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Thermal Impact of Different Interior Finishing Materials on Energy Consumption in Bahrain

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Abstract
The energy consumption is becoming increasingly important since last years. This has resulted in a movement towards designing more energy efficient buildings because buildings consume a significant amount of the energy. In Bahrain for example, buildings alone consume the largest amount of the total electric energy,it is (about 81%). Specifically, residential buildings consume 54.5% of the total energy use with an increasing rate of 7.5% in energy consumption every year. A large portion of this consumption is used to air-condition buildings for providing thermal comfort. So; the building envelope is one of the most important systems affecting energy efficiency of a building (e.g. walls, windows, roof and finishing).The main purpose of this research is to identify the effect of interior finishing materials on energy consumption for residential buildings in Bahrain and to provide a tool that could help designers to reach better understanding for energy conservation. In order to achieve the research objectives, a building evaluation model (a base case)had been designed and eQUEST 3-64 simulation program was used to evaluate the most common interior finishing materials on energy consumption. Another base case model was developed to simulate the impact of different orientation of a selected material on energy consumption.The results of the simulation show that, the best material to use as interior finishing for the residential buildings in Bahrain is the plywood material. The results show that using of plywood as interior finishing material will consumes about 7.6% less energy, less cooling demand and around 10% and approximately (14%) less in ventilation fans demand. The annual utility bills can therefore be saved by almost 16% if plywood finishing material is used in comparison to the base case model. In light of these conclusions, further futuristic studies are recommended to ascertain the effect of various parameters of interior finishing materials such as thickness, colors and surface roughness on the thermal comfort.
Keywords: Energy consumption, residential finishing, finishing effects, energy simulations.

1. Introduction

Now days, the increase in energy consumption becoming very important, because in the future shortage in energy and also global warming will be very clear and effective. The Efficient use of energy has turn out to be a key issue for the most energy policies. Especially for Buildings as it is one of the most energy consumers. (Yilmaz, 2007)

Since 1998, energy consumption in the kingdom of Bahrain (within ten years) has risen from 5773 GW to 10689 GW in 2007(BMEW, 2005). As it has seen that the buildings are largest energy consumers all over the world. Evidently data published by the Bahrain authority for Electricity & Water showed that buildings consume the largest portion (about 81%) of the total electric energy sold in the country, Residential buildings in Bahrain consumed 54.5% of the total energy use with increasing rate of 7.5% in energy consumption every year(BMEW, 2005). Across the International Energy Agency countries (IEA), buildings are consuming more than half of all electricity.(IEA, 2007) cited in (Srivastava-Modi, 2011).

Within the past decade, environmental goals and the energy have become a major issue due to the increasing in energy demand and growing public concern over the pollution associated with energy consumption. Energy usage in buildings has become one of the most selected topics for researchers in the past decade, due to the increasing of energy cost. Designing buildings which use less energy has become extremely important, and the ability to evaluate buildings before construction can save money in design changes (Stoakes, 2009).

The data of USA (EIA) Energy Information Administration, in the graph shows that since the year of 2000,the world energy usage has been increased and will increase tremendously (Srivastava-Modi, 2011). While a large portion of energy consumption is used to condition buildings to provide an acceptable standard of thermal comfort (Stoakes, 2009), A study in the Institute of King Fahd University shows that the air conditioning consume about 73% of total electricity in the residential sector (Elhadidy, Manzoor ul, & Ahmad, 2000).

The large amount of energy used in buildings is by air-conditioning and ventilation systems are directly related to the thermal load of the building. Heat transfer by conduction through walls and roofs component represent the major of the total thermal load for the buildings (Mohammad S. Al-Homoud, 2004).In residential buildings, almost 51% of the total energy consumption is used for air conditioning. The more efficient buildings can have a large saving in energy and cost related conditioning.(Stoakes, 2009)

This load of air-conditioning can be reduced through many strategies; one of these is the proper design and selection the components of building envelope (Mohammad S. Al-Homoud, 2004).Yilmaz has explore the most important design parameters that affect the indoor thermal comfort and the energy conservation of a building, these parameters are: building form or orientation, distance between buildings and the thermo physical properties of the building envelope. From these parameters building envelope, is the most important parameter as it separates the indoor and outdoor environment(Yilmaz, 2007).

So the thermal load of buildings is depending (among various factors) on indoor design temperature, the outdoor climatic conditions, and the selection of building construction materials. The thermal characteristic of building envelope significantly influences the room air temperature and subsequently the energy consumption. These characteristics are the principle properties of building component materials such as solar heat gain, heat transmission, heat storage and air infiltration (Fazio, Athienitis, Marsh, & Rao, 1997).

Givoni, has identified these characteristics as thermo physical properties of building envelope that include thermal resistance which related to thermal conductivity, surface convective coefficient, heat capacity and surface radiation properties; reflectivity, emissivity, and absorptivity(Givoni, 1969). These characteristics are the best way for utilizing the potential of any building envelope thermal performance. They should be well-known and properly considered in the early design stage to achieve building thermal comfort and reduce the energy consumption required (Al-Qadhi, 2008; Al-Saadi, 2006). There appears then the Building envelope design typically has a considerable impact on the residential buildings energy performance. Design decisions when made at some stage in earlier design process can cost less and have significant impact on the building performance (Mohammad Saad Al-Homoud, 1998).

2. Research problem

Many studies for energy consumption often deal with building envelopes and how they can be designed to minimize energy penetration into buildings. Most studies evaluate the main building structure or the exterior surface of the building envelope, and ignore that the interior finishing materials. There is no study tried to study the effect of interior finishing materials on energy consumption in Bahrain. The interior finishing materials can also affect the energy consumption within buildings. This study examines different interior finishing material of the building envelope to ascertain how specific materials and finishes may impact energy consumption for the residential buildings in Bahrain.

3. Scope of work and limitations

The scope of this research study will be limited to:

- The residential building sector.
- Hot and humid climate in kingdom of Bahrain.
- A model will be simulated to evaluate the impact of finishing materials on energy consumption.
- The research will fix many parameter to study the effect of changing interior finishing materials on energy consumption. The fixed parameters for the interior finishing materials are:
- Material properties such as color and roughness, because there are many variation for these properties.
- Price and coast, because there are many different material prices depend on the materials types.
- While the research will study the effect of different interior finishing materials with the proper material's thicknesses.

4. Research Methodology

The research used the following methodology:

4.1 Literature Review

A literature review was carried out to establish theoretical understanding of the influence of materials on building energy consumption. It was focused on the building envelope and its thermal performance transfer, because most literature deal with such aspects. However, an attempt was made to look at the walls components and their parameters affecting building thermal comfort. It also looked at guidelines and techniques that could help in achieving the objectives of this study.

4.2 Data Collection

The study use a computerized space and compared the energy consumption inside it by using different interior finishing materials. The research involved proposing a building evaluation model which acts as a Base Case Design model and other models with different interior finishingmaterials.

By reviewing the energy simulation tools, the most suitable program was selected to do the calculations. The research also produced numerous types of data such as weather, thermal properties of materials building details requires as input for the simulation program.

4.3 Data Analysis
This study uses a computer program eQUEST to calculate the results thenmake a comparison between these results to make the analysis. After simulating the base case model; a new Simulation for different interior finishing materials will be done.
Through this simulations' output reports, the evaluation of interior finishing materials on energy consumption is presented. After simulating the base case model, a new simulation with different interior finishing materials was done. From the simulation output reports, the evaluation of interior finishing materials on energy consumption was produced.
4.4 Design Guidelines
The results helped to produce conclusions on interior finishing materials for residences to enhance thermal comfort and to consume less energy in Bahrain. The evaluation models were used to recommend general design guidelines for using the best interior finishing materials which will give more benefit if they use those materials.

5. Research objectives
The objectives of the study were to identify the effect of interior finishing materials on energy consumption in residential buildings. This was to subsequently reduce energy consumption and finally to develop design guidelines and to get a scale for thermal design to improves energy efficiency of a typical residential building.

6. Simulation of Building Thermal Performance
The major advantage of using building simulation programs is the ability to determine the energy systems and the thermal performance of a building to possibly optimize during the design process.(Capehart, 2007) p.116. Building simulation programs can be applied in many situations; they are used by researchers, architects, and engineers to solve real-life problems, in addition to calculating the annual energy consumption and the peak cooling and heating loads.(Capehart, 2007) p.118
The present research study uses eQUEST 3-64, a popular simulation software; however the selection of a building simulation program is not that easy and might vary in each case. With the increasing interest in energy efficient buildings, whole building energy simulation programs are increasingly available.

7. Program Selection for Energy Performance Evaluation
There is more than one simulation program that can meet the requirements of this research. There are many factors that can be considered during the selection process such as; speed & cost, accuracy, reproducibility, sensitivity, usability, weather data availability, input complexity and output quality. (Al-Saadi, 2006; ASHRAE, 2008; Hong, Chou, & Bong, 2000) While these factors are connected to the simulation programs, other factors are related to the users. There are three factors to be considered from the user's side. The first concerns the needs or purpose. The second is related to the budget as purchasing, training or using the software. The third is the availability of existing computer facilities. The fourth is the availability of facilities.(Al-Saadi, 2006; Hong, et al., 2000)
The simulation programs have got several features and different capabilities. eQUEST is one of the most popular and widely used building energy simulation programs. The reason for this popularity is that it combines basic input wizards with detailed simulation tools and has the potential to meet different needs. Architects, engineers, and researchers can integrate graphical results with context-sensitive guidance. This tool can be used at the conceptual design stage, when little is known about the project, as well as at the final design process when most building details have been finalized(Rallapalli, 2010; Srivastava-Modi, 2011).

8. Weather Data for Energy Simulation Programs
Weather data is usually available as raw data formats for many years, normally 20-30 years in developing countries. This raw data is inappropriate for the energy simulation programs. A typical weather year, representing many years of weather data, has to be selected for the energy analysis. This obstacle has hindered the use of energy simulation programs in developing countries in the analysis of building thermal design.
The used simulationprogram eQWESTrequires the following input data with varying details:

- Weather and geographical data.
- Building physical data, internal loads, and operational characteristics.
- HVAC system and equipment characteristics.

9. Building Envelope
Building envelope generally refers to those building components that enclose conditioned spaces and through which thermal energy is transferred to or from the outdoor environment(Turner & Doty, 2007).
The thermal energy transfer rate is the "heat gain" which can be maintained in an indoor temperature lower than the outdoor temperature (Turner & Doty, 2007).

