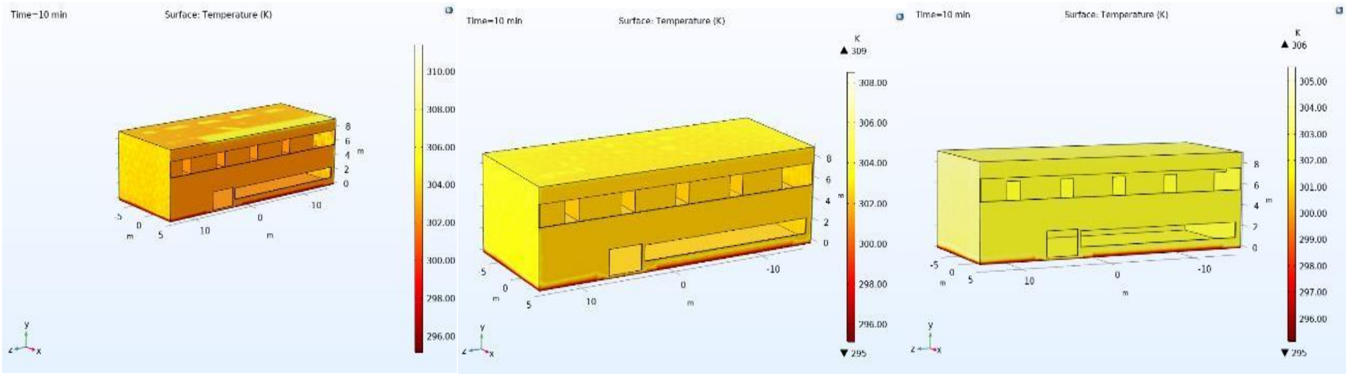

Figure 8: Temperature distribution for April, May, June

3.2 Simulation with different conditions

Direct simulation for all the conditions will result in normal mesh, thereby leading to an unfavorable impact in calculating efficiency. The simulations for different conditions on different model are given below:

3.2.1.1 Model 1: With room interior vegetation

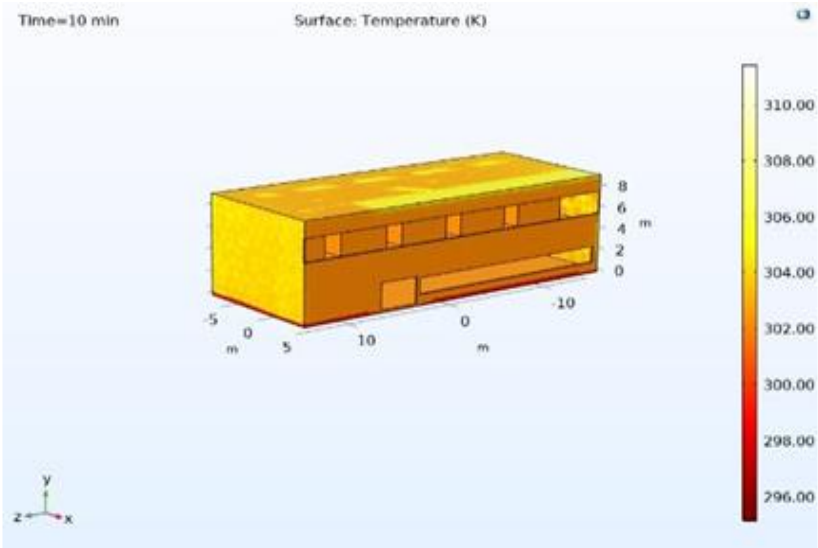

Figure 9: Temperature distribution for the month, April

From this simulation it can be seen that there is no significant change in temperature distribution. So interior vegetation is not helpful for reducing UHI effect. But it improves environment quality, boost moods and reduce air pollution.

