

ENERGY CONSUMPTION OF BUILDING ELEMENTS USING SUSTAINABLE CONSTRUCTION MATERIALS

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Abstract

Energy consumption of the buildings is high compared to the other economic sectors like agricultural and transportation fields. Due to climatic changes also, the building consumes more energy and these results in increasing the carbon-di-oxide emission in the environment. As a consequence, the carbon di- oxide emission into the environment is high in the range of 30-45% in overall carbon dioxide emission. Increasing the energy efficiency of the building is the key mitigation strategies to reduce the carbon di-oxide emission. In this work, two different type of construction material are used for analyzing energy consumptions of the building using Design Builder software. For the existing buildings the normal brick wall was insulated by polystyrene and the roof was insulated by fibre wool in these the energy loss is reduced by 77%. In new buildings the normal brick wall builds as cavity wall with polystyrene insulation and roof was coated with fibre wool and by this the energy loss is reduced by 80%.

Keywords: Carbon-di-oxide emission, energy loss, insulation material.

INTRODUCTION

Buildings are utilizing high energy percentage compared to other economic sectors. Although percentages vary from country to country, buildings are major cause for about 30 percentage of the global energy demand [1-3]. The energy usage in buildings accounts for a large amount of the total energy. In areas such as residential and the commercial sector the major part of the energy utilization takes place in buildings [4,5]. This includes energy utilization for controlling the climatic changes in the environment of buildings and also energy used for ventilation, cooling, heating, lighting and other appliances. In other sectors a small part of the energy consumption is used for similar purposes in relation to the buildings [6-8]. This is for instance the case for some buildings in the industry used for administration or some buildings agriculture or forestry [9]. This utilization continues to grow as well as buildings energy proportion in final consumption and CO_2 emission to environment.

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Increasing the energy efficiency of the building is the key mitigation strategies throughout the world [10]. There are different types of energy needs in buildings:

- For the provision of comfortable homes and working environments
- To preserve the food in safe condition
- To provide adequate lighting for homes and offices
- To use electronic equipment for communication and entertainment in efficient manner.

In this study the residential building is modelled using Design Builder software and the energy consumption of the normal construction material used in the buildings are studied. In this study using different insulation material which are having low rate of heat loss (U values) like XPS extruded polystyrene applied to the wall and fibre wool roofs are applied to the buildings and compare the energy loss in the buildings and the carbon dioxide emission into the environment [11,12].

ENERGY ASSOCIATED IN BUILDINGS

There are different types of energy like heat energy, electrical energy, mechanical energy, solar energy in this study the energy associate with buildings is presented here. There are two main types of energy associated in the buildings they are Embodied energy and Operational energy.

EMBODIED ENERGY

It refers to total energy utilized by all activities related with construction of building from extracting and processing the construction materials from its raw source and manufacturing, transporting and delivering to construction site.

OPERATIONAL ENERGY

This refers to the energy utilized for ventilation, cooling, heating, lighting and other appliances. It is further divided into two main types Thermal(heat) energy and Electrical energy.

HEAT ENERGY

Heat energy is used in houses and offices to provide the energy service of ‘comfort’. This means providing space heating in winter with some kind of heating system and possibly cooling in summer. Heat energy will flow through any object when the temperature on the two sides is different Although it is common to think of a house being heated solely by some form of heating System, in practice it is likely to be warmed by energy from three sources:

- The heating system

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- Free heat' gains − from occupants, lights, appliances and from hot water use.
- Passive solar gains from solar energy penetrating the windows.

In a really low-energy house design, free heat and solar gains may provide more useful heating than the heating system itself. Obviously in order to achieve a low overall space heating demand it is necessary to reduce the heat losses. Figure1 shows a small house and illustrates the ways in which heat flows into and out of a house. The losses are particularly important. There are:

- Fabric heat losses those through the building fabric itself, i.e. the walls, roof, floor and windows
- Ventilation losses due to air moving through the building.

HEAT LOSS MECHANISMS

Heat energy will flow through any object when the temperature on the two sides is different. The rate of this energy flow (i.e. the number of watts) depends on the temperature difference between the two sides and the total area available for the flow the insulating qualities of the material.

Conduction

In any material, heat energy will flow by this mechanism from hotter to colder regions. The rate of flow will depend on the area and temperature difference and on the thermal Conductivity of the material.

Convection

While still air is a good insulator, moving air can carry heat from a warm surface to a cooler one. A warmed fluid, such as air, will expand as it warms, becoming less dense and rising as a result, creating a fluid flow known as convection.