The thermal performance of a building envelope depends mostly on how the thermal characteristics and material thicknesses are selected and arranged within the building envelope (Al-Saadi, 2006).
The walls make up most of the exterior surface area of many buildings and therefore the energy transported through these surfaces is very important.

10. Material Properties
Three properties are necessary to completely define the thermal characteristics of a material: conductivity, density, and specific heat. (Doebber, 2004)
In addition to the energy used for cooling a building, energy is also embodied in the building materials and expended in the construction process.

11. Case Study(Base case consideration)
This study will simulate the thermal performance of a certain concrete block wall with different interior finishing materials to test thedifferent computerized models.
The research case study " Base case model" characteristics can be detailed in the followings:
11.1Building design:
The building has been considered in this study as a single room with residential function in Bahrain. Figure 1 shows the layout of the room; it is a cube of 3x3x3 meters. The room consists of two plain walls, one wall with a window and the other with a door.
11.2building materials:
The walls were built with the most commonly used material in Bahrain, which is "8 inch (0.2m) hollow concrete block" As it was evaluated by (Nuaimi&Khamis, 2009), While the ceiling and the floor made of 6 inch (0.15m) concrete Heavy Wight 140 lbd, the roof without insulation and the floor is designed to be connected to the earth. So, the base case building is located in Bahrain with a total floor area of 9m^2.
11.3 Building information:
The building is a single residential test model; the operation schedule is 24 hours a day and 7 days a week. The internal temperature for the building is considered to be 24 C, which is considered as the appropriate temperature for human comfort. The simulation was performed using weather data file for the years from 1998 to 2010 for Al-Hidd in Al-Muharaq Bahrain (TMY2), obtained from the web site "Weather Analytics Inc. providing Precision, On-site Weather Data for Energy Use Profiling, Modeling and Management"(Inc, 2012). The weather file contains hourly data for dry bulb temperature, wet bulb temperature, wind velocity, cloudiness, direct radiation and diffuse radiation. The values of physical parameters shown in Table 1 are to be used as base-case values. With dimensions of the plan and elevations shown in Figure 2.
11.4 Model title:
Project is named as 'Study Model as Multifamily, low residential building for the location of Bahrain' as the weather file shows. This has been descried earlier. For the cost of electricity, a custom energy rate for Bahrain was provided by Electricity & Water Authority. The total area of the study model is around 100 ft^2 as shown in Figure 3.
11.5 Model shape and orientation:
Building footprint is the page of building design. The research will be specifying building shape as square with a dimension of three meters and height of three meters, the building orientation will face north as it is shown in Figure 4.
11.6 Model envelope:
Building envelope construction is what will be evaluated in this study. The eQuestprogram window shown in figure5is for the base case model. It shows the roof and the floor which is six inches concrete with no insulation while the walls are eight inches hollow concrete block as the most common construction material used in Bahrain.
11.7Model's door:
Exterior door detail is at the middle of north wall with standard size one meter width and 2.1 meter height. The type of the door is hollow core flush. Exterior window specification as selected from eQUEST library in Figure 6 is one meter wide and 1.1 meter high at the east wall. While the glass thermal property is shown in the material section this window will be without shading.
11.8 Model conditions:
Building operation schedule is twenty four hours, seven days a week as it is a residential building model. Since the building model consists only one space, the activity areas is 100% in this room area.
The Non-HVAC end use to model input page, is the place that have been selected for the interior equipment such as lighting, cooking equipment and laundry facilities. This is kept as the default of eQUEST specified for the residential building. (Interior lighting load is calculated by eQUEST as the building type selected).
HVAC system types, and the defaults are based on a building type & HVAC equipment type from the first

screen. The number of actual systems used in the model varies and depends on system type. The cooling source is DX Coils while the system type is split system single zone.
There will be no change in HVAC system and fan schedule based on the building operating twenty four hour a day for the full week. (The electricity utility charges will be based on a custom energy rate for Bahrain provided by the Electricity & Water Authority).
11.9 Different tested materials:
The screen shot of eQUEST Materials properties page in Figure7 represents all the materials used in this simulation. The selection of those materials is based on the most common material available in the local market.
The main parameter in this simulation is the wall construction which is evaluated as presented in Figure 8 to set those constructions. The material properties and the layers will be the same in all cases and the internal finishing will change with the same thickness. The internal finishing materials will be; Base line without finishing, Slate stone finishing, Porcelain finishing, Plaster finishing, Particle board finishing, Stucco finishing, Granite finishing, Marble finishing, Terrazzo tile finishing, Gypsum finishing, Brick finishing and Plywood finishing.

12. The Effect of Interior Finishing Material on Heat Gain and Energy Consumption

The energy consumption for the base case is evaluated under various wall materials. When performing the computer simulations, only one parameter is changed keeping the rest of the parameters at their base-case values. The parameter which will be evaluated is the internal finishing material of the external walls.
In order to evaluate the thermal performance of different wall elements, they should be simulated in a typical residence. Rather than comparing these systems individually through their R-value, to design the whole house properly, the individual components that affect the building energy performance must be modeled as accurately as possible.
To assess the impact of finishing material on residential energy consumption, eleven finishing materials of the most common used in Bahrain have been evaluated as shown in Table 2.

13. Results

The annual energy consumption for the base case building model for Bahrain is presented in Table 3. The simulated design shows that the energy consumed by space cooling has taken the largest portion of the total energy of the space by 58% as shown in Figure 9.
The annual energy consumption of finishing material for the building model in Bahrain is presented in Table 4. The table shows that the changing of internal finishing material has affected the energy consumption inside the study model as the followings:
a- Plywood finishing material consumes about 7.6% less energy.
b- Brick finishing consumes 5% less energy.
c- Gypsum finishing consumes 4% less energy than the Base line model without finishing.
d- All other finishing materials simulated consumes between 0.6% and 1.2% less energy than the Base line model without finishing.
It is clear from the Figure 10, that there is a clear difference in energy consumption for the last three finishing materials, namely plywood, brick and gypsum compared to the base case model and to the other finishing material.
The monthly energy consumption of finishing material for the building model is shown in Figure 11and Table 5. The figure shows the range of the energy consumption in different months. It is clear that for the many months in the year, the energy consumption for the summer period (from May to September) is higher in terms of using air-conditioning. Therefore most of the savings in energy will be in these months.
The annual peak demand for the base case building model for Bahrain is presented in Figure 12 It shows that the space cooling is demanding on energy by 78%.
Energy consumption of the finishing model was less for plywood by 7.5%, for brick by 5% and for gypsum by 4% than the Base case design. Table 6 shows the monthly Peak Demand by End-use for the base case model.For gypsum finishing, the model shows less electricity demand by 4% relative to base case model as shown below in Table 7.
While for using brick finishing model shows less electricity demand by 7% relative to base case model as shown below in Table 8. And for using plywood finishing model shows less electricity demand by 8% relative to base case model as shown below in Table 9. 10% less energy consumption can be reduced if the plywood finishing is used as an internal finishing material, 7% if Brick finishing material used and 6% in Gypsum finishing in comparison to the Base case model, as represented in Figure 13.
It can be seen from the Figure 14 below, that the benefits of using these finishing materials to monthly total energy consumption is comparable to the base case model.
As it shows in comparison tables for the monthly peak demand, the Area Lights and Miscellaneous Equipment has no difference in the months demand, so the changing the finishing material will not affect those two aspects.

On the other hand, the difference is clearly noticed for the space cooling and Ventilation Fans.
The comparing space cooling demand for the plywood finishing model shows that it has less cooling demand; for about 10% less than base case model. And about 14% less in ventilation fans demand. However, the annual demand of space cooling and ventilation for the plywood finishing model is about 11% less than the base case model.
The brick finishing model is less by 11% in space cooling demand than the base case model. Further, the ventilation fans demand about 13% less. While for the annual demand of space cooling and ventilation for the Brick finishing model is about 11.5% less than the base case model.
For the gypsum finishing model simulation shows 5.5% less in space cooling demand and 7.5% than base case model, with a total of about 6% for the annual demand of space cooling and ventilation less than the base case model.
It can be seen that the brick has about 1% less for space cooling than the plywood finishing model because it performed better in the cool season as it is shown in previous Tables.
For a comparison purpose, we are going to use the space cooling and the ventilation to evaluate the energy consumption of the four models; The Base case Model, Plywood finishing model, Brick finishing model and the Gypsum finishing model.
The data of the Table 10 was taken from the individual run report of the simulation by eQuest for the Monthly Energy Consumption by end-use. Comparison for space cooling and the ventilation to evaluate the energy consumption of the four models: base case model, plywood finishing model, brick finishing model and gypsum finishing model.
Table 10 Shows the effect of the interior finishing material on monthly total energy consumption of space cooling and ventilation.
Electric cost and the saving benefit from using plywood finishing material is in the simulated model.
Figure 15 shows the monthly effect in energy consumption for plywood finishing model relative to the Base case model. It's clear that the summer months give more benefit for this comparison, since it has more demand on space cooling and ventilations as seen in Figure 16.
To estimate the eclectic cost in this simulation, a custom energy rate for Bahrain provided by Electricity & Water Authority is used.
The annual utility bills in Figure 17 and Figure 18 shows that we can save about 16% of the bill for the plywood finishing model in comparison to the base case model.

14. Result analysis

As the previous result of all the simulation on energy consumption, the research will investigate the material properties shown in Table 11 to check the most effective parameter that has influence on energy consumption. Table 11 can show that the thermal properties of each finishing material have different effects on the total energy consumption.
There is no single parameter affecting this difference in the total energy consumption. Combinations of these parameters such as thickness, density, specific heat and conductivity give a good result when knowing how each one work.

