Thermal Design for CPU cooling.

MECH 5825: Heat Transfer 2

Youngstown State University

Submitted by:

Sandesh Neupane

Date of Submission: March 14th ,2021

Submitted to:

Dr. K. Choo

I. Introduction

The objective of the study is to find the thermal performance of the residential housing. House are made up of different materials and different materials have different properties and thermal conductivity. Depending on the materials used to build the house, location of the house and orientation of the house, different house have different thermal performance. For this project, eQUEST software was used to simulate the thermal effectiveness. eQUEST software give the usage of natural gas and the electricity on the building. To verify the result from the eQUEST, actual utility bill is to be compared to the result from the eQUEST. Finally, based on the result obtained, various energy conservation methods are to be suggested.

II. Building Overview and Modeling

For this project, 3-bedroom floor of the residential house- 839 Fifth Avenue, Youngstown, OH was analyzed. Actual building is a two-floor building and different household lives in two different floors, and both have separate HAVC systems. Also, utility bill is available for only the first floor which will be used to compare with the eQUEST result.

Various conditions and assumptions were used as an input for the software, and they are listed below:

a. Building Geometry and Location

Figure 1 shows the SW view of the building. Main entrance for the building is faced to the West. Building contains total of 3 bedrooms, 1 kitchen and 1 bathroom. There is backdoor facing to the north which leads to the parking. The total area of the building is 2565 sq ft. Number of floor is 1 and there is no basement. Building is located in Youngstown, Ohio.

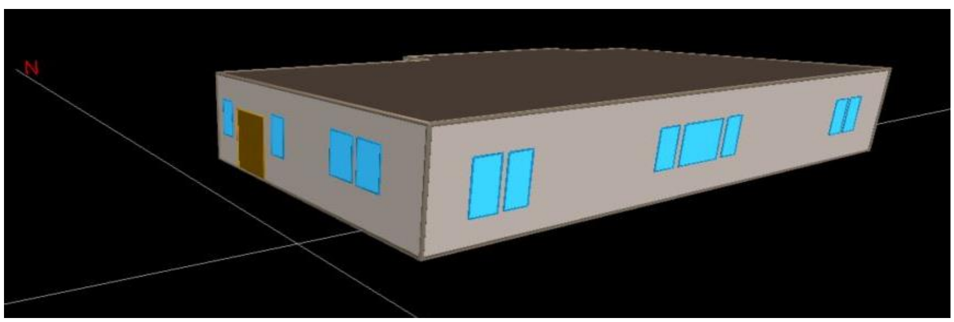

Figure 1: SW view of the building.

Figure 2 shows the NE view of the building.

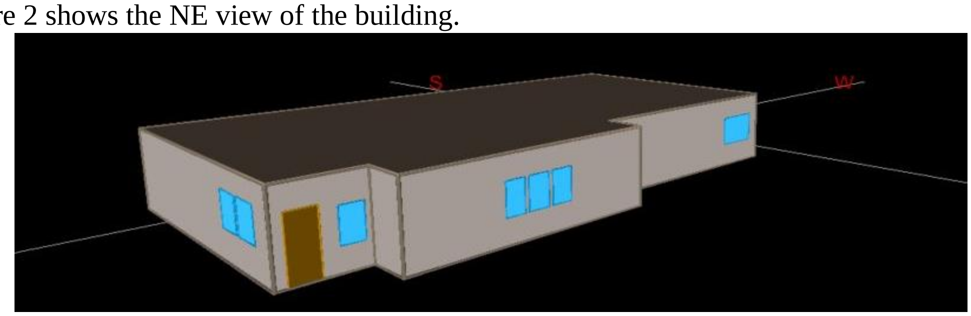

Figure 2: NE view of the building.

b. Roof

Since there is another conditioned floor above the first floor, there is practically no roof in the house, the heat transfer from the first floor to the upper floor is negligible.

c. Exterior and interior walls

Properties of exterior and the interior walls can be seen in Table 1.