Radiation

Heat energy can be radiated, in the same manner as it is radiated from the sun to the earth. The quantity of radiation is highly dependent on the temperature difference between the radiating body and its surroundings.

U-Values

Conduction, convection and radiation all contribute to the complex process of heat loss

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through a wall, window, roof, etc. In practice, the actual thermal performance of any particular building element is usually specified by a U-value.

ELECTRICAL ENERGY

The electrical energy requirement is very essential in all types of buildings. In residential buildings the electrical energy requirement is become a basic need and its consumption is varying from individual house and varies within in the house of different zones (rooms). The basic needs of electrical energy in a house for lighting, cooling, charge the laptops, mobiles and other accessories. The electrical energy consumption is calculated knowing the electrical consumption of the units multiplied by its consumption time. Heating systems and CO_2 emissions. The total fuel consumption building is calculated by the following formula Annual fuel use = annual heat demand / heating system thermal efficiency. All heating fuels produce the same amount of CO_2 for a given amount of heat produced and table 2.1 shows the CO_2 emission factor for different fuel.

HEATING SYSTEMS AND CO_2 EMISSIONS

The total fuel consumption building is calculated by the following formula. Annual fuel use = annual heat demand / heating system thermal efficiency. All heating fuels produce the same amount of CO_2 for a given amount of heat produced and table 1 shows the CO_2 emission factor for different fuel.

Table 1 CO_2 Emission factor

Fuel	Emission CO_2 /kg kWh
Natural gas	0.22
Liquefied petroleum gas	0.24
Heating oil (gas oil)	0.30
House coal	0.39
Electricity	0.52

GENERAL DETAILS OF THE BUILDING DESIGN BUILDER

The Design Builder is the most comprehensive interface for Energy Plus available today. Its current version4.5 includes a simplified CAD interface, templates, wizards, and most compact air system configurations of Energy Plus. It offers flexible geometry input and extensive material libraries and load profiles. Energy Plus is integrated with Design Builder's environment which allows carrying out simulation without leaving the interface. Simulation results can be effectively

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displayed and analyzed [13]. It has quality control procedures which assures the accuracy of the results in comparison to the other software like e-Quest.

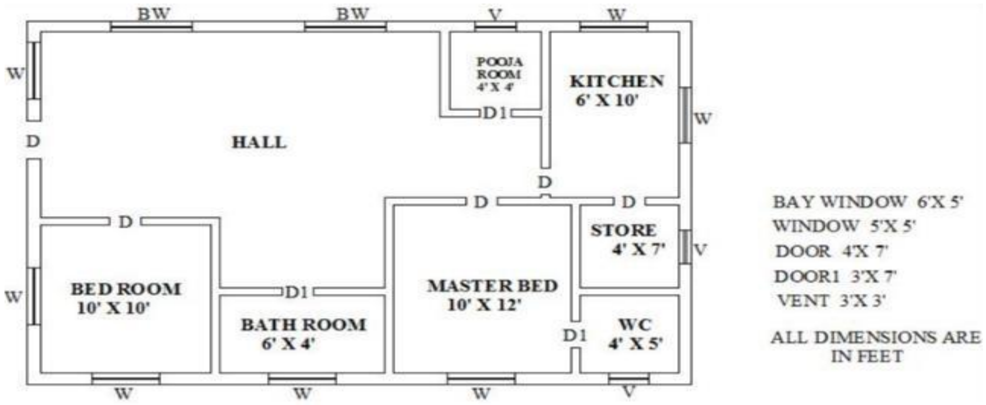

Figure 1 Ground floor plan

In this study the residential building was selected with G+1 storey which is located in Coimbatore (India). The total floor area of the building is 456m^2 and the wall area is 678m^2 and the areas of doors and window is 53m^2. The construction material used for simulation was for walls were normal brick, brick with polystyrene insulation and cavity wall with polystyrene insulation. For roof reinforced concrete slab coated with clay tiles and reinforced concrete slab coated with fibre wool insulation. The door material was teak wood and window frame with wooden and glass panel was double glazed.