15. Conclusion This research study has been carried out to evaluate the thermal and energy consumption of residential buildings in Bahrain as a hot-humid climate, by using the energy simulation program eQUEST 3-64. From all previous work the research conclude the following conclusions:
a- The best material to be used as an internal finishing material for the residential buildings in Bahrain is Plywood, in this case it consume less energy about 7.6%, then using Brick with 5% and using Gypsum with 4% less energy. While all other finishing materials simulated consume between 0.6% - 1.2% less energy than the Base case model without finishing.
b- The annual Peak Demand result shows that space cooling takes up the largest part of energy consumption, its consume 78% from the total energy consumption.
c- The results where plywood finishing has been used have less cooling demand; about 10% than base case model; when tests have been done for monthly peak demand of space cooling and ventilation for different finishing materials. And around 14% less in ventilation fans demand. With annual demand of both space cooling and ventilation approximately 11% less than the base case model.
d- The energy consumption of the best three finishing materials for space cooling and ventilation were tested and shows 10% less energy consumption for the plywood finishing, 7% in Brick finishing and 6% in Gypsum finishing in comparison to Base case model.
e- The electricity cost in the simulation by Bahrain electric rates show that the annual utility bills can save about 16% of our bill for the plywood finishing model in comparison to the base case model.
f- The relation between the selections of the interior finishing materials and the energy consumption in

residential buildings shows that some materials have aneffective relationship to energy saving while some materials have limited effects.
g- The relation between the thermal characteristics of the interior finishing materials and the energy use in buildings has been conducted and shows the effects. However, it needs more study to identify the most affected parameter.

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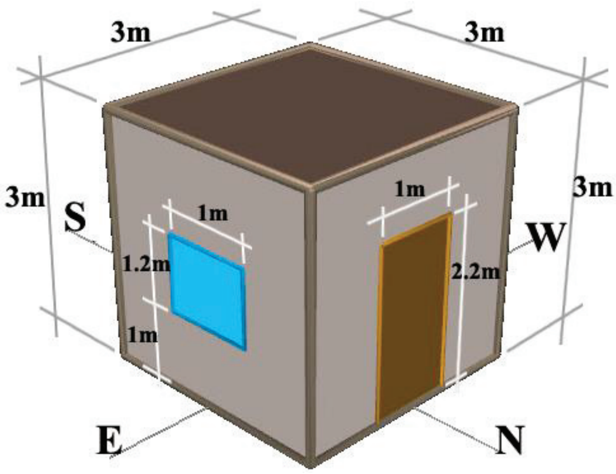