Table 1:Properties of exterior and interior wall

Construction	Wood Frame, 2 6, 24 in. o.c	
Ext Finish/Color	Wood/Plywood	Medium (abs=0.6)
Exterior Insulation	3/4 in. fiver bd sheathing (R-2)	
Additional Insulation	R-19 batt	
Interior insulation	1 in. polystyrene (R-4)	

d. Ground floor

Properties of the ground floor used as an input for the software can be seen in Table 2.

Table 2:Properties of the floor.

Exposure	Earth Contact
Construction	6 in. Concrete
Ext/Cav Insul.	Vert ext bd, R-10, 4ft deep
Interior Finish	Carpet with fiber pad

e. Ceiling

Properties of the ground floor used as an input for the software can be seen in Table 3.

Table 3:Properties of ground floor.

Interior finish	Drywall
Framing	Standard wood
Insulation	R-13 batt

f. Exterior doors

Table 4:Exterior door specifications

	Type 1	**Type 2**
Door type	Opaque	Opaque
Number	1	1
Orientation	North	West
Dimension	7’× 3’	8’ × 6’
Construction	Wood, 7/16 in. panel	Wood, Solid core Flush

g. Windows

Table 5: Window specifications

	Type 1	**Type 2**
Glass Category	Double Clear	Double clear
Glass type	Double Clear 1/4 in., 1/2 in. Air	Double Clear 1/4 in., 1/2 in. Air
Frame type	Wood, Aluminum Clad, Fixed	Wood, Aluminum Clad, Fixed
Frame Width	1.5 in	1.5 in
Height	4ft	4ft
Width	5ft	8ft

h. Activity area allocation

Table 6:Activity area allocation

Area Type	Percent Area (%)	Design Max Occup. (sf/person)	Design Ventilation (CFM/per)
Residential (Bedroom)	63	624	10
Storage (Conditioned)	10	500	75
Laundry	2	200	25
Kitchen and food preparation	10	200	15
Restrooms	5	300	50
Dining Area	10	100	20

i. Interior Lighting Loads and Profiles

Table 7: Interior lightning loads and profiles.

	Lighting W/SqFt
Residential (Bedroom)	0.3
Storage (Conditioned)	0
Laundry	0.1
Kitchen and food preparation	0.5
Restrooms	0.2
Dining Area	0.5

j. Miscellaneous Loads and Profiles

Table 8:Miscellaneous loads and profiles.

	Electric		Natural Gas	
	Load (W/SqFt)	Sensible Ht(frac)	Load (Btuh/SF)	Sensible Ht(frac)
Residential (Bedroom)	0.3	0.3	0	0.3
Storage (Conditioned)	0	0.1	0	0.1
Laundry	0.15	0.5	0	0.5
Kitchen and food preparation	0.3	0.5	0.8	0.5
Restrooms	0.1	0.3	0	0.2
Dining Area	0.1	0.3	0	0.3

k. Schedule Information

Table 9:Schedule information

Operating time	6am- 9pm
Occupancy Percentage	50%
Light Load Percentage	45%
Fan 'on' mode	Continuous
Cycle fans at night	no fan night cycling

l. Heating & Cooling

Table 10:Heating and Cooling information

Heating Source	Furnace	
Cooling Source	DX Coils	
System Type	Packaged Single Zone DX with Furnace	
Return air path	Direct	
Thermostat (Occupied)	75 F	68 F
Thermostat (Unoccupied)	75 F	68 F

The furnace used in the building was Lennox EL196E shown in Figure 3.

Figure 3: Furnace used in the design.

m. Design Temperatures and Air Flows

Table 11: Design temperature and air flows

	Indoor	Supply
Cooling Design Temp.	72 F	55 F
Heating Design Temp.	72 F	120 F
Minimum Design Flow	0.5 cfm/ft2	

n. Domestic Water Heating

Table 12: Domestic water heating.

