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# Energy Saving Assessment for Building Envelope of Supermarket Based on EnergyPlus and Openstudio

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**Abstract:** In this paper, a supermarket model located in Kathmandu is established by simulation software EnergyPlus. As one possible approach to improving the energy performance of the commercial building, this study develops an whole building energy simulation model to investigate the influence of two types of alternative walls – a insulated wall, a brick wall with 50 mm air gap and 4 inch additional brick wall on the energy performance of Bhatbhateni department store building at Krishna Galli, Lalitpur, Nepal. Single and double glazed glasses with varies thermal properties has been analyzed. This study finds that the 1 inch insulated external walls significantly improve the performance compared to the non-insulated wall. It is also found that the double glazed glass window models Envision and Reflectasol reduces the largest amount of energy. The results of this study can be used as basis data for estimating the potential energy saving with the replacement of alternative envelope (wall and window) under similar climate and orientation of the buildings.

**Keywords:** Building Envelope, Heat Balance Equation, EnergyPlus, Openstudio, Energy Saving, Simulation, Model Calibration

## 1. Introduction

The Kathmandu valley has a Warm Temperate climate with ambient temperatures ranging from round 10°C on a typical winter day to above 30°C on a typical summer day. Both the heating and cooling required for building to maintain the comfortable temperature. The energy consumption in buildings is more than 20% in India [6]. Even though it is not estimated the total building energy consumption in Nepal, for commercial building it can be more than 20% due to cooling and heating requirement throughout the year.

Presently commercial sectors consume around 1.3% of the total energy supply in Nepal [16]. However, consumption trend is increasing for this sector. The main uses of electricity in commercial sector, is similar to those in residential sectors, e. g. cooking, heating, lighting, water pumping and running other electrical appliances. The most of supermarkets in Kathmandu is air-conditioned with DX cooling and heating systems. Electricity consumption share for commercial sector is minimum i.e. about 11% compare to other sectors [16]. Electricity sales for commercial sector is 285.42 GWh i.e. 8.16% of total sales [10]. Various strategies has been adopted for demand side management and consumers shall be encouraged for demand side management to enhance energy conservation [9].

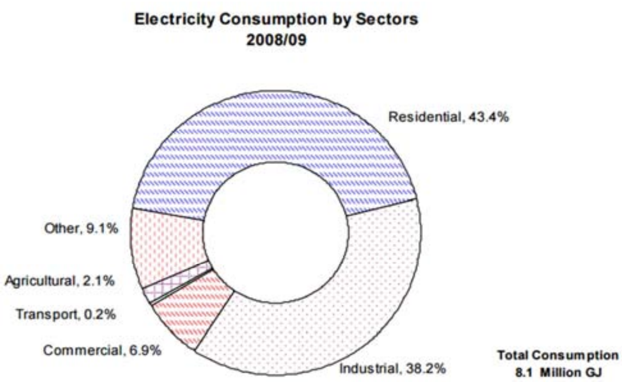


***Figure 1.*** *Electricity consumption by sectors [16].*

This energy consumption can be reduced significantly by designing and analysis in the perspective of energy saving with whole building energy simulation. Present scenario of Nepal is practicing the building design with the sole consideration of architectural and structural point of view not as integrated design of mechanical, electrical, architectural, and other systems with perspective of energy consumption as well.

Research has been carried out to address the potential energy saving in building by using passive solar heating and natural ventilation for residential buildings. Thermal comfort and energy saving can be enhanced by using insulation to the wall and roof [14]. Limited research has been published for commercial building in which energy consumption accounts greater.

Bhatbhateni supermarket and Department Store, Krisna Galli Branch is located in Krishna Galli, Lalitpur, Nepal. It is five storey building and has total floor area of 129306.651 square feet. It offers wide range of grocery; a broad range of leading international liquor, toiletries and cosmetics brands; and an extensive choice of kitchenware, clothing, sports, toys and electrical items. Every floor is air-conditioned with central chilled water system.

Each floor is provided with multiple air handling units (AHU) with fresh air provision. This building has been chosen for analysis as it has been facilitated with central air conditioning system and operation of the building is thorough the year.