Figure 1: Dimensions of the Study Model in perspective view

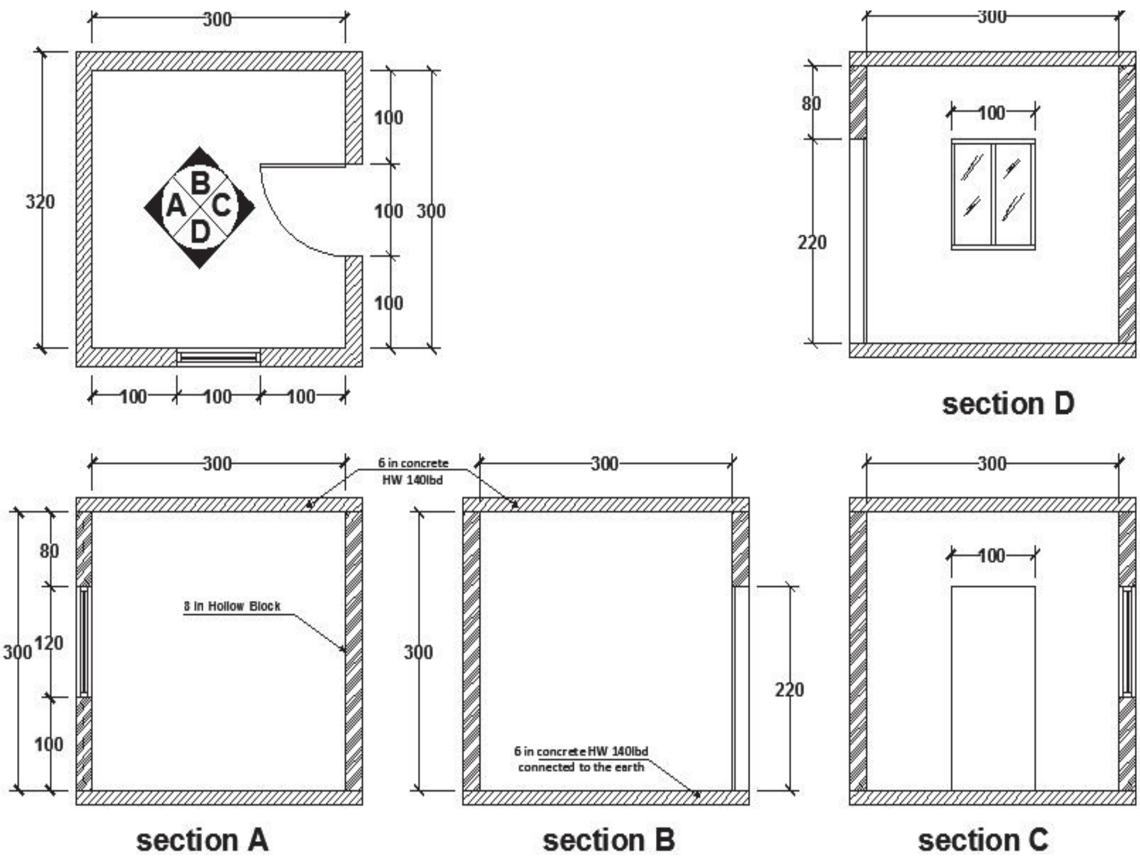


Figure 2: 2D drawing of Base Case Model: plan and elevations

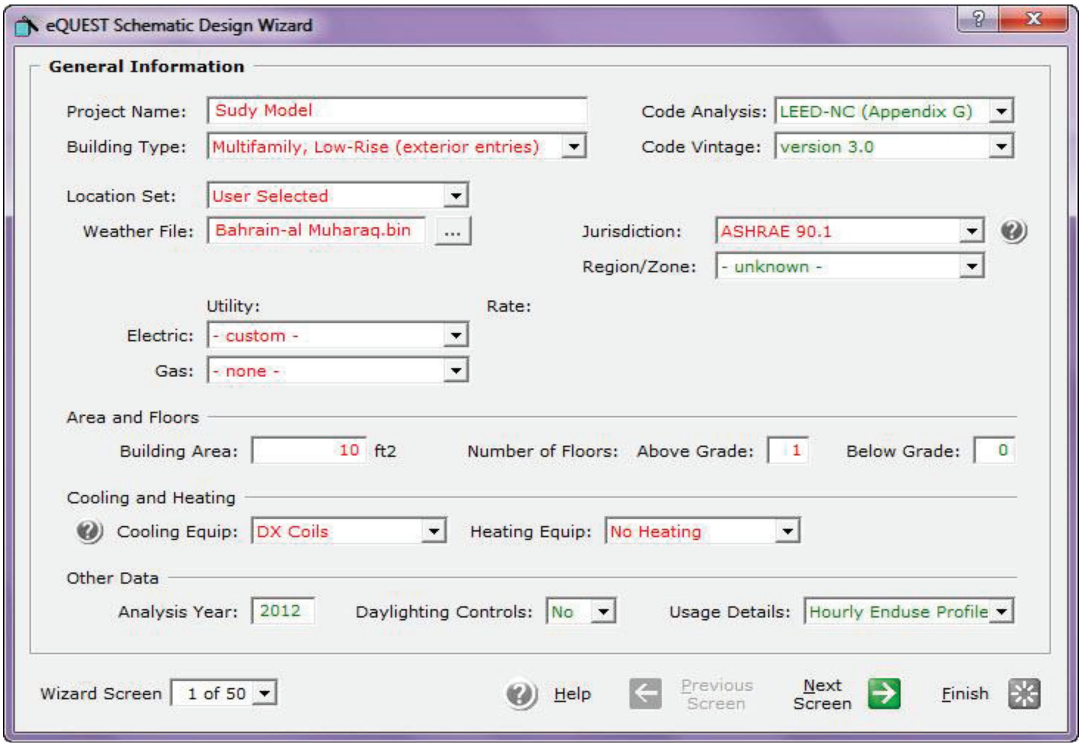


Figure 3: General information Data input of study model

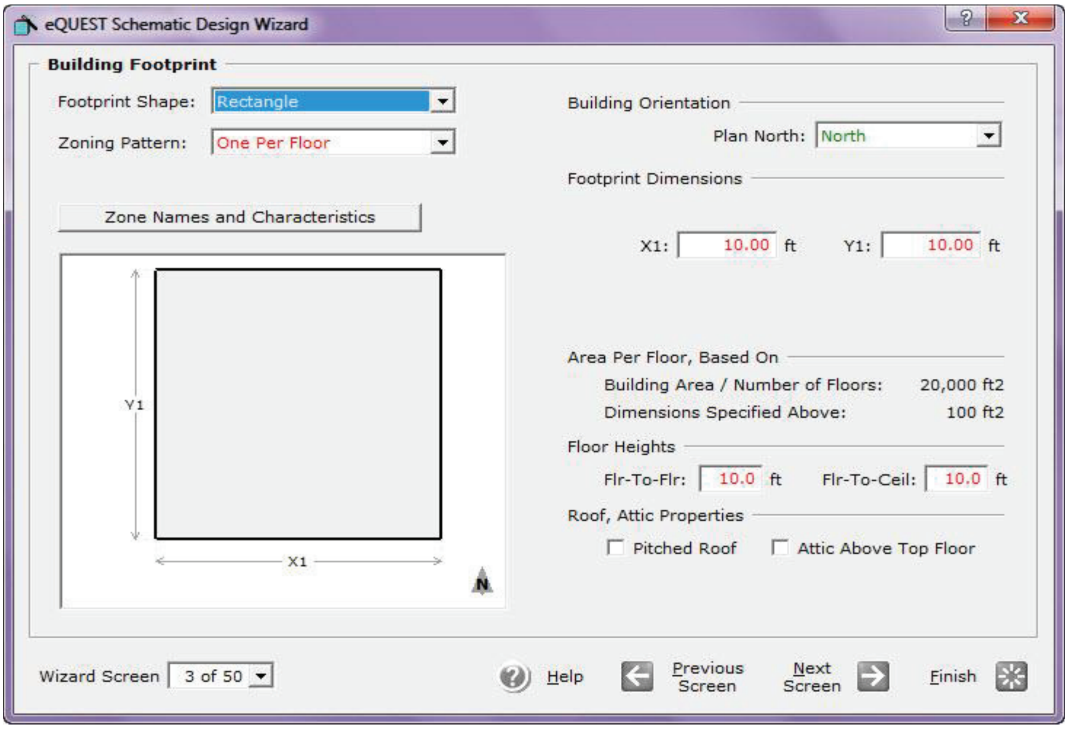


Figure 4: Building footprint Data input of study model

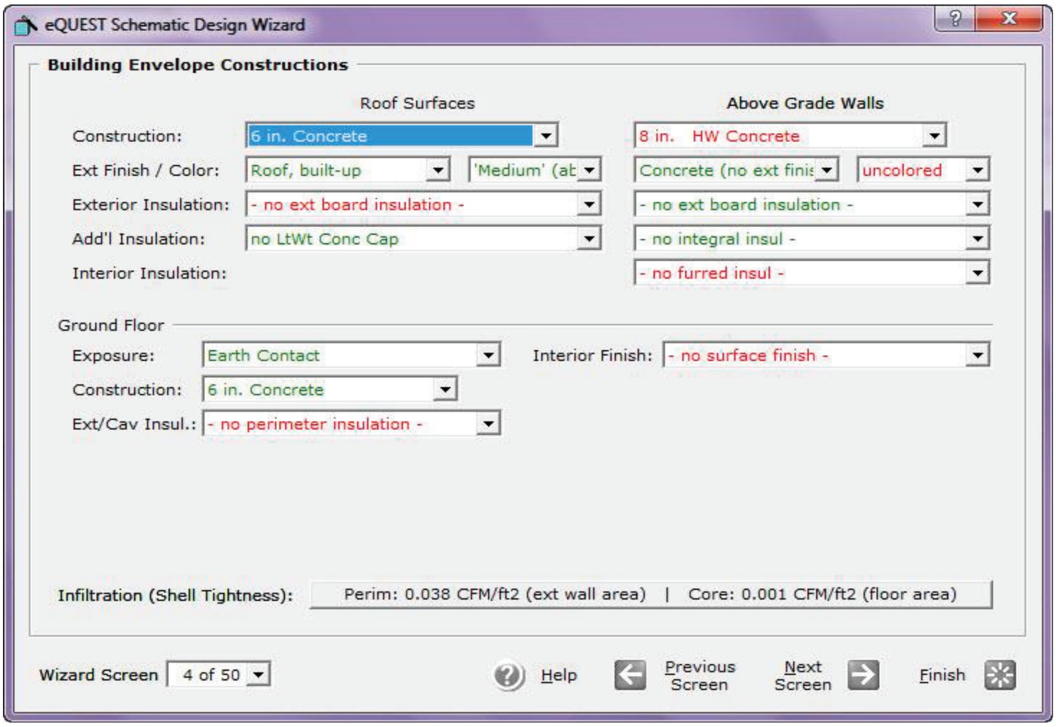


Figure 5: Building envelope construction Data input of study model

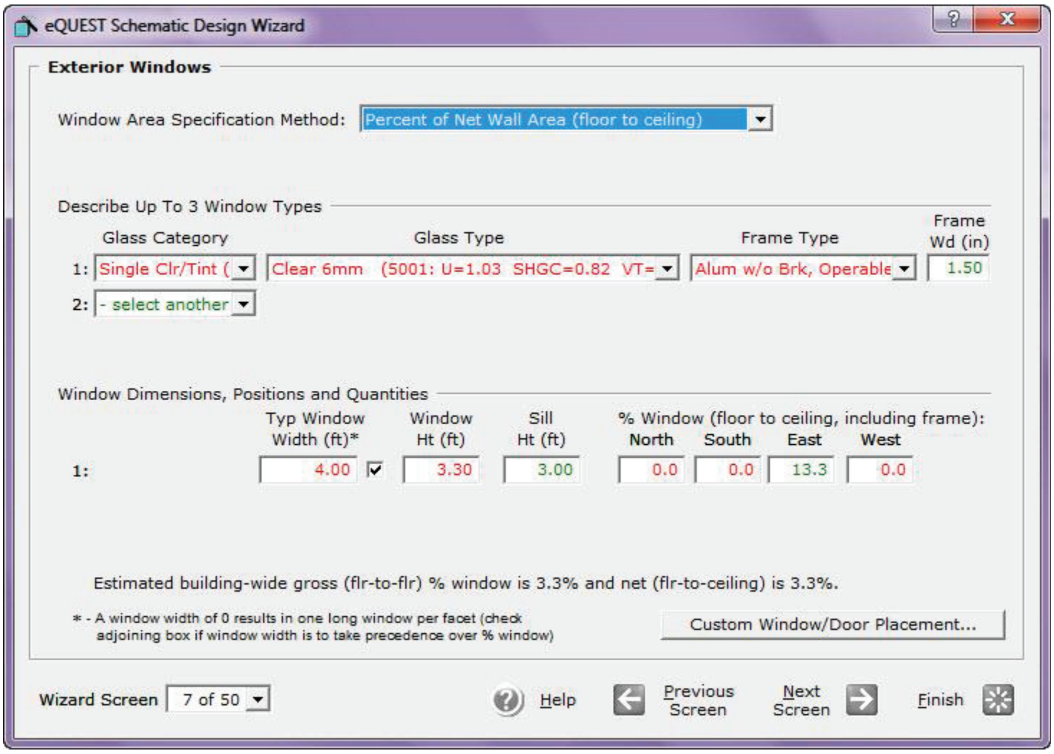
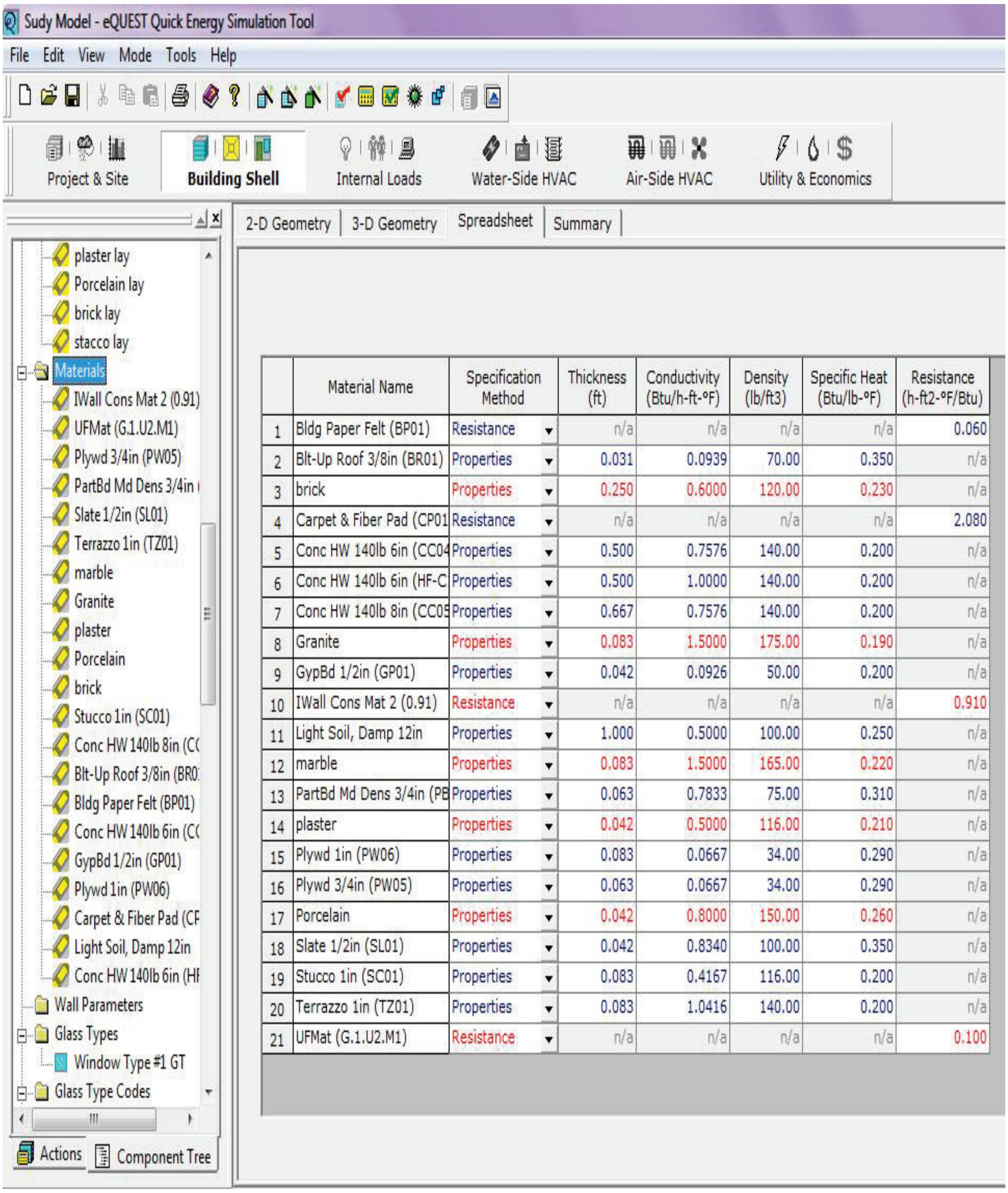
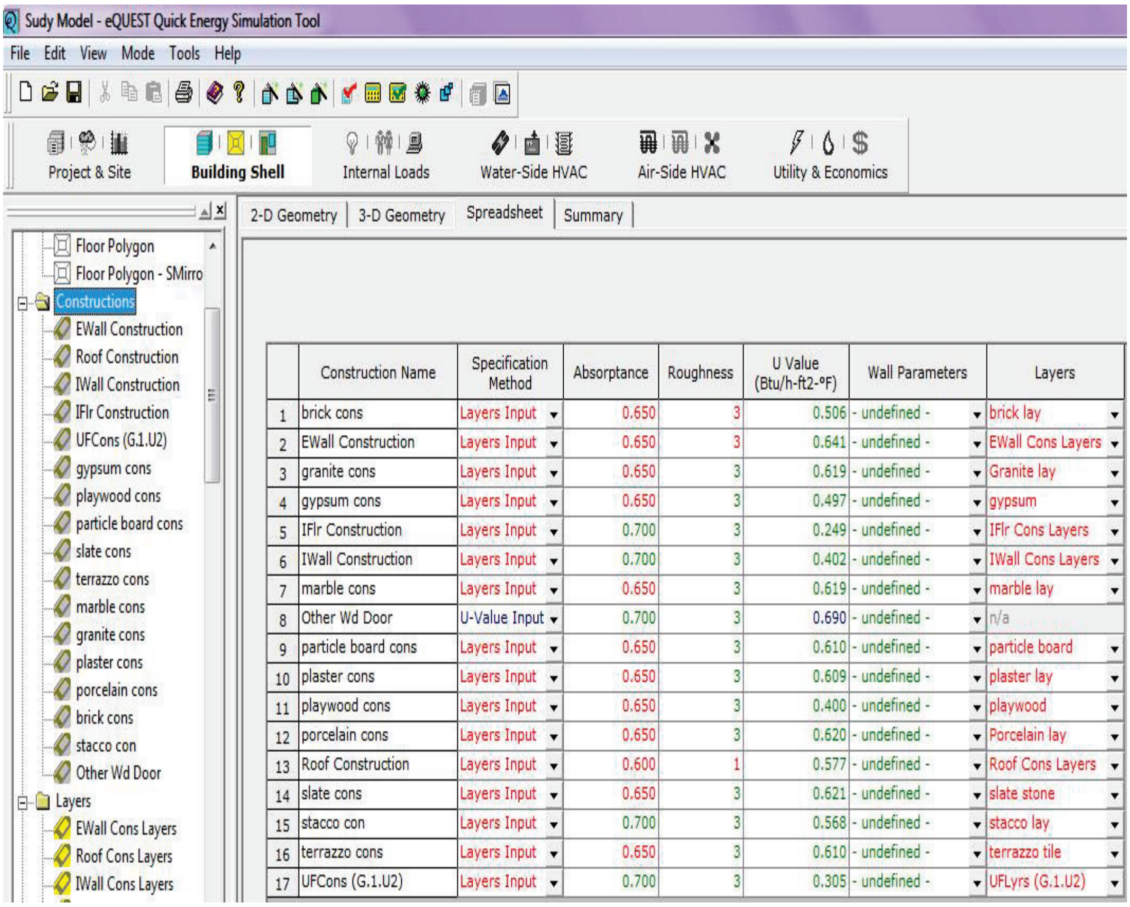


