roof model will produce better results.

REFERENCES

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[4] "Standards and guidelines," Ashrae.org. Accessed: 30-July-2023 [Online]. Available: https://www.ashrae.org/technical-resources/standards-and-guidelines.

[5] "Residential electricity and natural gas plans," EnergyRates.ca, 29-Nov-2016. Accessed: 30-July-2023 [Online]. Available: https://energyrates.ca/residential-electricity-natural-gas/.

APPENDIX

[1] The Total Site EUI for a year = (The Average Energy consumed for a year (kWh)/ Site Area in ft^2)) = 9500/1500 = 6.333 kWh/ft.^2