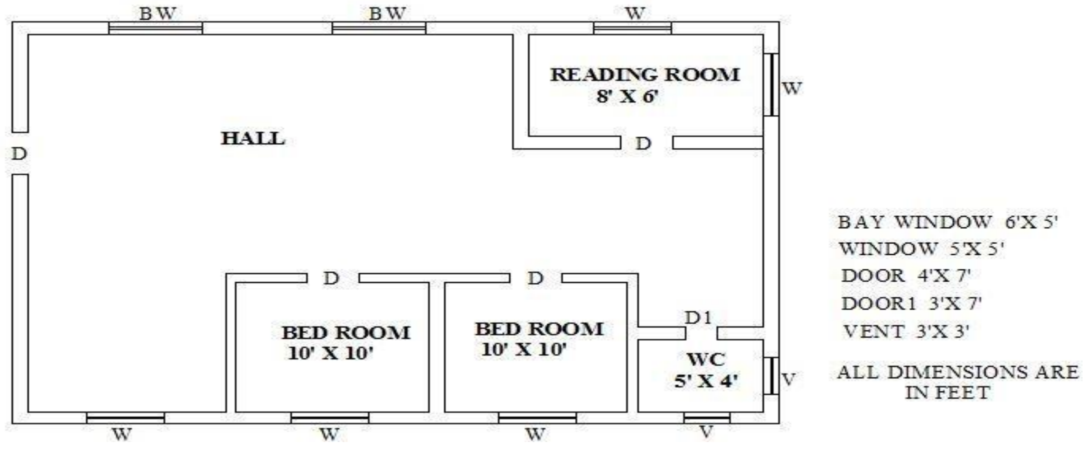

Figure 2 First floor plan

The lighting is set as led. The HVAC system is set as 4 coil fan unit. The ground floor plan and first floor plan are shown in the figure 1 and 2 respectively. Different construction material used in this study are shown from figure 3 to 7 and their properties are tabulated in table 2 and 3.

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Table 2 Properties of wall material

Type of construction material	Layer material	Thickness (mm)	U value W/m^2. k
Conventionalwall	Cement sand plaster	50	2.102
	Brick	200	
	Cement sand plaster	50	
Conventionalwall with polystyrene insulation	Cement sand plaster	12.70	0.130
	Polystyrene insulation	175	
	Brick	200	
	Cement sand plaster	12.70	
Cavity wall	Cement sand plaster	12.70	0.120
	Polystyrene insulation	250	
	Air gap	10	
	Brick	200	

Table 3 Properties of roof materials

Type of construction material	Layer material	Thickness (mm)	U value W/m^2. k
Conventional roof	Clay tiles	25	1.90
	RCC roof	152	
	plastering	25	
Conventional roof with Fibre wool insulation	Fibre wool insulation	50	1.19
	RCC roof	152	