Figure 6: Exterior windows Data input of study model



	Material Name	Specification Method	Thickness (ft)	Conductivity (Btu/h-ft-°F)	Density (lb/ft3)	Specific Heat (Btu/lb-°F)	Resistance (h-ft2-°F/Btu)
1	Bldg Paper Felt (BP01)	Resistance	n/a	n/a	n/a	n/a	0.060
2	Blt-Up Roof 3/8in (BR01)	Properties	0.031	0.0939	70.00	0.350	n/a
3	brick	Properties	0.250	0.6000	120.00	0.230	n/a
4	Carpet & Fiber Pad (CP01	Resistance	n/a	n/a	n/a	n/a	2.080
5	Conc HW 140lb 6in (CC04	Properties	0.500	0.7576	140.00	0.200	n/a
6	Conc HW 140lb 6in (HF-C	Properties	0.500	1.0000	140.00	0.200	n/a
7	Conc HW 140lb 8in (CC05	Properties	0.667	0.7576	140.00	0.200	n/a
8	Granite	Properties	0.083	1.5000	175.00	0.190	n/a
9	GypBd 1/2in (GP01)	Properties	0.042	0.0926	50.00	0.200	n/a
10	IWall Cons Mat 2 (0.91)	Resistance	n/a	n/a	n/a	n/a	0.910
11	Light Soil, Damp 12in	Properties	1.000	0.5000	100.00	0.250	n/a
12	marble	Properties	0.083	1.5000	165.00	0.220	n/a
13	PartBd Md Dens 3/4in (PB	Properties	0.063	0.7833	75.00	0.310	n/a
14	plaster	Properties	0.042	0.5000	116.00	0.210	n/a
15	Plywd 1in (PW06)	Properties	0.083	0.0667	34.00	0.290	n/a
16	Plywd 3/4in (PW05)	Properties	0.063	0.0667	34.00	0.290	n/a
17	Porcelain	Properties	0.042	0.8000	150.00	0.260	n/a
18	Slate 1/2in (SL01)	Properties	0.042	0.8340	100.00	0.350	n/a
19	Stucco 1in (SC01)	Properties	0.083	0.4167	116.00	0.200	n/a
20	Terrazzo 1in (TZ01)	Properties	0.083	1.0416	140.00	0.200	n/a
21	UFMat (G.1.U2.M1)	Resistance	n/a	n/a	n/a	n/a	0.100

Figure 7: Materials properties used in study model



	Construction Name	Specification Method	Absorptance	Roughness	U Value (Btu/h-ft2-°F)	Wall Parameters	Layers
1	brick cons	Layers Input	0.650	3	0.506	- undefined -	brick lay
2	EWall Construction	Layers Input	0.650	3	0.641	- undefined -	EWall Cons Layers
3	granite cons	Layers Input	0.650	3	0.619	- undefined -	Granite lay
4	gypsum cons	Layers Input	0.650	3	0.497	- undefined -	gypsum
5	IFlr Construction	Layers Input	0.700	3	0.249	- undefined -	IFlr Cons Layers
6	IWall Construction	Layers Input	0.700	3	0.402	- undefined -	IWall Cons Layers
7	marble cons	Layers Input	0.650	3	0.619	- undefined -	marble lay
8	Other Wd Door	U-Value Input	0.700	3	0.690	- undefined -	n/a
9	particle board cons	Layers Input	0.650	3	0.610	- undefined -	particle board
10	plaster cons	Layers Input	0.650	3	0.609	- undefined -	plaster lay
11	playwood cons	Layers Input	0.650	3	0.400	- undefined -	playwood
12	porcelain cons	Layers Input	0.650	3	0.620	- undefined -	Porcelain lay
13	Roof Construction	Layers Input	0.600	1	0.577	- undefined -	Roof Cons Layers
14	slate cons	Layers Input	0.650	3	0.621	- undefined -	slate stone
15	stacco con	Layers Input	0.700	3	0.568	- undefined -	stacco lay
16	terrazzo cons	Layers Input	0.650	3	0.610	- undefined -	terrazzo tile
17	UFCons (G.1.U2)	Layers Input	0.700	3	0.305	- undefined -	UFLyrs (G.1.U2)