Heater Fuel	Natural Gas
Heater type	Storage
Hot water usage	20 gal/person/day
Input Rating	31.6 kBtuh
Energy Factor	0.05
Tank Capacity	300 Gal
Insulation R- value	12 h-ft2-F/Btu
Supply water Temp	110 F
Inlet water Temp	Equal Ground Temperature

The schematic of the model's HVAC system is pictured below:

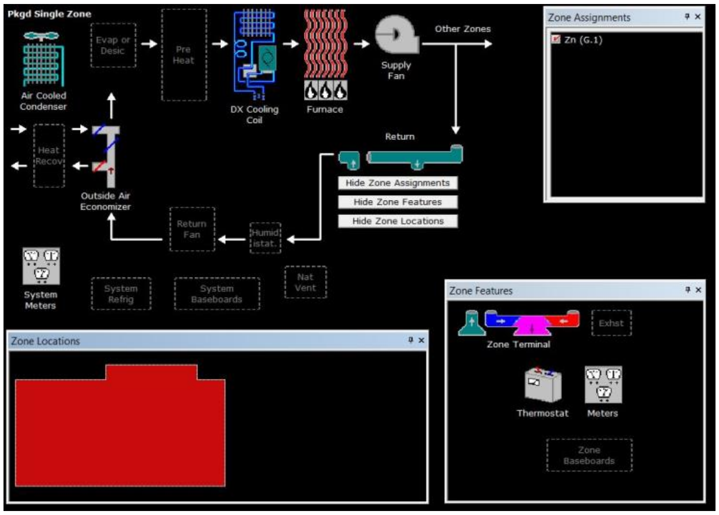

Figure 4: Schematic of model HVAC system.

III. Result and Discussion

Figure 5 shows the Electricity Consumption (kWh) obtained from the software. Maximum electricity consumption was seen in months of July and August. Due to the warm weather during July and August in Youngstown, there is need of the space cooling, so the electricity consumption is higher in those months. Significant amount of electricity was consumed by miscellaneous equipment like microwave, blender, vacuum cleaner and so on. Ventilation and Fans also consume some electricity. Area lighting also contribute to the significant amount of electric consumption. Table for the detailed electricity consumption can be seen in Appendix A.

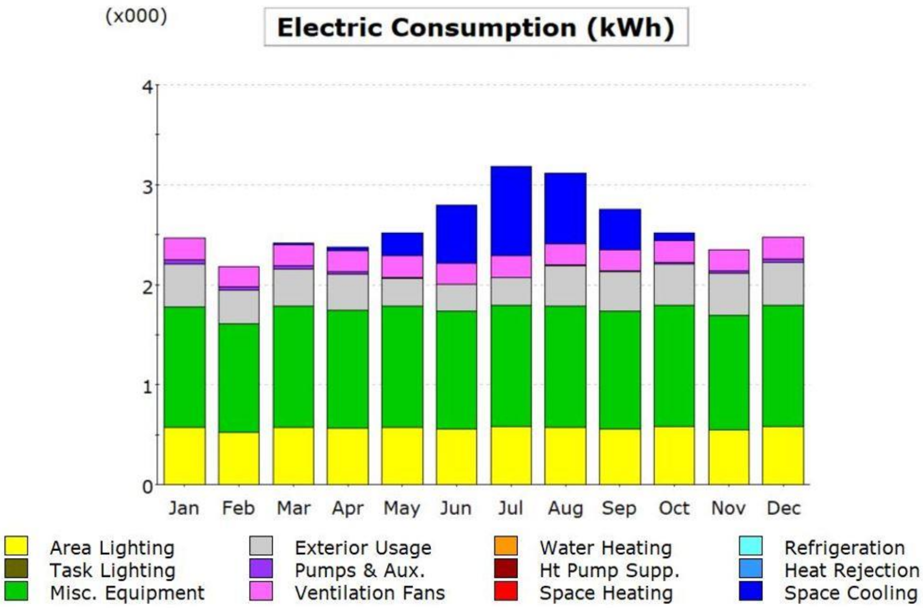

Figure 5: Electricity Consumption (KWh)

Figure 6 shows the actual utility bill for the electric consumption. The actual electricity consumption looks very similar to the result obtained from the simulation. While the shape of the graphs is very similar in both cases, actual electric bill is little less than the software results as lots of assumptions were made during the simulation. Due to the correlation on the shape of the bar graphs, we can be confident about the result from the simulation.