3.2.1.2 Model 2: With rooftop vegetation

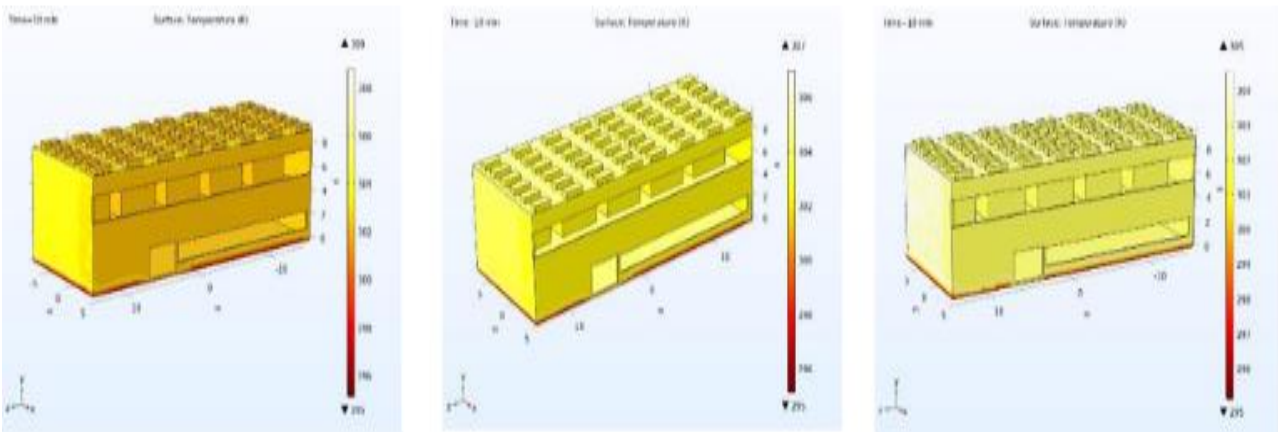

Figure 10: Temperature distribution for April, May, Jun

3.2.1.3 Model 3: With interior vegetation

The distribution of maximum and minimum temperature for April, May, June 2020 is 308.66K and 296K, 306.54K and 296K, 304.43K and 296K respectively. The maximum temperature can be seen on partial portions of rooftop and the sidewall where the sunlight directly strikes. The lowest temperature can be seen in the ground portion.

3.2.1 Using proper vegetation

We had done three different simulations in which vegetation was created on different aspects. The temperature distribution analysis of three different simulations are given below:

The distribution of maximum and minimum temperature for April, May, June 2020 is 308.80K and 296K, 306.95K and 296K, 304.565K and 296K respectively. The maximum temperature can be seen on partial portions of rooftop and the sidewall where the sunlight directly strikes. The lowest temperature can be seen in the ground portion.