Figure 8: Constructions properties used in study model

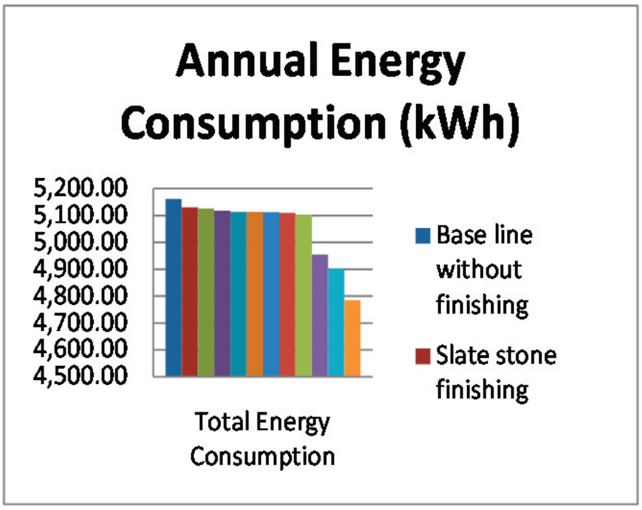


Figure 9: annual energy consumption for the base case building model

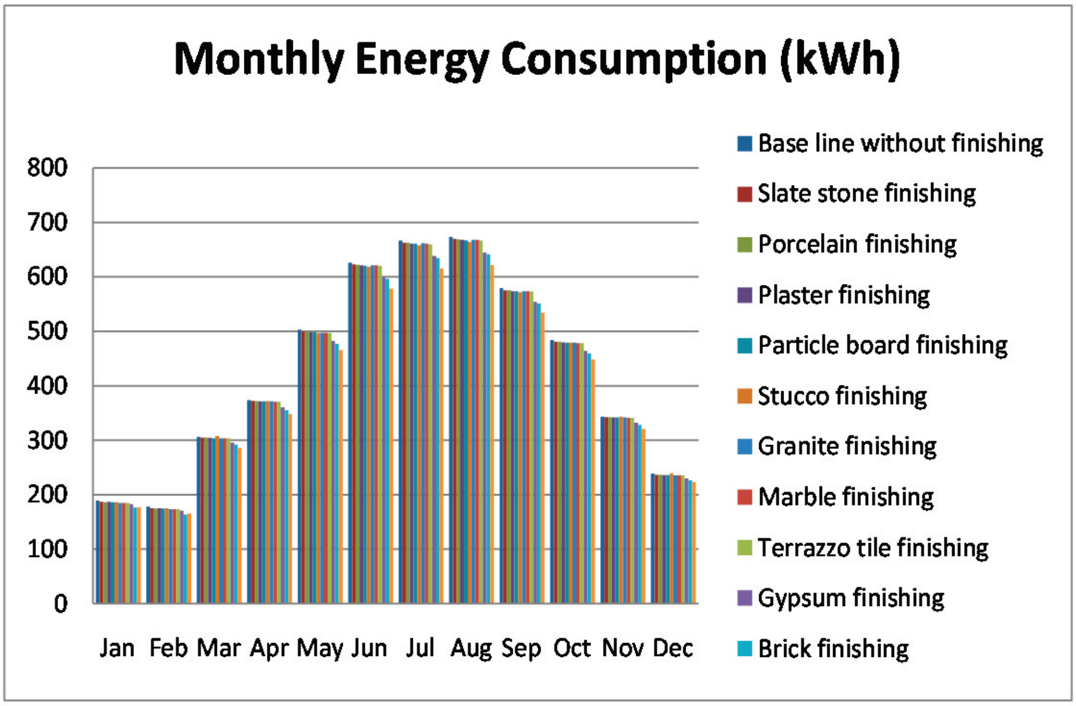


Figure 10: Annual Energy Consumption for different finishing material

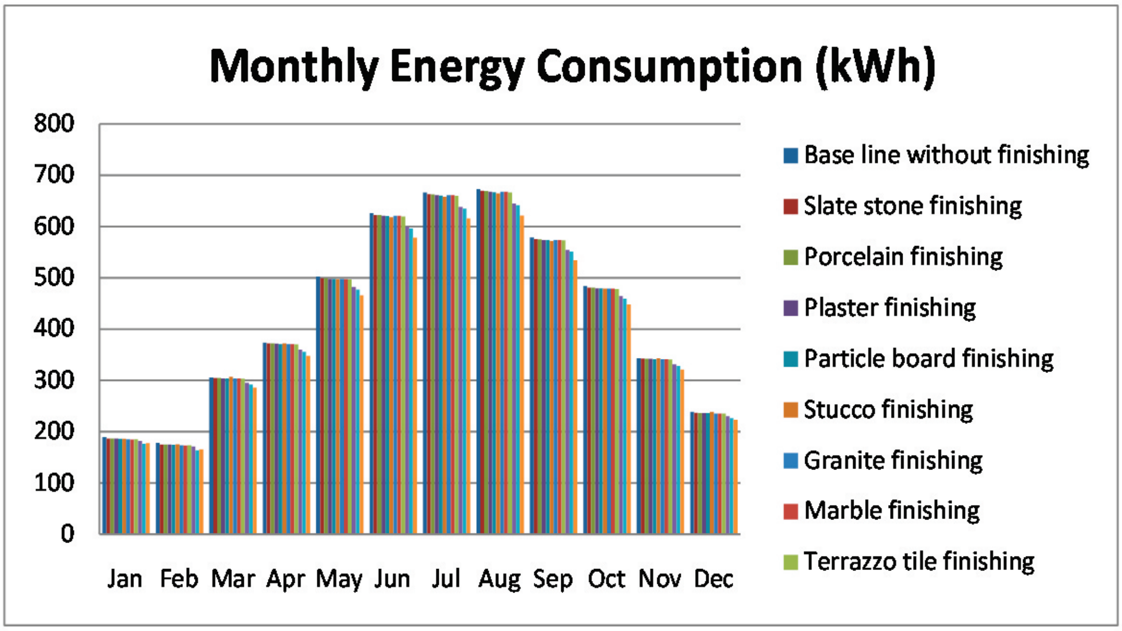


Figure 11: Monthly energy consumption of wall finishing materials

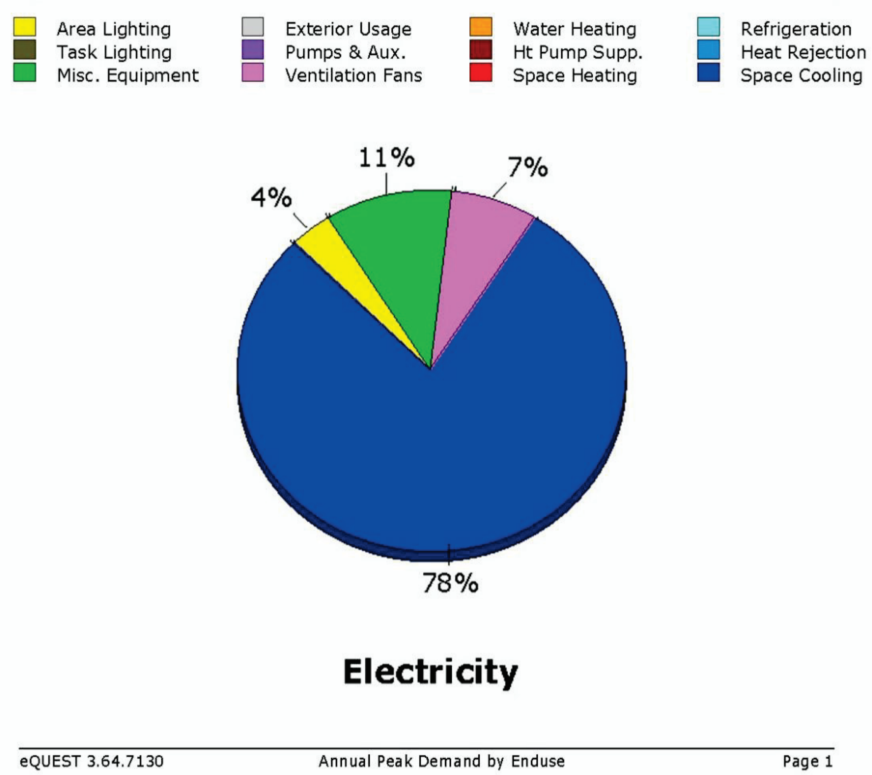


Figure 12: Annual peak demand by end-use for Base case model

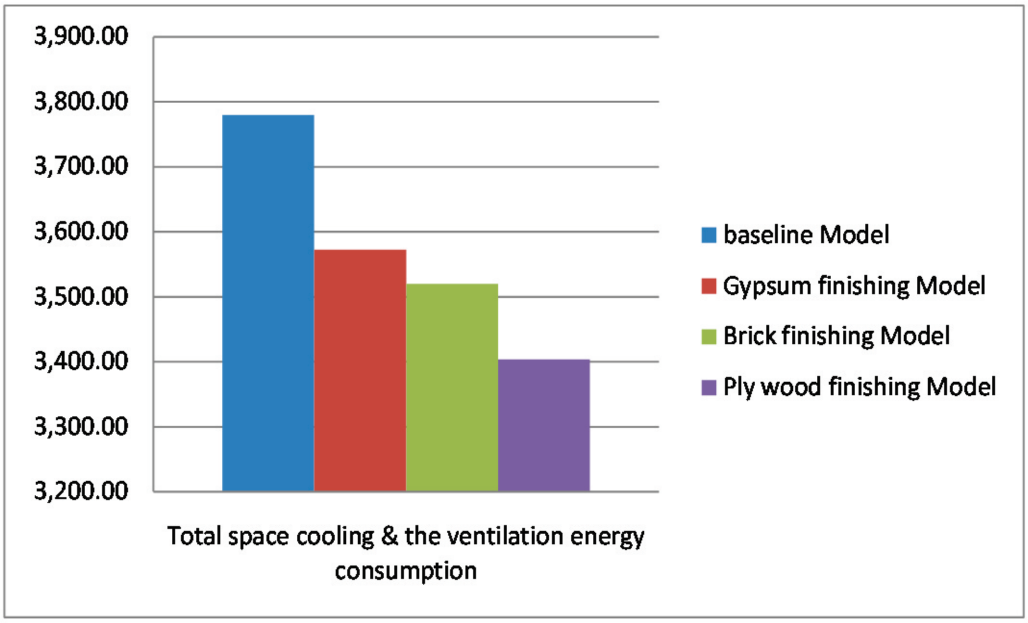


Figure 13: Annual space cooling and the ventilation energy consumption

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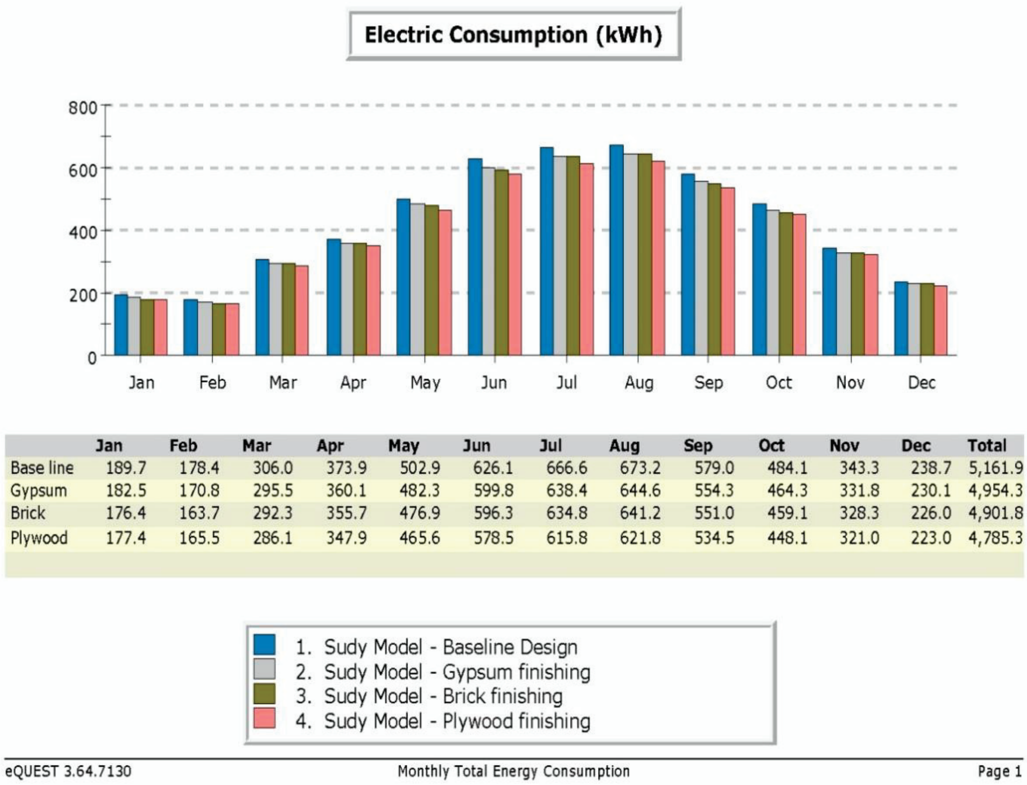
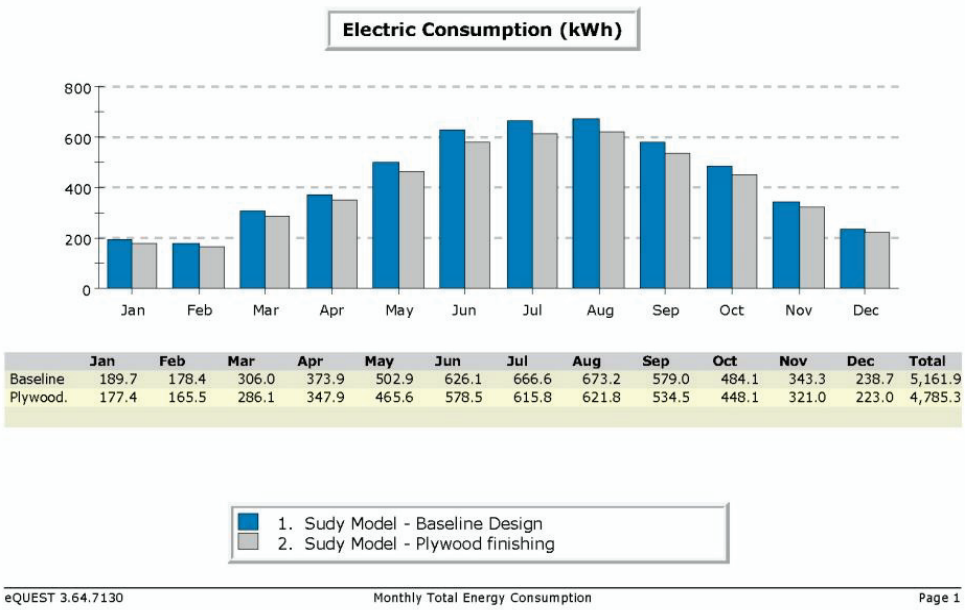