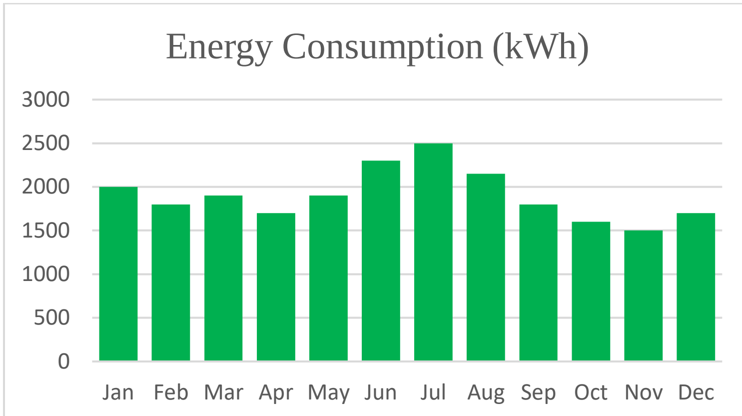

Figure 6: Actual Electricity Consumption (KWh)

Figure 7 shows the graph of gas consumption (Btu) obtained from the simulation. Majority of the gas consumption is for the spacing heating during the winter and the water heating. Due to the extreme cold temperature of Youngstown in winter, it is reasonable that the large number of the gas is consumed for the space heating. Moreover, significant amount of the gas was consumed for the water heating as well. The amount of gas consumed for water heating is constant for all weather regardless of hot or cold. But in reality, the amount of the gas consumed for the water heating is more in winter then in summer because people prefer to use cold water more during summer.

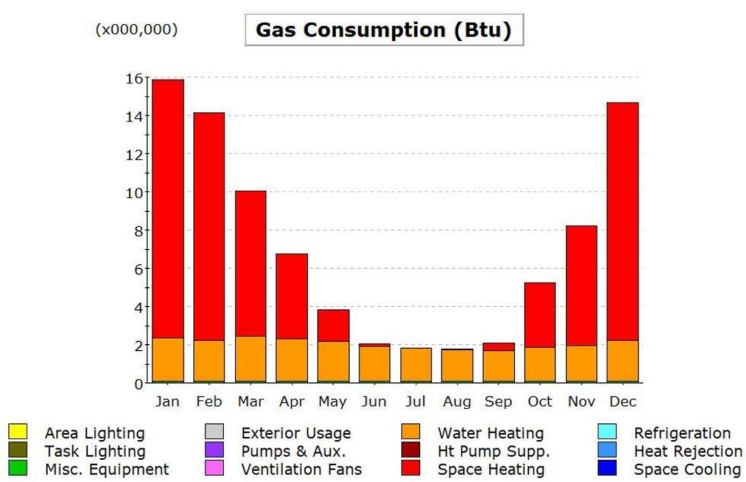

Figure 7: Gas consumption from simulation

Figure 8 shows the actual gas consumption chart for the building. Those two charts have very strong correlation. The amount of gas usage in actual utility bill is litter higher than the simulated results. This might be due to the assumptions made during the simulations and there might be crack in the house here and there from where the cold air gets in into the house.