Figure 3 Conventional wall material

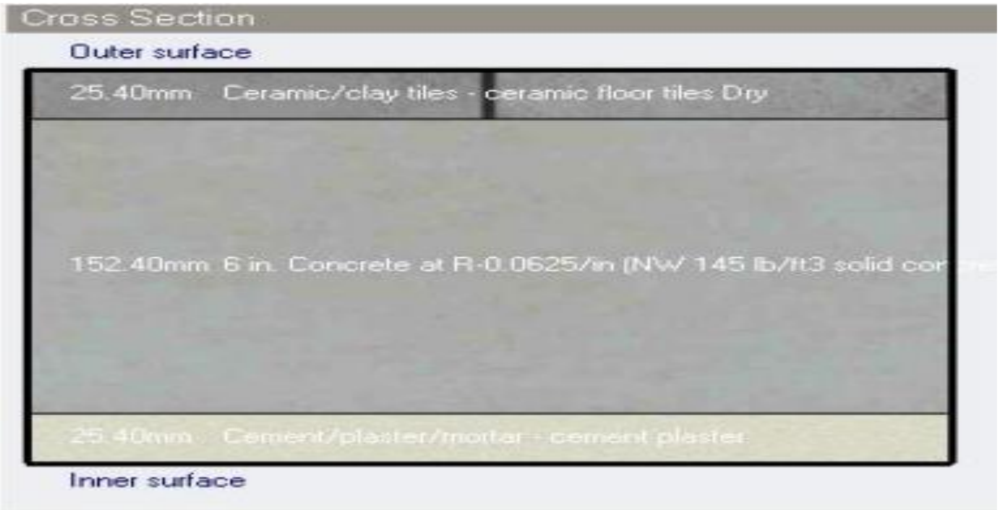

Figure 4 Conventional roof material

Figure 5 Polystyrene insulated wall material

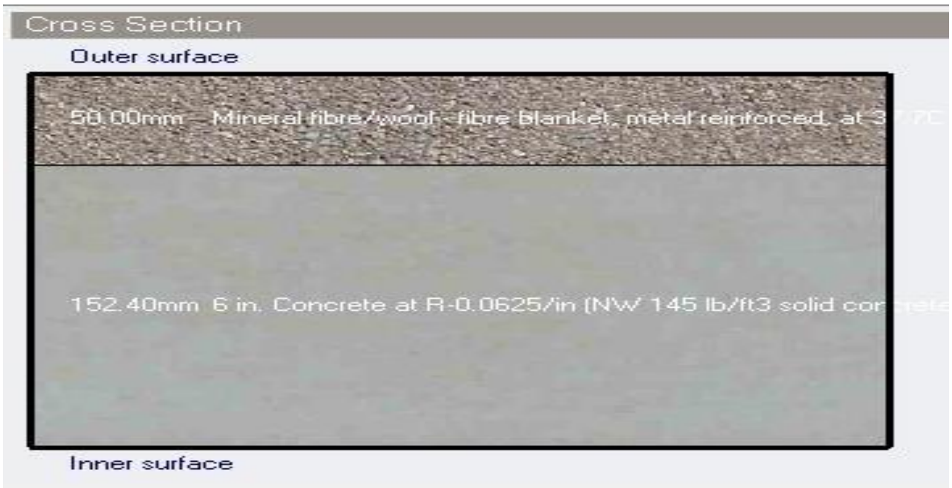

Figure 6 Fibre wool coated roof material

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Figure 7 Cavity wall with polystyrene insulation

The activity of the different rooms is set according to the zone. For instance, the bed room activity is set from bedroom template for halls the common circulation area is selected. The different tools used for simulate the materials, openings, lighting, HVAC system are shown from figure 8 to 12.

ACTIVITY TOOL

In this the activity template the details of people's occupancy data like density i.e. number of people per square meter their occupancy timing in the different portions of the buildings is given. The heating and cooling temperature of the building portions are defined in this tab.

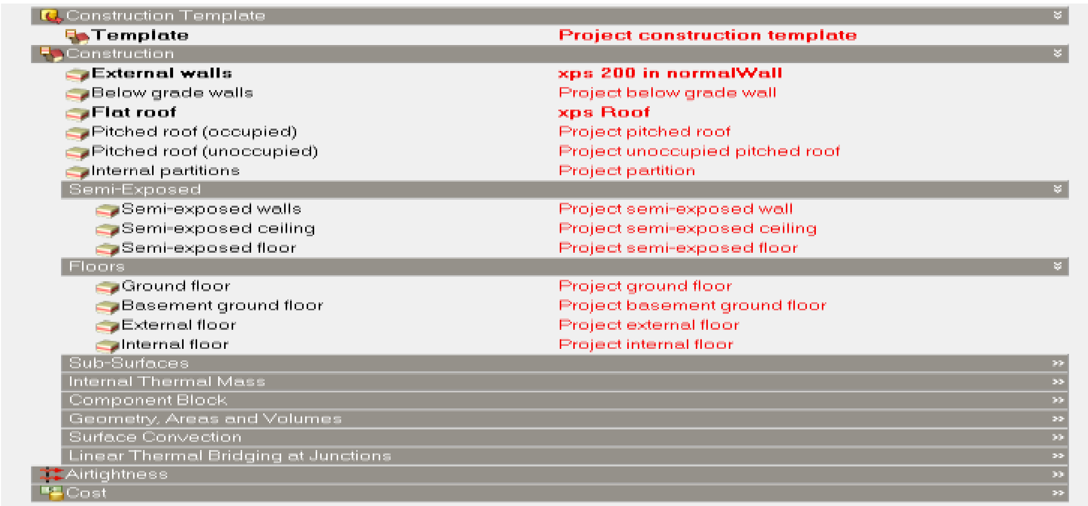

Figure 8 Activity window

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CONSTRUCTION TOOL

In this tab the material used in the building construction are need to define. The design builder offers lot of construction material type for the different components of the building. For walls brick material like aerated brick, burned brick, hollow blocks etc. For roofs different concrete like aerated concrete, RCC slab with different thickness also provided and it also allow to define the required thickness manually in the templates.