Since 1984 A. D, Bhat-Bhateni has grown from a ‘single shutter’ 120 sq. ft. cold store to become the leading supermarket and departmental store chain in Nepal, and the highest tax payer in the sector since 2008 A. D. with more than 40,000 customers daily. There are currently twelve 12 stores conveniently located in central Kathmandu and other major cities of Nepal.

The precise and error-free input for internal loads greatly determine the realistic simulation of energy balance of the building. The variation in energy consumption or so-called ‘performance gap’ from the simulated at design stage and actual energy performance of the building is obvious when system is monitored.

It is well known that building energy consumption simulated at the design stage rarely agrees with observed data post design, and with increasing deployment of energy monitoring systems this so-called ‘performance gap’ is becoming increasingly visible [17].

One would expect that forecast consumption for an already existing building would be in closer agreement with reality, yet it is still notoriously difficult to match the simulation to the observed data [15].

The internal loads are inextricably linked to occupant behavior directly or indirectly though the heat expel from the occupant and appliance schedule. Major proportion of energy consumption is occupant related activities in the building so careful estimation are to be made to closer match with the building simulation model. However internal loads related to occupants is hard to identify as occupant behaves stochastically so energy consumption comprises of uncertainty in model [4].

Building energy models without calibration or calibration with few parameters such as indoor temperature, internal equipment energy consumption proved to be unreliable for model performance and also high risk is associated in accuracy of results. Has proposed building calibration methodology to reduce risk and applying to medieval buildings with EnergyPlus based on energy audit.

Most of commercial building in Nepal is has not been considered to energy efficiency. Renovation is key strategies to improve energy performance and thermal comfort. Energy Simulation can help to quantify energy saving for each alternatives. But well-calibrated model only help to get rid of misleading conclusions. Sensitivity analysis has been conducted in Waaghaus (weigh house) is located in the historic center of Bolzano in northern Italy to identify parameters cause error between model results and indoor air temperatures. The validated model has root mean square error of 0.4 to 0.8 K. The model has been validated hourly [13].

Thermal mass has been evolved as strategies of conservation of energy, even though it always has been aspect of building. Proper use of thermal mass has important aspect in design of climate-responsive sustainable building [5]. Concrete and masonry comprises distinctive properties for energy savings as they have intrinsic thermal mass. For net zero building and comfortable indoor air quality, importance of thermal mass has become more prominent by application of more stringent insulation standards. (Perino et al, 2015). The materials having high thermal mass absorbs the heat slowly and retain it for longer period of time than the low thermal mass materials. This lag reduces the peak load in the building which reduces the energy and capacity of equipment required for thermal comfort. The less temperature variation can overserved when using thermal insulation inside wall in high weight building structure [18]. High weight structure maintained high temperatures radiant in winter and eliminated overheating in summer [11]. But high weight structure need much time to heat and cool the building so it requires more energy for thermal comfort [7].

## 2. Method and Tools

This study is quantitative research which mainly deals with energy consumption in the buildings. The literature study has been done through research reports, journals. After collecting the building data officially from department store, modeling has been carried out. The weather data in EnergyPlus software format has been studied. Based on analysis of building data and weather data of local context, the design model of building is developed referring building orientation, building form, size of openings, sun shading device, type of building materials etc. The existing building has been analyzed by altering or adding building envelope. The energy saving for each measures has been evaluated.