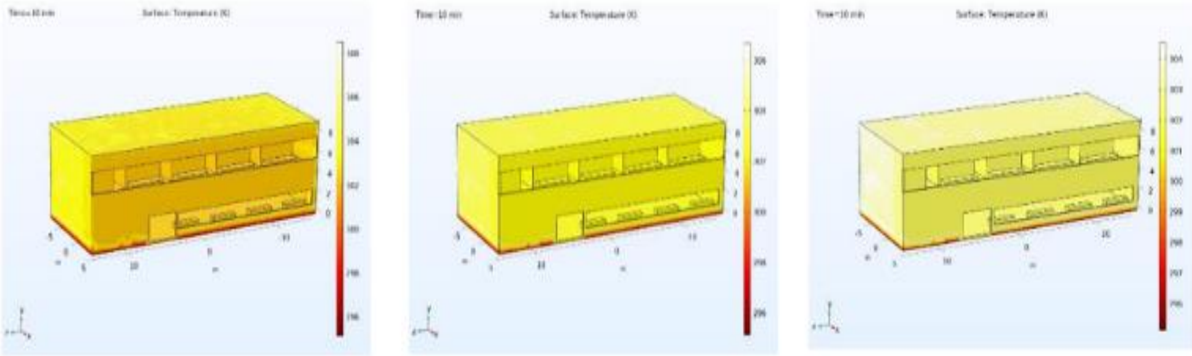

Figure 11: Temperature distribution for April, May, June

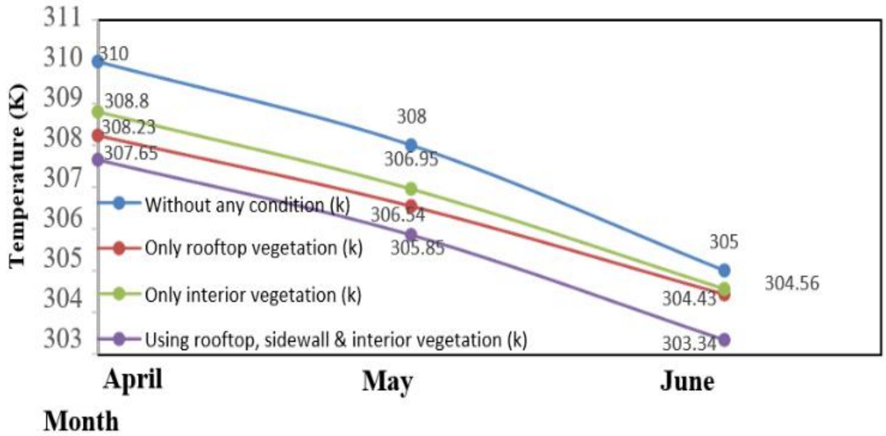

Figure 12: Comparison of temperature variation with vegetation vs Month

Figure 12 shows the mitigation of temperature with increasing vegetation. When there is no vegetation, it shows a higher temperature. But if there is proper distribution of vegetation on rooftop or interior or both rooftop and interior, it shows portentous reduction in temperature. For creating only rooftop or interior vegetation, it reduces around 1°C. But for creating optimized vegetation on rooftop and interior, it reduces almost 3°C.

3.2.2 With PCM

The distribution of maximum and minimum temperature for April, May, June 2020 is 307K and 296K, 305.52K and 296K, 301.85K and 296K respectively. The maximum temperature can be seen on partial portions of rooftop and the sidewall where the sunlight directly strikes. The lowest temperature can be seen in the ground portion.