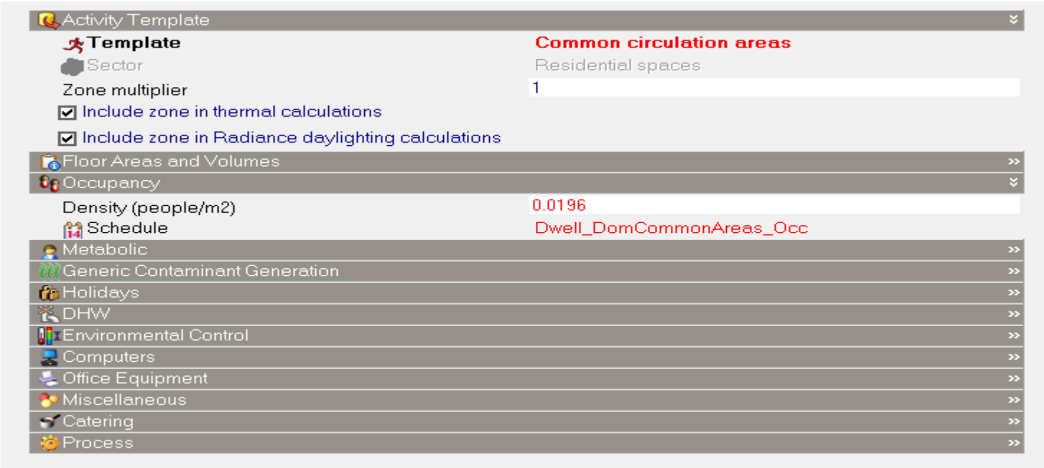

Figure 9 Construction window

LIGHTING TOOL

In this tab the lighting requirement of the different portions of the building are defined using the different template available in software.

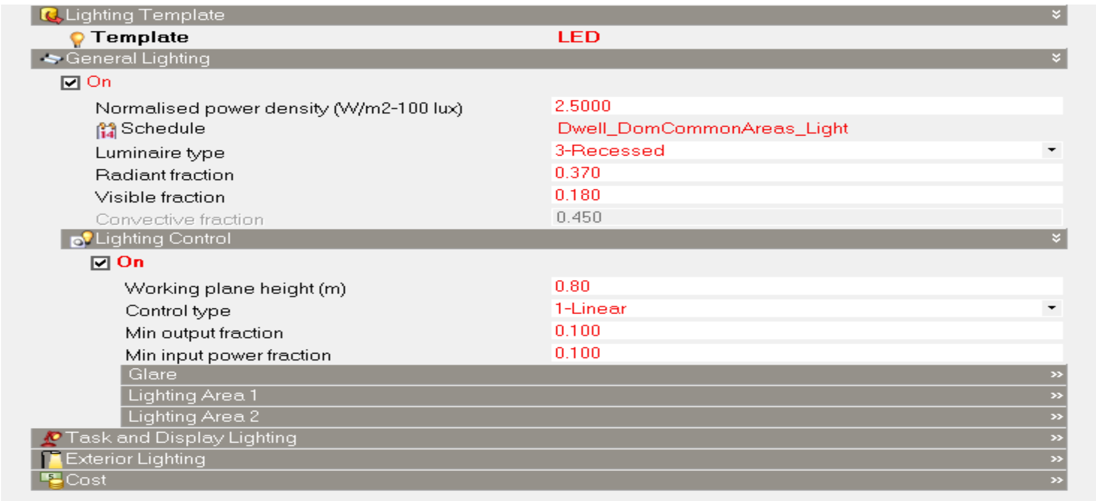

Figure 10 Lightings Tool

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The lighting template defines the timings of the lightings needed in the building and how long the lightings are required and their electrical energy consumption for the portion of the buildings are defined and calculated

OPENING TOOL

This template allows the provision for windows, doors and vents. The sill level for the windows and size of the window, size of the door and vent location and their size are defined in this template

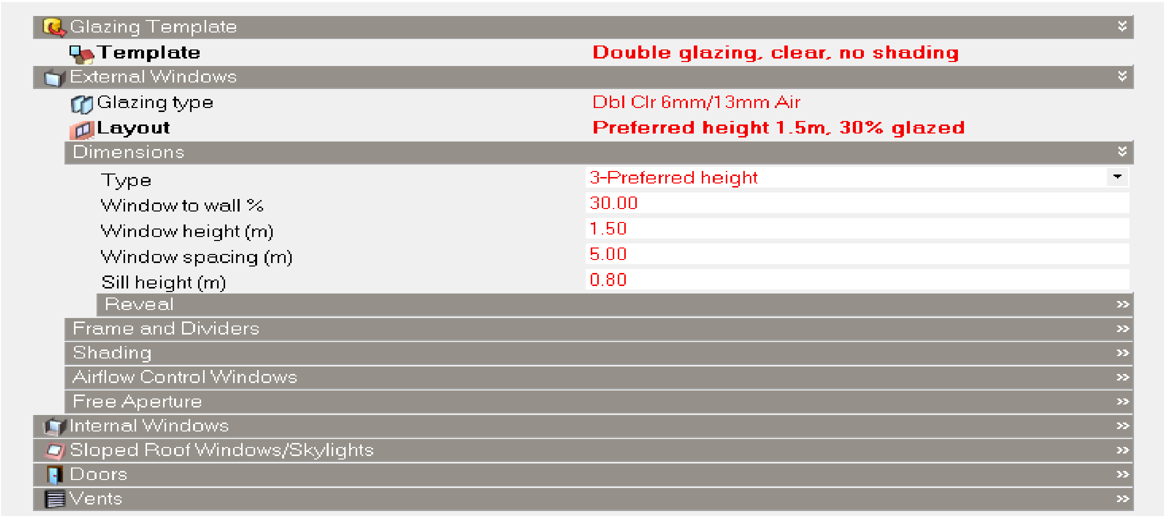

Figure 11 Openings window

HVAC TOOL

In this template cooling for the different building portion are defined. The cooling system for the building are fan, air conditioning and air cooler.