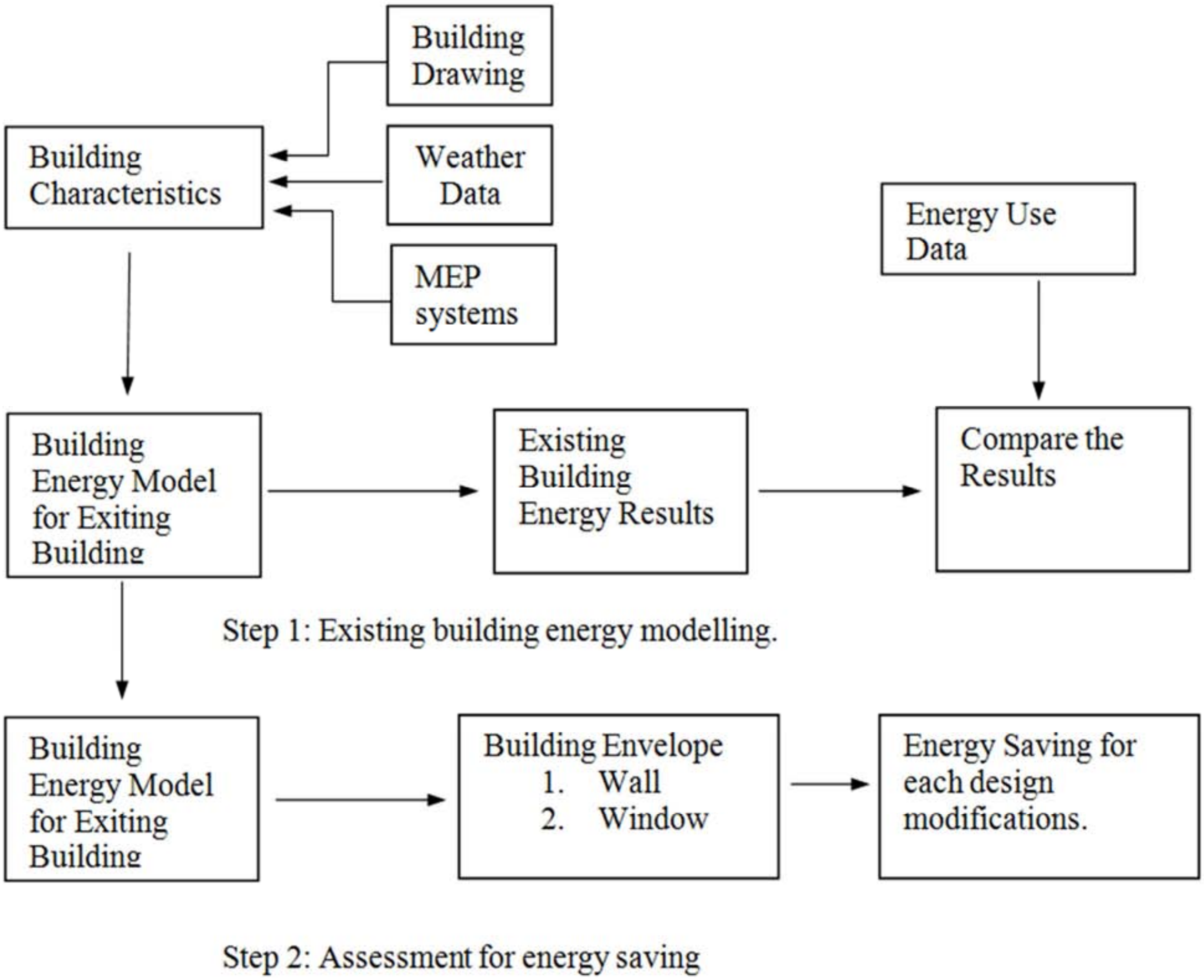


***Figure 2.*** *Analysis and evaluation approach.*

Energy plus has been developed by U.S. Department of Energy (USDOE) and is most powerful tool for building energy simulation for new construction, renovation and selection of proper selection of electro-mechanical systems. It evaluates the cooling and heating loads to meet set point temperature based on user input for the building through the year. The open studio is the graphics user interface for the energyplus which has been employed for this study.

## 3. Building Energy Model

The dimensions from plans and elevations has been verified as per actuation building construction and modeling has been done. Each floor has been divided into one and two spaces. All the dimensions are utilized from building drawings.

Weather data used for modeling which is provided by department of hydrology and metrology, government of Nepal. The data has been processed in. epw format by [1]. Monthly data for 8 locations in Nepal has been collected for at least 20 years [2]. METEONORM, a software tool is used to generate weather data in. epw format to use with EnergyPlus software [8].

The double and single glazed glasses of different thermal properties has been analyzed. And similarly the insulation and other design alternatives has been applied to the wall.