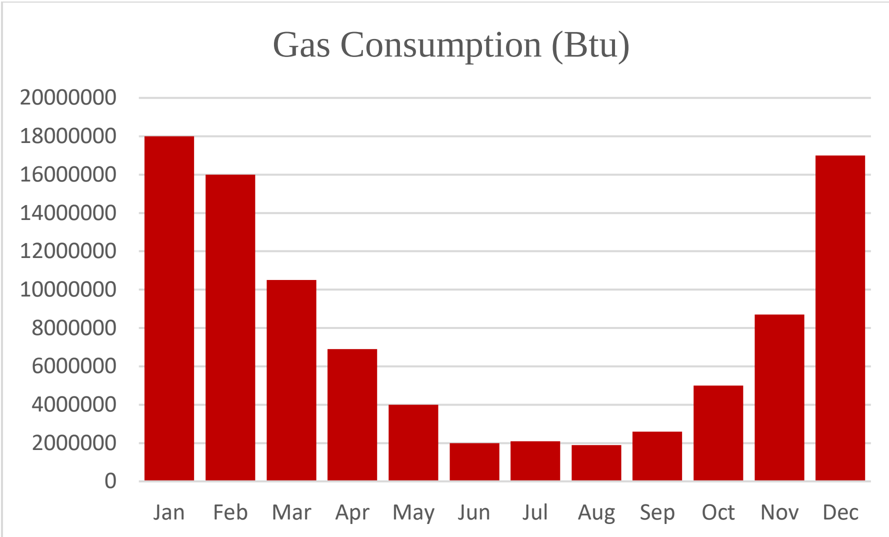

Figure 8: Actual gas consumption of the building

Figure 9 shows the percentage of electricity and gas consumption allocated for various sectors. Large amount of the electricity was consumed by the miscellaneous equipment followed by the area lighting, while the large number of the gas was consumed for the space heating followed by water heating. Based on the result obtained from the simulations, various energy conservation methods can be suggested.

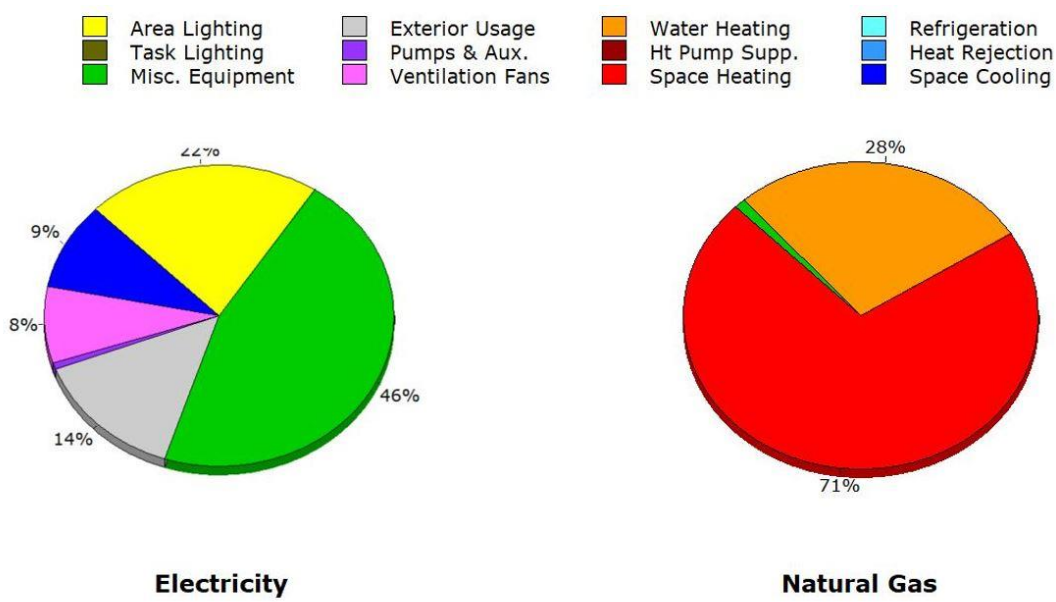

Figure 9: Energy allocation for the building.

Form the Figure 9, sector for majority energy consumption can be seen. Improving in those sectors might help in energy conservation decreasing the electricity and gas consumption. Following suggestions can be made based on above results:

a. **Reduce Area Lighting**
   About 22% of the electricity consumption was from the area lightning. Area lightning can be reduced easily to make the building energy efficient. Turing the light off while no one in the house or turning lights on the room only when needed can be good habit to conserve the energy and decrease the cost. Using LED lights in every room can be very beneficial

b. **Reduce use of unnecessary equipment**
   The use of the equipment like vacuum cleaner, mixture, grinder, microwave, hair dryer etc can be reduced if possible. Those equipment consume about 46% of the total electricity so using that equipment less often can significantly decrease the energy consumption. Equipment that consumes less electricity can be purchased to decrease the cost in long term. Replacing old equipment's which consumes lot of power can be replaced.

