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Smart Building Technologies and Passive Strategies for Energy optimization - a case of Multi-Residential Buildings in Kathmandu Valley

Bijay Kumar Prajapat [a], Tri Ratna Bajracharya [b], Sanjaya Uprety [c]

[a, c] *Department of Architecture, Pulchowk Campus, IOE, TU, Nepal*
[b] *Department of Mechanical Engineering, Pulchowk Campus, IOE, TU, Nepal*
Corresponding Email: [a] amplebijay@gmail.com, [b] triratna@ioe.edu.np, [c] suprety@ioe.edu.np

Abstract

Energy efficiency is one of the most important attempts in the world because of various environmental, economical and developmental aspects of energy. The climate change and its adverse effect due to human activities has taken the central stage in the current global political agenda and global news. In this context, energy performance of buildings has been a critical issue since buildings constitute approximately half of total energy consumption. Architects, Designers and Planners has continuously searched and experimented with many energy efficient strategies and come up with many efficient passive design strategies. One of the new concepts in rise in terms of building efficiency is smart building which has been attractive recently, contributes to the issue with smart technologies. While some passive design techniques which have been used throughout the history are still applicable for energy saving, the study is focused to evaluate the impact of technological devices and traditional methods and how the two strategies combine together performs in the location where the climate is temperate. While researching impacts of various active or passive building components to energy efficiency, the study not only focused on heating and cooling load reduction but also lighting electricity saving by use of daylight. Selected various active systems and passive strategies is tested on a base-case module, which is a apartment flat in an existing residential tower in Kathmandu valley, i.e. Guna Colony Apartment, Shinamangal and LP Apartment, Lazimpart by the help of computer based energy simulations. Systems and strategies are selected in the light of literature by considering wide availability in market and also the limitation of the energy simulation software: Energyplus. During the process, three series of simulation variations including eighteen different scenarios are tested. Only active systems is tested in the first series and only passive strategies in the second. Finally, impact of using both active systems and passive strategies together is tested in the third series in both the building Cases. The result shows that with the combination of active and passive strategies the overall energy of about 30 percent can be saved in the multi- residential building in Kathmandu.

Keywords

Smart Building Technologies, Passive strategies, Energy optimization, energy simulation, multi-residential buildings

1. Introduction

Energy is one of the most important elements for the environmental, economic and developmental aspects of any country in the world. Thus, energy efficiency is not just any alternative features anymore but a necessity for the development of any country. Energy performance of buildings is critical since buildings constitute approximately half of total energy consumption in the world [1]. In this 21st century where technology is in its highest peak, the concept of intelligent building has arisen. The concept of smart building which has been attractive recently, contributes to the issue with smart technologies that can be embedded in building systems applicable for energy saving.

In the past, buildings used to be simple while the lifestyle of the people didn't used communication systems, when the purpose for the building was simply to provide shelter, safety and a place to dwell and even work upon. But today with growth of the network and technologies human life has got a lot complex with no understanding what so ever about how technology works but with the necessary idea of how to make use of it to make the life easy, comfortable, safe and more in control than ever in the history of mankind. With the complexity of the life that technology has created the building is no more just a covered space for shelter but the networks of complex system in which multiple system such as lighting, security, heating, ventilation and air conditioning systems has to work together for it to work. But in the present scenario we still have very little control and tracking of how our system works and how efficient they are. With the advancement of the technology over time, each of the components inside a building has been developed and improved, allowing modern-day building owners to select the components independently, as if they were putting together a home entertainment system. The main objective of this study is to understand the various available smart building technologies and merge them together with passive strategies to develop smart buildings such that the energy performance of the building can be improved.

2. Methodology

The quantitative research approach is carried out for achieving the objectives of the study. The study, firstly, contains a literature survey to find out various smart building technologies and components of smart building which can be embedded to any building types for better energy performance of buildings. Survey contains background information, definitions of SB concept, smart technologies and BAS for energy performance, conducted studies on this subject. Secondly, the research region is selected and within the region the residence is selected as the base-case module then the energy audit of the present case scenario is carried out. Then the energy model is designed to evaluate energy performance according to weather condition and regulations of Nepal. Smart technologies with BAS are simulated with computer software. At the last stage, simulation results of different alternatives and scenarios are compared among each other in terms of energy performance.