The energy consumption from the energy modeling has been validated with actual energy consumption. It has been found that the energy consumption from the model is 10.41% higher than the actual energy consumption. The reason might be the air conditioning system is not used during the opening hours of the supermarket due to load shedding. And also the internal equipment may not be operated uniformly during all the months and days.

Figure 3 shows the thermal mass model of the building with rendering of wall, window and roof in which different color has been assigned for wall, roof and window. Figure 4 shows the front (north) and side (west) view of the building. Figure 5 shows the rendering of building with respect to building storey and boundary condition. The each story has different color. External wall which is exposed to the atmosphere and wall with air conditioned outside has distinct color assigned.

From model it has been observed that the Energy Usage

Index (EUI) is 39.94. As per Energy Star, the EUI for National Median Source for supermarket/grocery is 500 [3]. Net site energy and total building area is found to be 3,800,424 kBtu and 118,979 square feet.

***Table 1.*** *Building Model Summary.*

| Net Site Energy | 3,800,424 | kBtu |
|---|---|---|
| Total Building Area | 118,979 | $ft^2$ |
| EUI (Based on Net Site Energy and Total Building Area) | 31.94 | $kBtu/ft^2$ |

***Table 2.*** *Weather Summary.*

| Weather File | KATHMANDU International Airport Station Number: SWERA WMO#=444540 |
|---|---|
| Latitude | 27.7 |
| Longitude | 85.37 |
| Elevation | 1337 (meter) |
| Time Zone | 5.75 |
| North Axis Angle | 0 |

***Table 3.*** *The Typical Display Space Area Summary.*

| Definition | Value | Unit |
|---|---|---|
| People Definition Display Area | 200 | people |
| Electric Equipment Definition First to fifth floor Display Area | 2,000 | W |
| Lights Definition | 1.08 | $W/ft^2$ |
| OA Ventilation Display Area (outdoor air method Sum) | 5 | cfm/person |
| OA Ventilation Display Area | 0.06 | cfm/floor area $ft^2$ |

***Table 4.*** *The Typical Lobby Space Area Summary.*

| Definition | Value | Unit |
|---|---|---|
| People Definition Lobby | 10 | people |
| Electric Equipment Definition First to fifth floor Lobby | 700 | W |
| Lights Definition | 1.08 | $W/ft^2$ |
| OA Ventilation Lobby Area (outdoor air method Sum) | 5 | cfm/person |
| OA Ventilation Lobby Area | 0.06 | cfm/floor area $ft^2$ |

***Table 5.*** *Window Wall Ratio of the Building.*

| Description | Total (%) | North (%) | East (%) | South (%) | West (%) |
|---|---|---|---|---|---|
| Gross Window-Wall Ratio | 28.41 | 49.06 | 36.66 | 1.26 | 33.29 |

***Table 6.*** *Building Envelope (Wall and Roof) Detail.*

| Construction | Net Area ($ft^2$) | Surface Count | R Value ($ft^2$*h*R/Btu) |
|---|---|---|---|
| Exterior Wall ( 9in) | 35715 | 82 | 2.47 |
| Roof | 16997 | 2 | 0.46 |

***Table 7.*** *Building Envelope (Window) Detail.*

| Construction | Area ($ft^2$) | Surface Count | U-Factor (Btu/$ft^2$*h*R) |
|---|---|---|---|
| External Window East Side | 2043 | 4 | 1.0038 |
| External Window North Side | 9666 | 34 | 1.0038 |
| External Window South Side | 211 | 12 | 1.0038 |
| External Window West Side | 2783 | 12 | 1.0038 |