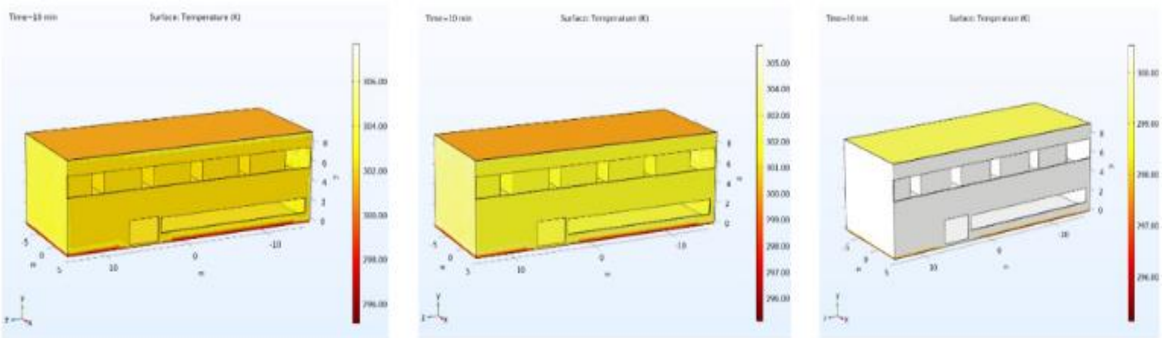

Figure 13: Temperature distribution for April, May, June

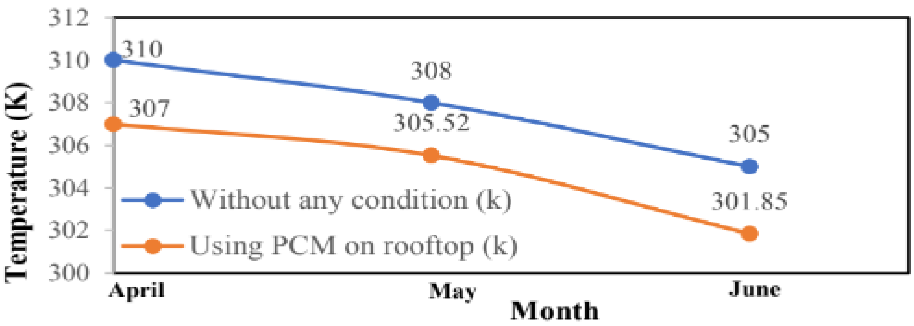

Figure 14: Comparison of temperature variation using PCM vs Month

Figure 14 shows the temperature reduction when PCM is used on rooftop. When there is no layer of PCM, it shows more temperature. It reduces almost 3°C temperature with the use of PCM.

3.2.3 With vegetation and PCM

The distribution of temperature after combining interior and rooftop vegetation with PCM material on rooftop is shown below. It can be seen maximum and minimum temperature is 305.46K and 296K respectively. The maximum temperature can be seen on rooftop and the sidewall where the sunlight directly strikes. The lowest temperature can be seen in the ground portion.