c. **Seal infiltration in the building during winter.**
   During winter, infiltration in doors and windows plays major role to cool the place. Sealing those infiltration can drastically decrease the consumption of natural gas. Habit of opening doors and windows frequently can be improved to decrease the natural gas consumption. Fixing the cracks on the building will also be beneficial to decrease the consumption of natural gas.

d. **Use of double panel window with argon in every room.**
   Double pan window is very efficient in insulating the building during winter. Heat from the building will not go outside to high thermal resistance of the double panel window with argon between the glasses.

e. **Addition of insulation**
   Old and ineffective insulation can be replaced by the new and highly efficient insulation materials. High quality insulation material might cost more during buying but in the long run it will be cost effective as the consumer will be saving lot of money from the low consumption of natural gas and electricity.

f. **Purchase more energy efficient furnace**
   The current gas furnace in the building is (), has nominal thermal efficiency of 80%. So, purchasing more efficient furnace can be highly beneficial to decrease the energy consumption. Furnace such as Lennox SLP98V, Carrier which has efficiency more then 98% can be used to increase the energy efficiency of the building.

Simulation was run one more time to see the change in energy consumption. Figure 10 and Figure 11 shows the new results obtained from the simulation.

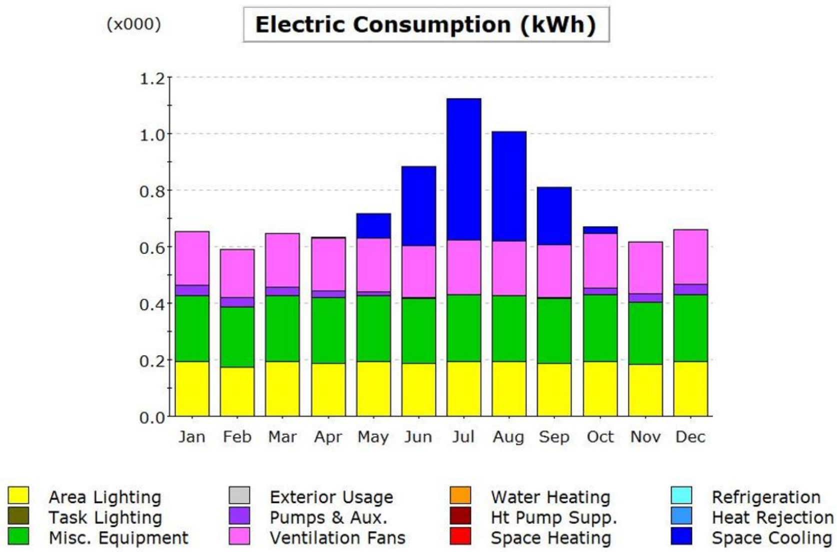

Figure 10: Electricity consumption after ECM

It can be seen that the electricity consumption decreases significantly for the updated building from 31.13 $\times 10^3$ KWh to 9 $\times 10^3$ KWh.

Figure () shows the reduction of gas consumption after applying the energy conservation measures. Gas consumption was decreased from 86 $\times 10^6$ Btu to 67 $\times 10^6$ Btu.