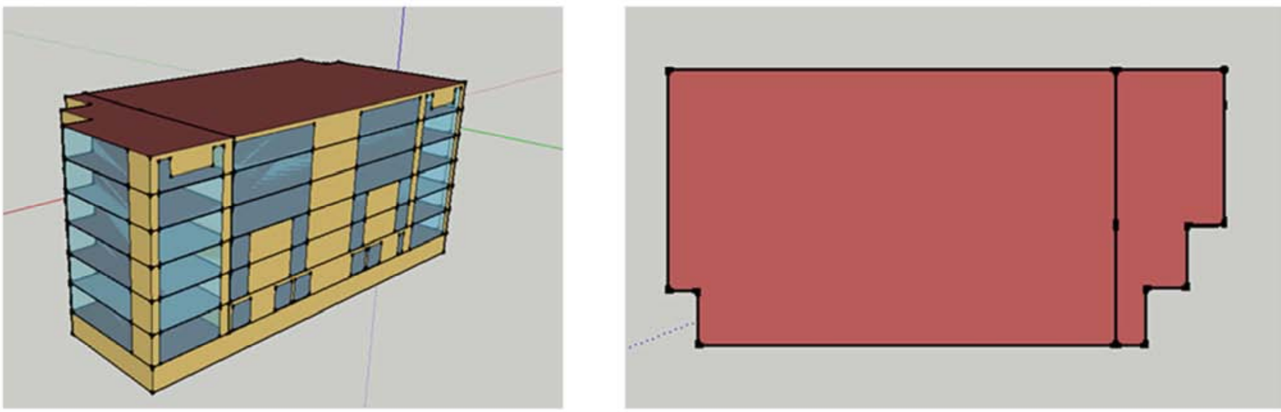

***Figure 3.*** *Isometric and top view of thermal mass of the building.*

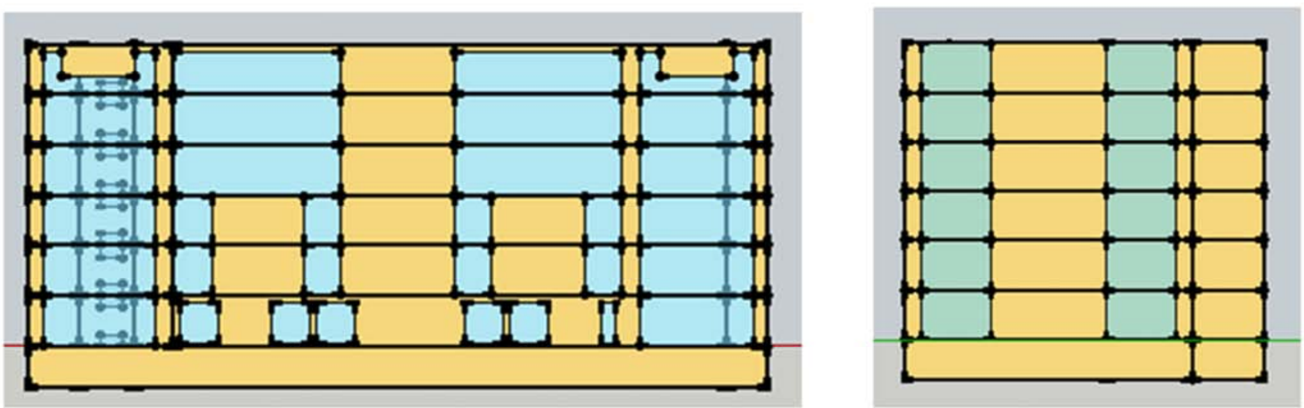

***Figure 4.*** *Front and vide view of thermal mass of the building.*

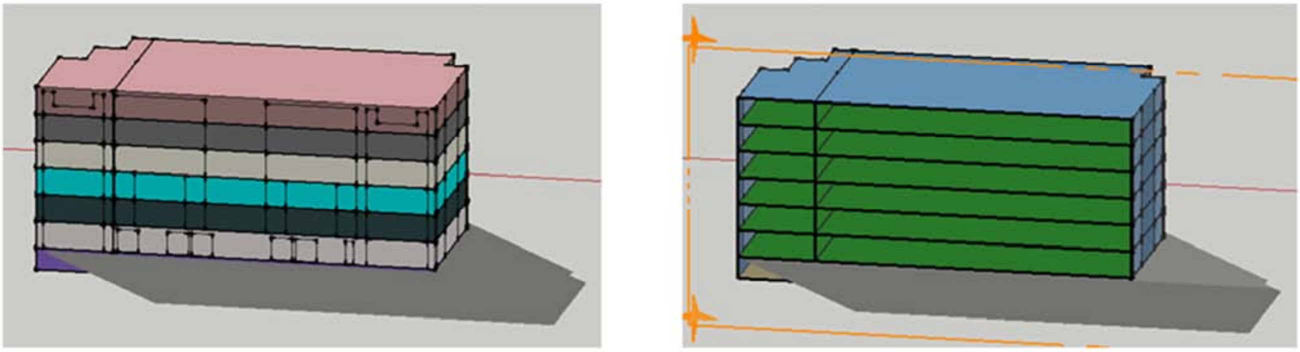

***Figure 5.*** *Rendered as reference to building storey and boundary condition with shading effect at 9:30 am on 08th, September.*

## 4. Energy Saving Assessment

The parameters for energy saving assessment are as follows.

1. Wall
2. Window Glass Material

For wall the 9 inch Brick Wall is which is exiting wall of building is considered as base case. And insulation has been applied in one case and additional wall with air gap is considered in another case.

For windows single and double glazing glasses has been considered for alternative to the existing glass whose properties has been taken from manufacturer data sheets.

***Table 8.*** *Wall base case and Energy Efficiency Measures.*

| (Base Case) | Alternative 1 | Alternative 2 |