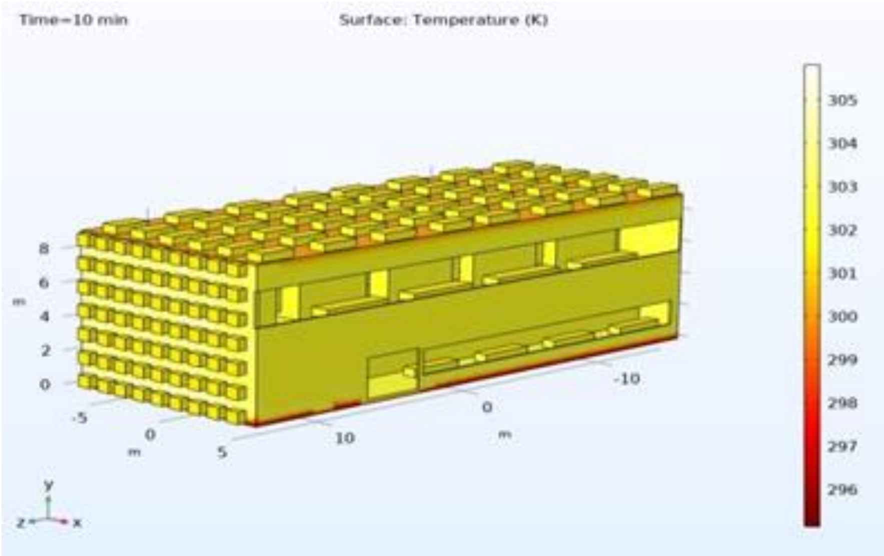

Figure 15: Temperature distribution using vegetation and PCM

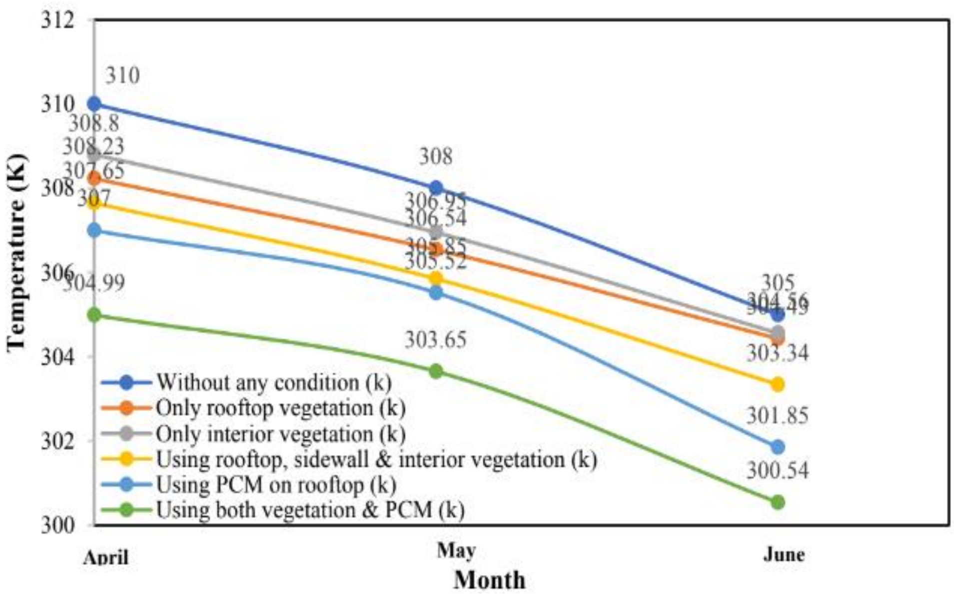

Figure 16: Comparison of temperature variation with different conditions vs Month

From Figure 15, it can be easily seen that there occurs a portentous change while considering both vegetation and PCM on the model at the same time. It reduces almost 5°C from normal condition.

4. Cost Analysis

4.1 Assumption and calculation

Assuming the ac to be a 3 star rated, its Energy Efficiency Ratio (EER)=2.7 Cooling capacity of 1 ton is equal to 3.517kW of power (Maheshwary and Al-Murad, 2001)

For 1.5 ton AC power consumption of ac = cooling capacity/EER

=1.5*3.517/2.7=1.954 kW

AC consists of two units, Indoor unit which is called the evaporator and the Outdoor Unit which called the Compressor. So, it is preferable for calculation that total power is consumed only by the compressor (Zhu, 2013). Compressor unit starts only when the indoor temperature is more than desired temperature and stops once the desired temperature is achieved. Compressor run time to drop temperature down 2 °C is 30 minutes (Moders, 2016)

Case 1: When there is no vegetation Ambient temperature, t_{amb}= 37°C Desired temperature, $t_{desired}$= 25 °C

So for dropping the temperature from 37 °C to 25 °C (T= 12 °C) run time of the compressor is= 30* 12/2 =180 min =3 hr

Energy consumption =1.954*3=5.862 kWh

Case 2: When there is vegetation on the rooftop, interior, sidewall and PCM over the roof it reduces the temperature around 5°C

Ambient temperature, t_{amb}= 32 °C Desired temperature, $t_{desired}$= 25 °C

So for dropping the temperature from 32 °C to 25°C (T= 7 °C) run time of the compressor is= 30* 7/2 =105 min

=1.75 hr

Energy consumption =1.954*1.75 =3.4195 kWh

So total energy consumption is reduced by vegetation = 5.862-3.4195= 2.4425kWh

Assuming electricity cost 7 TK per unit or KWh, an overall estimation of cost reduction is given below (Bpdb.gov):

Table 3: Cost reduction with different conditions

Months	Energy consumption without any condition	Energy consumption with vegetation & PCM on rooftop	Reduction in energy consumption (KWh)	Cost reduction per day (BDT)	Cost reduction average per month (BDT)
March	3.19	0.96	2.22	15.59	467.78
April	5.01	2.56	2.44	17.13	513.95
May	4.89	2.89	2.00	14.05	421.62
June	4.41	2.23	2.17	15.25	457.52
July	4.32	2.42	1.90	13.30	399.05
August	3.97	1.69	2.28	15.96	479.07
September	3.91	1.70	2.21	15.45	463.68
October	3.63	1.38	2.25	15.76	472.91
November	2.68	0.87	1.80	12.65	379.56
Annual reduction			19.27		4055.16

If a room size is above 201-300 sq ft, then 1.25 or 1.5 Ton AC is enough for cooling the room (Blog.Addotoday.com). The area of one room of our computaional model is 2660 square feet. So, for this model total 15 number of 1.5 ton ac is required .