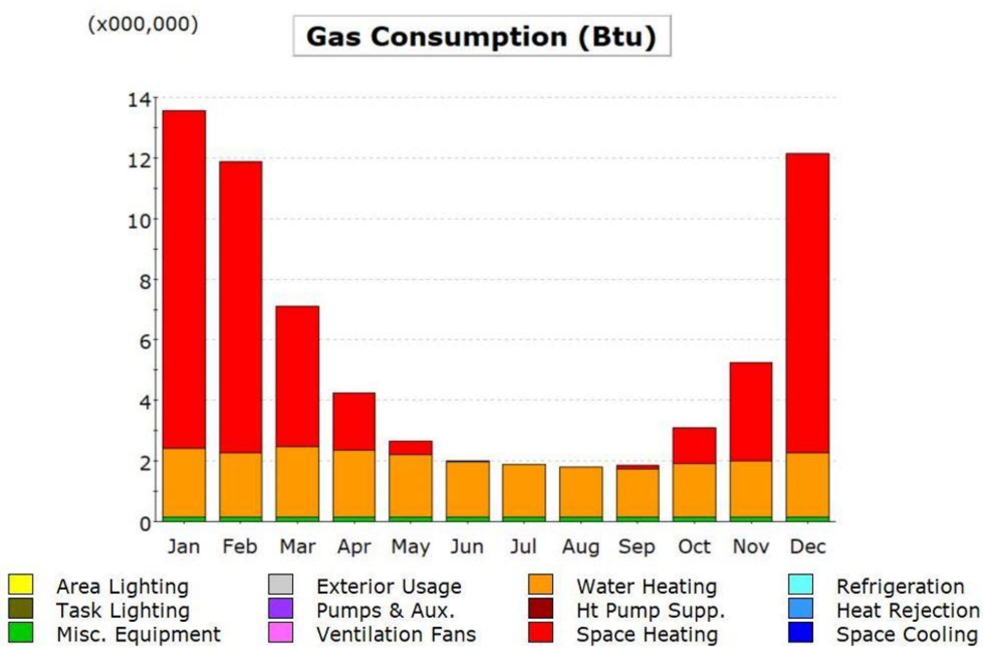

Figure 11: Gas consumption after ECM.

Gas Consumption (Btu x000,000)

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
Space Cool	-	-	-	-	-	-	-	-	-	-	-	-	-
Heat Reject.	-	-	-	-	-	-	-	-	-	-	-	-	-
Refrigeration	-	-	-	-	-	-	-	-	-	-	-	-	-
Space Heat	13.51	11.91	7.60	4.47	1.63	0.14	-	0.04	0.42	3.38	6.26	12.42	61.78
HP Supp.	-	-	-	-	-	-	-	-	-	-	-	-	-
Hot Water	2.29	2.15	2.36	2.23	2.10	1.84	1.74	1.65	1.62	1.80	1.89	2.14	23.81
Vent. Fans	-	-	-	-	-	-	-	-	-	-	-	-	-
Pumps & Aux.	-	-	-	-	-	-	-	-	-	-	-	-	-
Ext. Usage	-	-	-	-	-	-	-	-	-	-	-	-	-
Misc. Equip.	0.08	0.07	0.08	0.08	0.08	0.08	0.08	0.08	0.08	0.08	0.07	0.08	0.92
Task Lights	-	-	-	-	-	-	-	-	-	-	-	-	-
Area Lights	-	-	-	-	-	-	-	-	-	-	-	-	-
Total	15.88	14.13	10.04	6.78	3.80	2.05	1.82	1.77	2.11	5.26	8.22	14.65	86.51

Electric Consumption (kWh x000)

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
Space Cool	-	-	0.01	0.03	0.22	0.58	0.90	0.70	0.40	0.07	0.00	-	2.92
Heat Reject.	-	-	-	-	-	-	-	-	-	-	-	-	-
Refrigeration	-	-	-	-	-	-	-	-	-	-	-	-	-
Space Heat	-	-	-	-	-	-	-	-	-	-	-	-	-
HP Supp.	-	-	-	-	-	-	-	-	-	-	-	-	-
Hot Water	-	-	-	-	-	-	-	-	-	-	-	-	-
Vent. Fans	0.22	0.20	0.22	0.21	0.22	0.21	0.22	0.22	0.21	0.22	0.21	0.22	2.56
Pumps & Aux.	0.04	0.03	0.03	0.02	0.01	0.00	0.00	0.00	0.01	0.02	0.03	0.04	0.23
Ext. Usage	0.43	0.34	0.38	0.36	0.28	0.27	0.28	0.41	0.40	0.41	0.42	0.43	4.40
Misc. Equip.	1.21	1.09	1.21	1.18	1.21	1.17	1.21	1.21	1.17	1.21	1.15	1.21	14.24
Task Lights	-	-	-	-	-	-	-	-	-	-	-	-	-
Area Lights	0.57	0.52	0.57	0.56	0.57	0.56	0.58	0.57	0.56	0.58	0.55	0.58	6.78
Total	2.46	2.18	2.41	2.37	2.51	2.79	3.19	3.11	2.75	2.51	2.35	2.48	31.13

Figure 12: Originally simulated electricity and gas consumption for the building.