	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
Base line	189.7	178.4	306.0	373.9	502.9	626.1	666.6	673.2	579.0	484.1	343.3	238.7	5,161.9
Gypsum	182.5	170.8	295.5	360.1	482.3	599.8	638.4	644.6	554.3	464.3	331.8	230.1	4,954.3
Brick	176.4	163.7	292.3	355.7	476.9	596.3	634.8	641.2	551.0	459.1	328.3	226.0	4,901.8
Plywood	177.4	165.5	286.1	347.9	465.6	578.5	615.8	621.8	534.5	448.1	321.0	223.0	4,785.3

Figure 14: Monthly total energy consumption comparison of the four models selected



	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
Baseline	189.7	178.4	306.0	373.9	502.9	626.1	666.6	673.2	579.0	484.1	343.3	238.7	5,161.9
Plywood.	177.4	165.5	286.1	347.9	465.6	578.5	615.8	621.8	534.5	448.1	321.0	223.0	4,785.3

Figure 15: Monthly total energy consumption for base case model and plywood finishing model

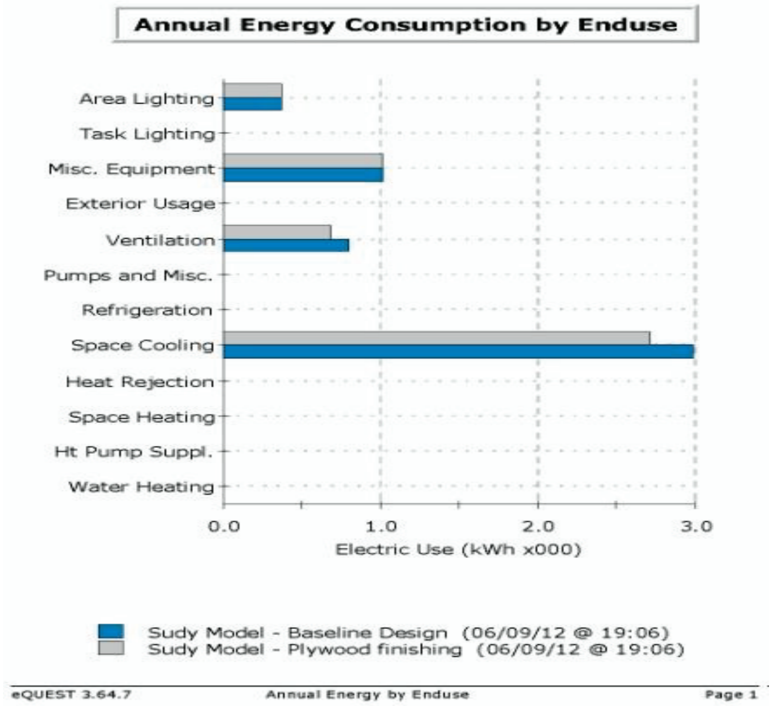


Figure 16: Annual energy consumption by end-use for base case model and plywood finishing model

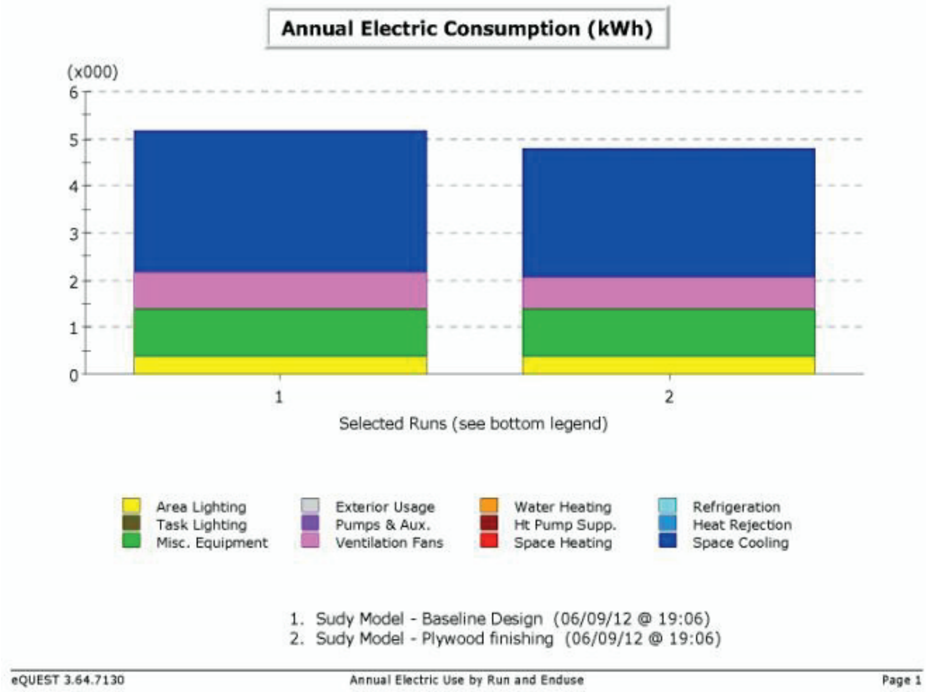


Figure 17: Annual electric consumption for base case model and plywood finishing model

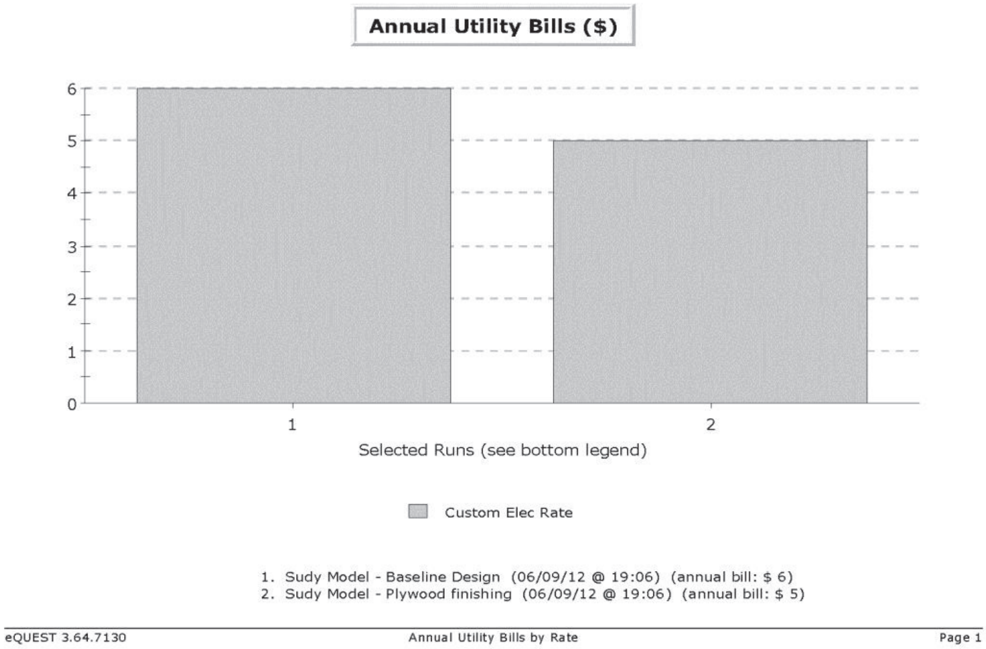


Figure 18: Annual utility bills for base case model and plywood finishing model

Table 1: Details of the Selected building model.

Characteristics	Description of the Base Case
Plan View	Square
Number of Floors	1floor
Floor to Floor Height	3m
Floor Area	9 m2
Total Area of Opaque Walls	32.6 m2
Total Area of Glazing	1.2 m2
Total Area of doors	2.2 m2
Interior Temperature, Tj	24 (C)
Occupancy density	25 (m2/person)

Table 2: Thermal Properties' of the finishing material

	Material	Thickness Inch	Density lb/ft3	Specific heat btu/lb-°F	Conductivity btu/h-ft-°F
No.	Con. Hollow Block	8 in	140	0.2	0.7576
1	Slate stone finishing	½ in	100	0.35	0.8340
2	Porcelain finishing	½ in	150	0.26	0.8000
3	Plaster finishing	½ in	116	0.21	0.5000
4	Particle board finishing	¾ in	75	0.31	0.7833
5	Stucco finishing	1 in	116	0.20	0.4167
6	Granite finishing	1 in	175	0.19	1.5000
7	Marble finishing	1 in	165	0.22	1.5000
8	Terrazzo tile finishing	1 in	140	0.20	1.0416
9	Gypsum finishing	½ in	50	0.20	0.0926
10	Brick finishing	3 in	120	0.23	0.6000
11	Plywood finishing	¾ in	34	0.29	0.0667

Source: e-Quest material library

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Table 3: Base case Design Annual Energy Consumption by End-use

Annual Energy Consumption by End-use				
	Electricity (kWh)	Natural Gas (Btu)	Steam (Btu)	Chilled Water (Btu)
Space Cool	2984.2	-	-	-
Hot Water	-	-	-	-
Vent Fans	795.9	-	-	-
Pumps & Aux	0.1	-	-	-
Misc. Equip.	1014.2	-	-	-
Task Lights	-	-	-	-
Area Lights	367.5	-	-	-
Total	5161.9	-	-	-

Table 4: Annual Energy Consumption (kWh) For Deferent Interior Finishing Material

	Total Energy Consumption (kWh)
Base line without finishing	5,161.9
Slate stone finishing	5,129.8
Porcelain finishing	5,126.8
Plaster finishing	5,117.2
Particle board finishing	5,113.6
Stucco finishing	5,113.4
Granite finishing	5,112.2
Marble finishing	5,109.2
Terrazzo tile finishing	5,103.5
Gypsum finishing	4,954.3
Brick finishing	4,901.8
Plywood finishing	4,785.3