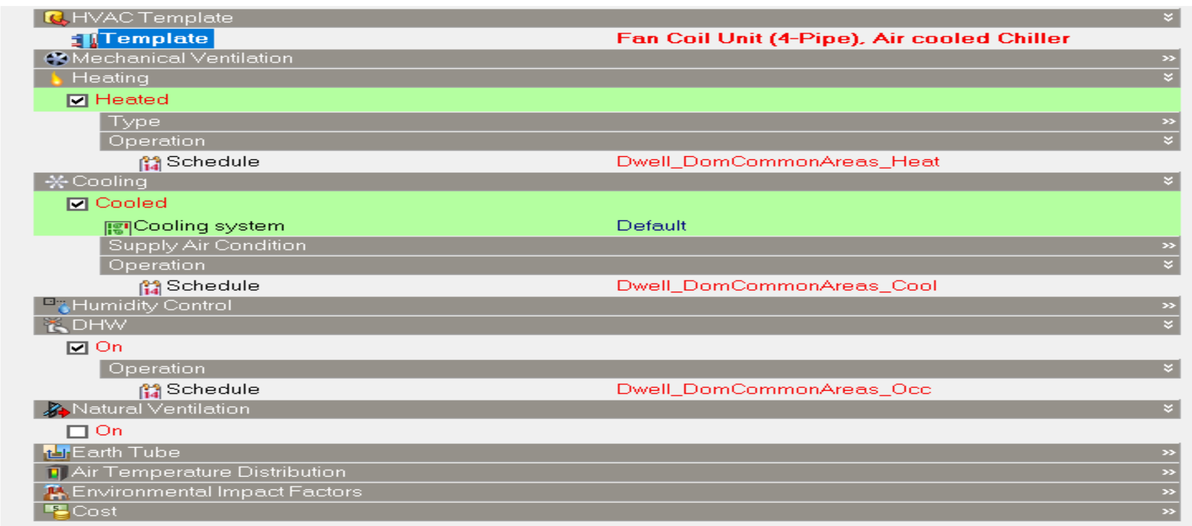

Figure 12 HVAC window

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RESULTS AND DISCUSSION

The result obtained from the Design Builder software such as energy loss, cooling load and variation of energy with time in roof and walls was discussed here for the building at ground floor level, first floor level and in the whole building.

ENERGY LOSS COMPARISON IN THE BUILDINGS

The energy loss at the different levels in the building for the new material, polystyrene materials are compared with conventional material are shown from figure 13 to 15 and the table 4 to 6 represent the corresponding data.

Table 4 Comparison of energy loss in overall building

Components	Energy loss x10^3 (kWh)		
	Conventional material	Polystyrene material	New material
Glazing	- 48.79	-66.68	-66.30
Walls	-138.63	-33.20	-39.38
Ceilings (int)	- 84.50	-20.62	-20.47
Floors (int)	84.85	25.85	25.31
Ground Floors	13.43	22.08	21.51
Partitions (int)	0.18	2.63	2.58
Roofs	-277.54	-109.29	-109.45
External Infiltration	25.15	23.59	24.09