Electric Consumption (kWh x000)

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
Space Cool	-	-	0.00	0.00	0.09	0.28	0.50	0.39	0.20	0.02	-	-	1.49
Heat Reject.	-	-	-	-	-	-	-	-	-	-	-	-	-
Refrigeration	-	-	-	-	-	-	-	-	-	-	-	-	-
Space Heat	-	-	-	-	-	-	-	-	-	-	-	-	-
HP Supp.	-	-	-	-	-	-	-	-	-	-	-	-	-
Hot Water	-	-	-	-	-	-	-	-	-	-	-	-	-
Vent. Fans	0.19	0.17	0.19	0.19	0.19	0.19	0.19	0.19	0.19	0.19	0.18	0.19	2.25
Pumps & Aux.	0.04	0.03	0.03	0.02	0.01	0.00	0.00	0.00	0.01	0.02	0.03	0.04	0.23
Ext. Usage	-	-	-	-	-	-	-	-	-	-	-	-	-
Misc. Equip.	0.23	0.21	0.23	0.23	0.23	0.23	0.24	0.23	0.23	0.24	0.22	0.24	2.77
Task Lights	-	-	-	-	-	-	-	-	-	-	-	-	-
Area Lights	0.19	0.17	0.19	0.19	0.19	0.19	0.19	0.19	0.19	0.19	0.18	0.19	2.27
Total	0.65	0.59	0.65	0.63	0.72	0.88	1.12	1.01	0.81	0.67	0.62	0.66	9.01

Gas Consumption (Btu x000,000)

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
Space Cool	-	-	-	-	-	-	-	-	-	-	-	-	-
Heat Reject.	-	-	-	-	-	-	-	-	-	-	-	-	-
Refrigeration	-	-	-	-	-	-	-	-	-	-	-	-	-
Space Heat	11.12	9.61	4.62	1.91	0.43	0.03	-	0.00	0.12	1.18	3.23	9.88	42.14
HP Supp.	-	-	-	-	-	-	-	-	-	-	-	-	-
Hot Water	2.26	2.12	2.32	2.19	2.06	1.81	1.72	1.63	1.59	1.76	1.86	2.11	23.44
Vent. Fans	-	-	-	-	-	-	-	-	-	-	-	-	-
Pumps & Aux.	-	-	-	-	-	-	-	-	-	-	-	-	-
Ext. Usage	-	-	-	-	-	-	-	-	-	-	-	-	-
Misc. Equip.	0.16	0.14	0.16	0.15	0.16	0.15	0.16	0.16	0.15	0.16	0.15	0.16	1.85
Task Lights	-	-	-	-	-	-	-	-	-	-	-	-	-
Area Lights	-	-	-	-	-	-	-	-	-	-	-	-	-
Total	13.54	11.87	7.10	4.26	2.65	2.00	1.88	1.79	1.86	3.10	5.23	12.15	67.43

Figure 13: Electricity and gas consumption for the building after ECM.

***Payback Calculation*:**

Further considerations to be implemented as energy conservation methods are:

a. Energy efficient LED lightbulbs (8 pieces/12 packs, 60W): $9.69×12 = $116.28
b. Seal infiltration: $8 per ft = $3000
c. Wall insulation (R-13, fiberglass): $400
d. New efficient furnace: $ 2000
e. New efficient misc. equipment: $1500

Total: $7016.28.

Savings generated from energy conservation measures: $1886/year = $157.16

Finally, the total payback period comes out to be:

$$Payback\ period = \frac{\$7016.28}{157.16}$$

$$Payback\ period = 45\ months$$

IV. Conclusion and recommendation

From the simulation, it was found that the energy consumption can significantly decreased by following various energy conservation methods like Reducing area lighting, using new equipment, using energy efficient furnace. By following these methods $1886/year can be saved each year. The payback period for this energy conservation method was found to be about 45 months.