|---|---|---|
| 9 Inch Brick Wall (Existing Wall) | 9 Inch Brick Wall with 1 inch Insulation | 9 Inch Brick Wall with 50 mm Air Gap and 4 inch (101.6 mm) Insulation |
| R = 0.435 m2*K/W | Conductivity K= 0.03 W/mK Thickness = 0.0254 m<br>R = 1.24 $m^2$ *K/W | R = 0.724 $m^2$ *K/W |

***Table 9.*** *Glass window base case and energy efficiency measures.*

| Glass Definition | Base Case | Energy Efficiency Measures | | | | |
|---|---|---|---|---|---|---|
| | | Alternative 1 | Alternative 2 | Alternative 3 | Alternative 4 | Alternative 5 |
| | Single Glazed Unit | | Double Glazed Unit | | DOUBLE GLAZED UNIT 6mm Coated | |
| Model | Reflectsol | Evolite | Reflectsol | Nanosilver | Reflectsol | Envision |
| Shade | Light Gold | Neutral | Light Gold | Chroma | Light Gold | Magma |
| Thermal Properties | U= 5.7 W/m2K; SHGC = 0.58 | U= 5.0 W/m2K; SHGC = 0.58 | U= 2.8 W/m2K; SHGC = 0.49 | U= 1.6 W/m2K; SHGC = 0.34 | U= 1.8 W/m2K; SHGC = 0.43 | U= 1.5 W/m2K; SHGC = 0.32 |