Table 5: Monthly Energy Consumption (kWh) For Deferent Interior Finishing Materials

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Tot.
Base line	189.7	178.4	306.0	373.9	502.9	626.1	666.6	673.2	579.0	484.1	343.3	238.7	5,161.9
Slate stone finishing	186.8	175.2	304.9	372.4	499.5	622.6	663.1	669.6	575.5	480.9	342.6	236.7	5,129.8
Porcelain finishing	186.6	174.9	304.7	372.2	499.2	622.3	662.7	669.2	575.3	480.6	342.4	236.5	5,126.8
Plaster finishing	186.9	175.3	304.2	371.6	498.3	620.8	661.0	667.5	573.8	479.7	341.8	236.4	5,117.2
Particle board finishing	186.3	174.6	304.0	371.3	497.9	620.6	660.8	667.3	573.6	479.3	341.6	236.1	5,113.6
Stucco finishing	186.4	175.4	307.5	372.3	497.1	618.4	658.2	664.4	572.0	479.2	343.3	239.0	5,113.4
Granite finishing	185.2	173.4	304.0	371.2	497.7	621.1	661.4	667.9	574.0	479.0	341.6	235.6	5,112.2
Marble finishing	184.9	173.1	303.9	370.9	497.3	620.8	661.1	667.7	573.8	478.7	341.5	235.4	5,109.2
Terrazzo tile finishing	185.3	173.6	303.5	370.6	496.8	619.7	659.9	666.5	572.8	478.3	341.1	235.4	5,103.5
Gypsum finishing	182.5	170.8	295.5	360.1	482.3	599.8	638.4	644.6	554.3	464.3	331.8	230.1	4,954.3
Brick finishing	176.4	163.7	292.3	355.7	476.9	596.3	634.8	641.2	551.0	459.1	328.3	226.0	4,901.8
Plywood finishing	177.4	165.5	286.1	347.9	465.6	578.5	615.8	621.8	534.5	448.1	321.0	223.0	4,785.3

Table 6: Monthly peak demand by end-use for Base case model

Electric Demand (kW)													
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
Space Cool	0.17	0.19	0.38	0.65	0.76	0.93	0.98	0.93	0.84	0.63	0.40	0.22	7.08
Heat Reject	-	-	-	-	-	-	-	-	-	-	-	-	-
Refrigeration	-	-	-	-	-	-	-	-	-	-	-	-	-
Space Heat	-	-	-	-	-	-	-	-	-	-	-	-	-
HP Supp	-	-	-	-	-	-	-	-	-	-	-	-	-
Hot Water	-	-	-	-	-	-	-	-	-	-	-	-	-
Vent Fans	0.09	0.09	0.09	0.09	0.09	0.09	0.09	0.09	0.09	0.09	0.09	0.09	1.09
Pumps & Aux	-	-	-	-	-	-	-	-	-	-	-	-	-
Ext. Usage	-	-	-	-	-	-	-	-	-	-	-	-	-
Misc. Equip.	0.15	0.15	0.15	0.15	0.15	0.15	0.14	0.14	0.14	0.15	0.15	0.15	1.76
Task Lights	-	-	-	-	-	-	-	-	-	-	-	-	-
Area Lights	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.56
Total	0.46	0.48	0.67	0.93	1.05	1.22	1.25	1.21	1.12	0.91	0.68	0.50	10.49

Table 7: Monthly peak demand by end-use for Gypsum finishing model

Electric Demand (kW)													
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
Space Cool	0.15	0.18	0.36	0.61	0.71	0.89	0.94	0.89	0.81	0.59	0.37	0.20	6.69
Heat Reject	-	-	-	-	-	-	-	-	-	-	-	-	-
Refrigeration	-	-	-	-	-	-	-	-	-	-	-	-	-
Space Heat	-	-	-	-	-	-	-	-	-	-	-	-	-
HP Supp.	-	-	-	-	-	-	-	-	-	-	-	-	-
Hot Water	-	-	-	-	-	-	-	-	-	-	-	-	-
Vent Fans	0.08	0.08	0.08	0.08	0.08	0.08	0.08	0.08	0.08	0.08	0.08	0.08	1.01
Pumps & Aux	-	-	-	-	-	-	-	-	-	-	-	-	-
Ext. Usage	-	-	-	-	-	-	-	-	-	-	-	-	-
Misc. Equip.	0.15	0.15	0.15	0.15	0.15	0.15	0.14	0.14	0.14	0.15	0.14	0.15	1.75
Task Lights	-	-	-	-	-	-	-	-	-	-	-	-	-
Area Lights	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.56
Total	0.43	0.46	0.64	0.89	0.99	1.17	1.20	1.16	1.08	0.87	0.65	0.48	10.01

Table 8: Monthly peak demand by end-use for Brick finishing model

Electric Demand (kW)													
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
Space Cool	0.10	0.13	0.33	0.57	0.67	0.85	0.90	0.86	0.79	0.55	0.35	0.19	6.30
Refrigeration	-	-	-	-	-	-	-	-	-	-	-	-	-
Hot Water	-	-	-	-	-	-	-	-	-	-	-	-	-
Vent Fans	0.08	0.08	0.08	0.08	0.08	0.08	0.08	0.08	0.08	0.08	0.08	0.08	0.95
Pumps & Aux	-	-	-	-	-	-	-	-	-	-	-	-	-
Misc. Equip.	0.15	0.15	0.15	0.15	0.15	0.15	0.14	0.14	0.14	0.15	0.14	0.15	1.75
Area Lights	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.56
Total	0.38	0.41	0.60	0.85	0.95	1.12	1.16	1.12	1.06	0.83	0.62	0.46	9.56

Table 9: Monthly peak demand by end-use for Plywood finishing model

Electric Demand (kW)													
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
Space Cool	0.13	0.16	0.34	0.58	0.68	0.85	0.90	0.86	0.78	0.56	0.35	0.19	6.38
Heat Reject	-	-	-	-	-	-	-	-	-	-	-	-	-
Refrigeration	-	-	-	-	-	-	-	-	-	-	-	-	-
Space Heat	-	-	-	-	-	-	-	-	-	-	-	-	-
HP Supp	-	-	-	-	-	-	-	-	-	-	-	-	-
Hot Water	-	-	-	-	-	-	-	-	-	-	-	-	-
Vent Fans	0.08	0.08	0.08	0.08	0.08	0.08	0.08	0.08	0.08	0.08	0.08	0.08	0.94
Pumps & Aux	-	-	-	-	-	-	-	-	-	-	-	-	-
Ext. Usage	-	-	-	-	-	-	-	-	-	-	-	-	-
Misc. Equip.	0.15	0.15	0.15	0.15	0.15	0.15	0.14	0.14	0.14	0.15	0.14	0.15	1.75
Task Lights	-	-	-	-	-	-	-	-	-	-	-	-	-
Area Lights	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.56
Total	0.41	0.44	0.61	0.85	0.95	1.12	1.16	1.12	1.05	0.83	0.62	0.46	9.63

Table 10: Monthly space cooling and the ventilation energy consumption

		Ja	Fe	Ma	Apr	Ma	Jun	Jul	Au	Sep	Oct	No	Dec	Total	Less
base case Model	Cool	6.9	11.6	117.8	195.9	316.5	444.6	483.8	485.1	401.1	299.5	165.3	55.9	2,984.2	
	Fans	67.6	61.1	67.6	65.4	67.6	65.4	67.6	67.6	65.4	67.6	65.4	67.6	795.9	
	Total	74.5	72.7	185.4	261.3	384.1	510.0	551.4	552.7	466.5	367.1	230.7	123.5	3,780.1	
Ply wood finishing Model	Cool	3.8	6.9	107.1	178.7	288.4	405.8	442.2	442.8	365.4	272.7	151.9	49.4	2,715.1	9 %
	Fans	58.5	52.8	58.5	56.6	58.5	56.6	58.5	58.5	56.6	58.5	56.6	58.5	688.4	13.5%
	Total	62.3	59.7	165.6	235.3	346.9	462.4	500.7	501.3	422.0	331.2	208.5	107.9	3,403.5	10%
Brick finishing Model	Cool	2.2	4.6	112.6	185.8	299	423	460.5	461.5	381.2	282.9	158.5	51.7	2,823.6	5.5%
	Fans	59.1	53.4	59.1	57.2	59.1	57.2	59.1	59.1	57.2	59.1	57.2	59.1	696.4	12.5%
	Total	61.3	58.0	171.7	243.0	358.1	480.2	519.6	520.6	438.4	342.0	215.7	110.8	3,520.0	7%
Gypsum finishing Model	Cool	5	8.8	112.7	187.2	301.2	423.3	460.9	461.7	381.4	284.9	158.9	52.6	2,838.6	5%
	Fans	62.3	56.3	62.3	60.3	62.3	60.3	62.3	62.3	60.3	62.3	60.3	62.3	733.9	8%
	Total	67.3	65.1	175.0	247.5	363.5	483.6	523.2	524.0	441.7	347.2	219.2	114.9	3,572.5	5.5%

Table 11: Thermal Properties of the finishing materials

	Material	Thickness (Inch)	Density (lb/ft3)	Specific heat (btu/lb-°F)	Conductivity (btu/h-ft-°F)	Total Energy Consumption (kWh)
BD	Con. Hollow Block	8 in	140	0.2	0.7576	5,161.9
1	Slate stone finishing	½ in	100	0.35	0.8340	5,129.8
2	Porcelain finishing	½ in	150	0.26	0.8000	5,126.8
3	Plaster finishing	½ in	116	0.21	0.5000	5,117.2
4	Particle board finishing	¾ in	75	0.31	0.7833	5,113.6
5	Stucco finishing	1 in	116	0.20	0.4167	5,113.4
6	Granite finishing	1 in	175	0.19	1.5000	5,112.2
7	Marble finishing	1 in	165	0.22	1.5000	5,109.2
8	Terrazzo tile finishing	1 in	140	0.20	1.0416	5,103.5
9	Gypsum finishing	½ in	50	0.20	0.0926	4,954.3
10	Brick finishing	3 in	120	0.23	0.6000	4,901.8
11	Plywood finishing	¾ in	34	0.29	0.0667	4,785.3