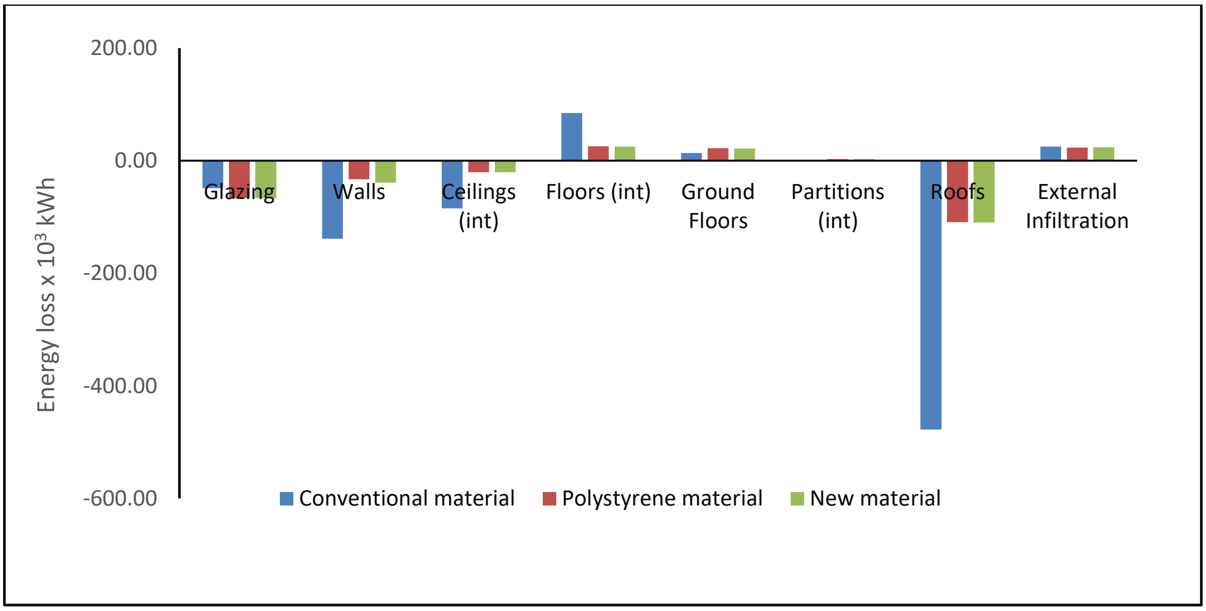

Figure 13 Energy loss for conventional, polystyrene, new material in overall building

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The figure 13 show the energy loss between conventional material, polystyrene material, and new material in the whole building which is the average energy loss (kWh) value in all the components of the entire building. The maximum loss occurs in the roofs and in walls and the minimum value at partitions.

Table 5 Comparison of energy loss at first floor level

Components	Energy loss x10^3 (kWh)		
	Conventional material	Polystyrene material	New material
Glazing	-16.47	-26.69	-26.5
Walls	-25.471	4.291	1.385
Floors (int)	84.496	25.85	25.305
Partitions (int)	0.023	0.905	0.904
Roofs	-277.05	-109.29	-109.45
External Infiltration	11.74	10.96	11.22

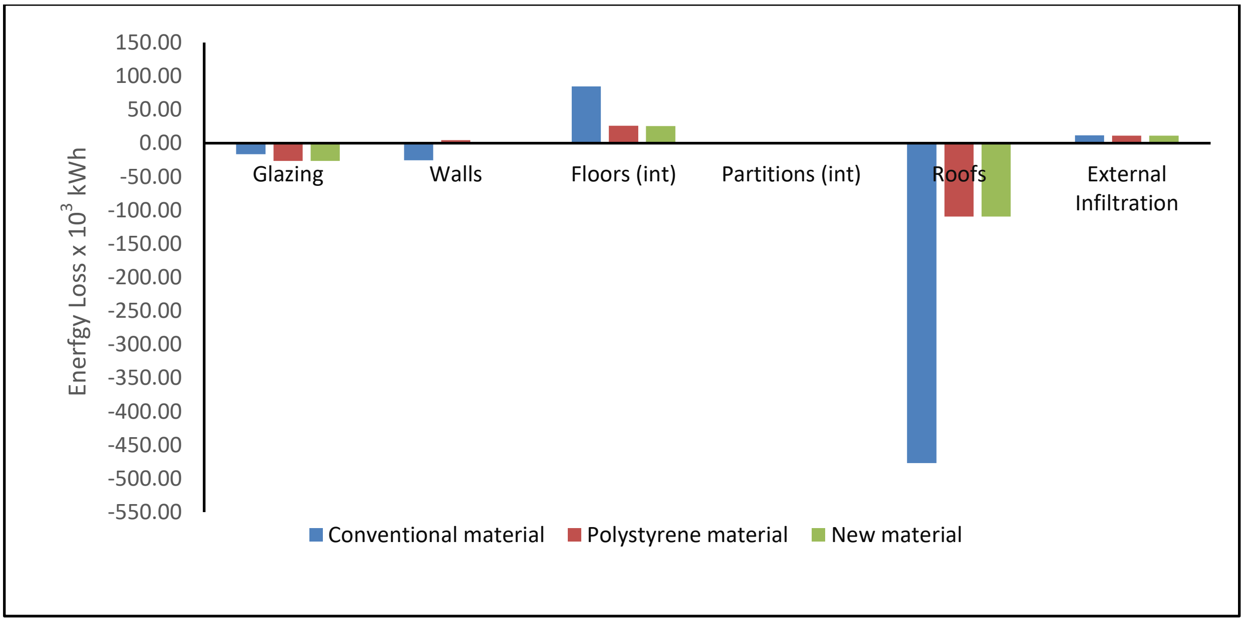

Figure 14 Energy loss for conventional, polystyrene, new material in first floor level

The figure 14 show the energy loss between conventional material and polystyrene material, new material in the first-floor level which is the individual loss (kW) value in all the components of the building in the first-floor level. Here also it seen that the energy loss from roof and wall is high and low in partition.