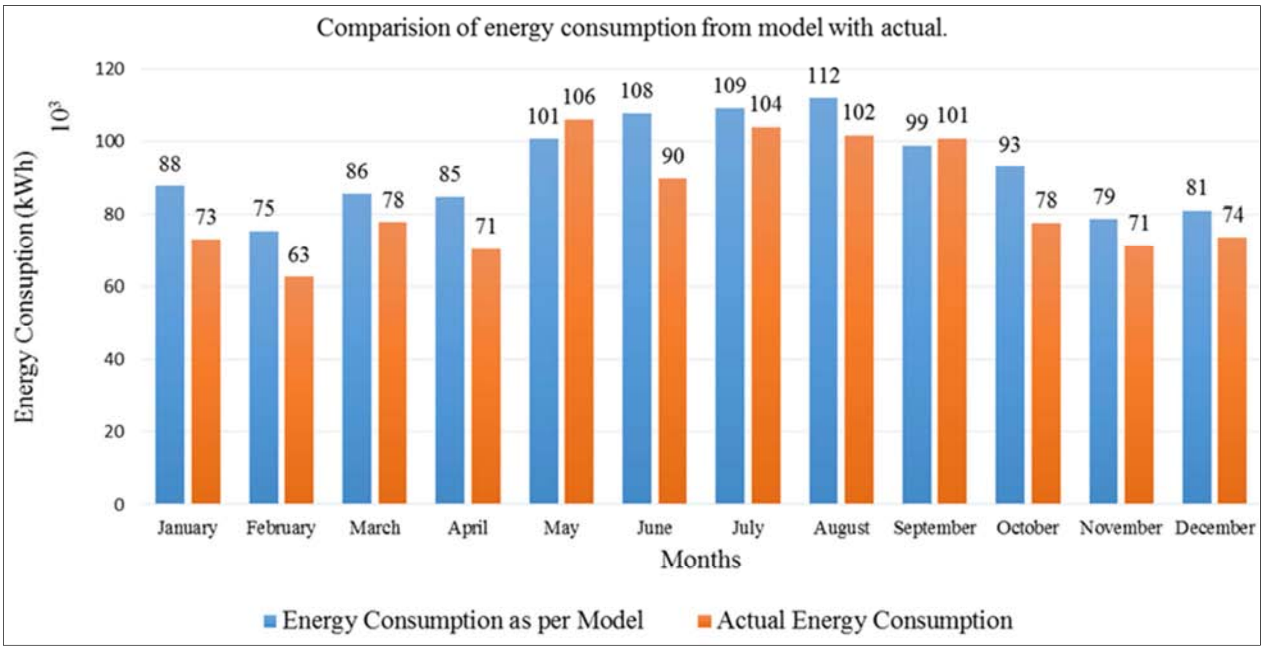


***Figure 6.*** *Comparison of energy consumption from model with actual.*

***Table 10.*** *Summary of energy consumption with all proposed glasses.*

| 1 | **Energy Conservation Measures** | | | **Heating (kWh)** | **Cooling (kWh)** | **Fans (kWh)** | **Total Energy (kWh)** | **Total HVAC Energy (kWh)** | **Decrease in Total Energy ((%)** |
|---|---|---|---|---|---|---|---|---|---|
| | **Model** | **Color Shade** | **Thermal Properties** | | | | | | |
| 1 | Reflectsol | Light Gold | U= 5.7 W/m$^2$K; SHGC = 0.58 | 53550 | 315791 | 142113 | 1113794 | 369341 | |
| 2 | Evolite | Neutral | U= 5.0 W/m$^2$K; SHGC = 0.58 | 52293 | 314883 | 140667 | 1110182 | 367176 | 0.32 |
| 3 | Reflectsol | Light Gold | U= 2.8 W/m$^2$K; SHGC = 0.49 | 49564 | 298798 | 135998 | 1086699 | 348362 | 2.43 |
| 4 | Nanosilver | Chroma | U= 1.6 W/m$^2$K; SHGC = 0.34 | 48035 | 285576 | 133511 | 1069461 | 333611 | 3.98 |
| 5 | Reflectsol | Light Gold | U= 1.8 W/m$^2$K; SHGC = 0.43 | 47114 | 295412 | 133960 | 1078825 | 342526 | 3.14 |
| 6 | Envision | Magma | U= 1.5 W/m$^2$K; SHGC = 0.32 | 47618 | 286006 | 133280 | 1069243 | 333624 | 4.00 |

***Table 11.*** *Summary of energy consumption with all combination of wall.*

| **S. N.** | **Energy Conservation Measures** | | **Heating (kWh)** | **Cooling (kWh)** | **Fans8 (kWh)** | **Total Energy (kWh)** | **Total Heating/Cooling Energy8** | **Decrease in Total Energy8 (%)** |
|---|---|---|---|---|---|---|---|---|
| | | **Thermal Properties** | | | | | | |
| 1 | Base Case (9 Inch Brick Wall) | R = 0.435 m$^2$ *K/W | 53550 | 315791 | 142113 | 1113794 | 369341 | |
| 2 | Wall Insulation 25.4 mm | Conductivity K= 0.03 W/mK Thickness = 0.0254 m, R = 1.24 m2 *K/W | 52867 | 314792 | 134775 | 1106772 | 367658 | 0.63 |
| 3 | Wall With 50 mm Air Gap and additional 4 inch Brick Wall | R = 0.724 m2 *K/W | 51714 | 314448 | 137901 | 1106403 | 366162 | 0.66 |