Therefore, total cost reduction for 15 AC in 1 year =4055.16*15=60827.4 Tk Total reduction of energy consumption per year = 289.05 KWh

A graph for the consumption of energy in different month is given below:

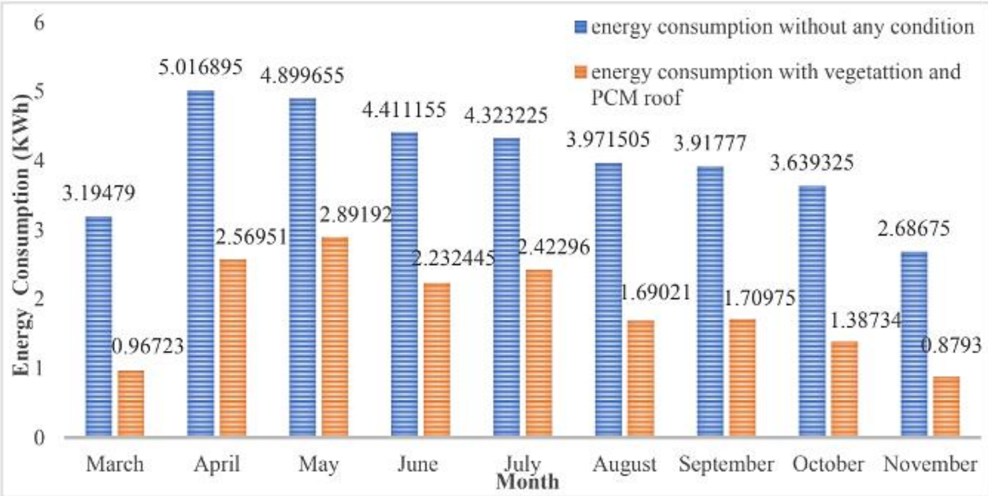

Figure 17: Graph for energy consumption vs. month

5. Conclusions

This study showed that for interior vegetation temperature didn't reduce. But it makes the environment healthy and reduces stress. It was observed that with increasing vegetation, the temperature decreased up to 3°C but after a certain period temperature didn't decrease more than 3°C although vegetation increased. By using WPC on the rooftop as a phase change material temperature decreased around 4°C. By using all conditions (rooftop, sidewall, interior vegetation & PCM on rooftop) together temperature could be mitigated around 5°C. From the cost analysis, it was found that for the mitigation of around 5°C, energy consumption can be decreased annually by around 289.05 KWh and the total cost could be decreased by around 60827.4 TK.

References

Blog.Addatoday.com," [Online].

Maheshwari, G.P., Al-Murad, R., 2001. Impact of energy-conservation measures on cooling load and air-conditioning plant capacity. Applied Energy, 69 (1), Pp. 59-67.

Mengyu Zhang, Mengyu Zhang, Jeeyeop Kim, 2019. The Effects of the Layouts of Vegetation and Wind Flow in an Apartment Housing Complex to Mitigate Outdoor Microclimate Air Temperature. Sustainability 2019, 11 (11), Pp. 3081.

Modarres, G., 2016. Experimental investigation of energy consumption and environmental impact of adaptive defrost in domestic refrigerators. Meas. J. Int. Meas, 92, Pp. 391-399.

Ozcan, H.G., Varga, S., Gunerhan, H., Hepbasli, A., 2021. Numerical simulation and parametric study of various operational factors affecting a PV-battery-air conditioner system under prevailing European weather conditions. Sustainable Cities and Society, 67, Pp. 102754.

Tashnim, J., and Anwar, M.A., 2016. Reasons And Remides Of Heat Island Phenomena For Dhaka City. Proceedings of the 3rd International Conference on Civil Engineering for Sustainable Development, Pp. 12~14.

Voogt, "Urban heat islands: Hottercities," Web article, 2004.

Wikipedia, "Wikipedia, the free encyclopedia," [Online].

Wikipedia, the free encyclopedia," [Online]. Available: https://en.wikipedia.org/wiki/Main_Page.

www.bpdb.gov.bd," [Online].

Yang, Y.K., Kang, I.S., Chung, M.H., Kim, S., Park, J.C., 2017. Effect of PCM cool roof system on the reduction in urban heat island phenomenon. Building and Environment, 122, Pp. 411-421.

Zhu, 2013. Generic simulation model of multi-evaporator variable refrigerant flow air conditioning system for control analysis. Int. J. Refrig, 6, Pp. 1602-1615.