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Table 6 Comparison of energy loss at ground floor level

Components	Energy loss x10^3 (kWh)		
	Conventional material	Polystyrene material	New material
Glazing	-34.15	-39.99	-39.79
Walls	-112.90	-37.49	-40.76
Ceilings(int)	-84.50	-20.62	-20.47
Ground Floors	13.43	22.08	21.51
Partitions (int)	0.15	1.73	1.67
External Infiltration	13.42	12.63	12.88

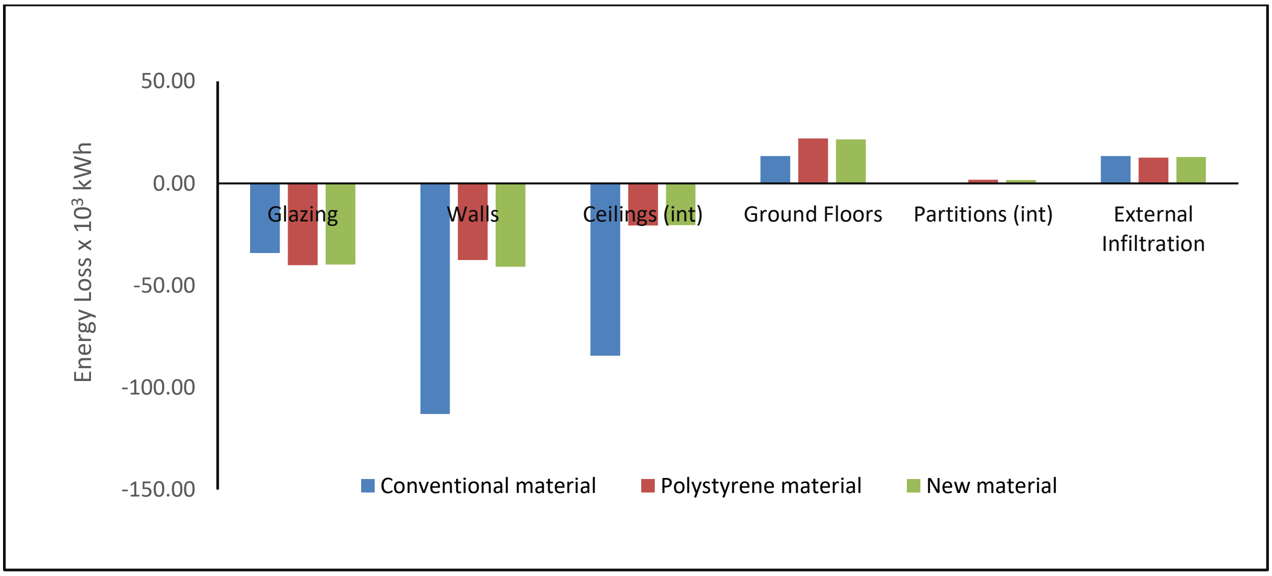

Figure 15 Energy loss for conventional, polystyrene, new material in ground floor level

The figure 15 show the energy loss between conventional material and polystyrene material, new material in the ground floor level which is the individual loss (kWh) value in all the components of the building in the ground floor level. Here also it observed that the energy loss in the ceiling and wall is high and low in partitions.

From figure 13 to 15 it was observed that the energy loss in roofs and walls are high because it occupies large area of the building through which maximum heat transfer takes place. By using the new material and polystyrene material instead of conventional material the total loss of energy in the building was reduced from 77% and 80%. It is also observed that the energy loss from the ground floor and first floor are the heat gains to the first floor and the top roofs.

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CONCLUSION

By using the polystyrene material and new material the energy loss in the building was reduced by 77% and 80% respectively in comparison with conventional material. The carbon di-oxide emission in the environment was reduced by using the polystyrene material and new material in comparison with the conventional material. The overall energy efficiency of the buildings was increased by using the polystyrene material and new material in comparison with the conventional material and thereby it reduces the carbon dioxide emission into the environment.

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