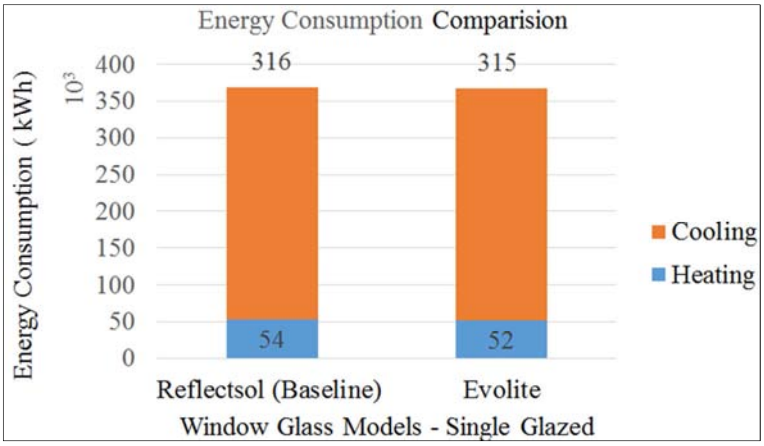


***Figure 7.*** *Energy consumption comparison of Reflectasol Single Glazed and Envision Double Glazed window glass model.*

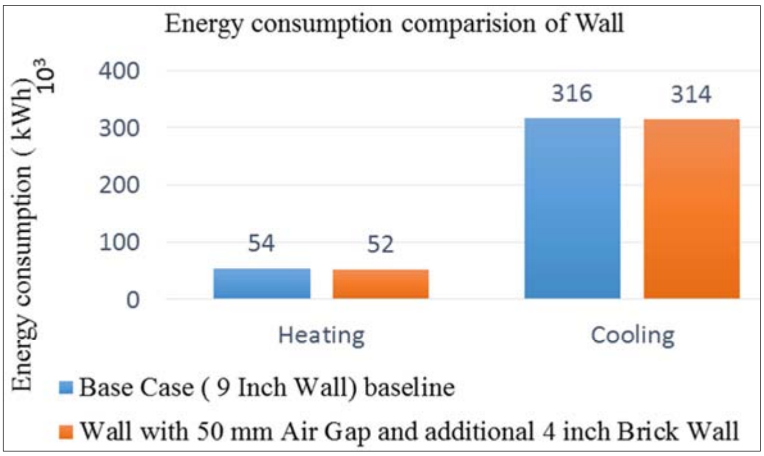


***Figure 8.*** *Energy consumption comparison of 9 inch Brick Wall same wall with 50 mm air gap and additional 4 inch Brick Wall.*

# 5. Conclusion

This study presented a new approach to achieve building energy efficiency using parametric analysis of building envelope and mechanical systems with the help of whole building energy simulation and optimization.

Using a developed energy simulation model of a Bhatbhateni department store's building with a 9 inch brick wall as a baseline. This study investigates the energy improvement of the building with two of alternative walls i) 1 inch insulation ii) 50 mm air gap with 4 inch additional brick work. This study finds that the 1 inch insulated external walls significantly improve the performance compared to the non-insulated wall. This improves the energy consumption by 1.28% which is beneficial for long run of the building. And second alternative reveals that 3.43% improvement in energy saving.

Based on the results of the simulation study, it is found that the double glazed glass window ( Envision) reduces the largest amount of energy by on average 4.0%, and a double glazed glass window (Reflectasol) reduces 3.14% operation energy.

Although the Nepalese traditional building has been recently revitalized as an environmentally friendly building in terms of building materials and building construction methods, the commercial building still requires a concerted effort to decrease energy consumption with the help of building energy simulation for cooling and heating demand and further, to mitigate the environmental impact of the Nepal's building sector.

# Recommendation

This research primarily has been focused on the exiting building architecture and structure where window glass ratio and orientation is fixed. It can further analyses by varying window glass ratio for energy saving by balancing heat fluxes enters to the building and daylight saving.

The energy saving from each of the alternatives can be assessed for green raring system by credit calculation.

The thermal comfort, air distribution and fresh air requirements can be further analysis with CFD modelling to verify the effectiveness of the air conditioning system.

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