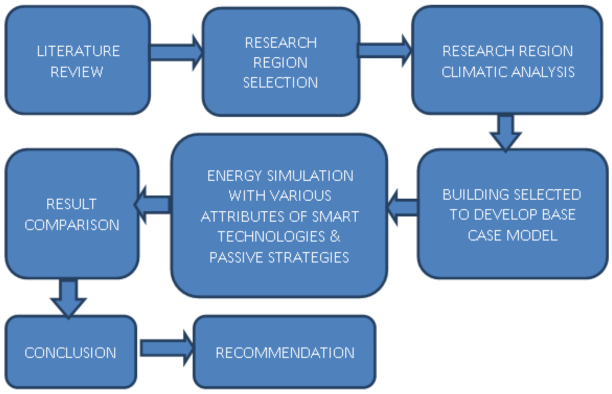

Figure 1: Research Methodology Flowchart

3. Limitation

The study is limited to the evaluation of energy are as follows:

- Only preliminary energy auditing is carried out on the basis of electrical drawing available and site visit and recording the equipment's in use in some sample apartment.
- All the properties of each space type and thermal zone assigned in the energy model has not been set manually but rather the ASHRAE Standard set by the Energyplus software is used.
- Occupant behavior set for the energy model of two apartment building is not survey based.
- Air Infiltration through openings in the building is set according to the ASHRAE standard which in case of Nepal can be much higher.
- All the smart technology mentioned in the study is not available here in Nepal, thus the cost of the smart equipment, installation and running cost could not be carried down.

4. Literature Review

4.1 Building energy Scenario

Awareness about energy performance in architecture in this century mainly depends on two overlapping issues which are related with environmental, economical and developmental aspects: global warming and oil crises [1] . Energy efficiency in architecture is critical since buildings consume approximately 40 percent of total energy in the world [2]. Also, a continuous increase in energy consumption of buildings is expected [3]. While buildings' energy consumption constitutes 38 percent of total global energy consumption with 2,900 Mtoe, buildings' total direct and indirect CO2 emissions were 8.8 Gt i.e. 33 percent of the total CO2 emissions in 2005 [3]. The increase in energy use in buildings is driven by a combination of growing population and increasing prosperity, allowing people to live and work in greater comfort [4].

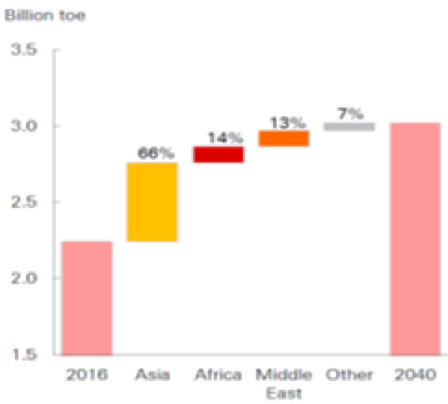

Figure 2: Growth in final energy consumption in buildings by region 1016-2040 [4]

Table 1: Energy Consumption by sector [3]

Sector	Energy Consumption 2005(Mtoe)	Energy Consumption 2020(Mtoe)	Energy Saving potential 2020 (Mtoe)	Energy saving potential 2020(%)
Households (residential)	280	338	91	27
Commercial buildings	157	211	63	30
Transport	332	405	105	26
Manufacturing industry	297	382	95	25

In order to describe the efforts needed to reduce CO2 emissions and energy consumption, IEA developed some scenarios which explore different technological pathways to reduce emissions and energy consumption in comparison with baseline scenario which forecast the business-as-usual situation in absence of policy change. There are two main groups of scenarios; first one is the ACT map scenario which returns CO2 emissions to 2005 levels by 2050 with the help of technological developments and second one is the BLUE map scenario which is more ambitious in order to return emissions at 50 percent of 2005 levels by 2050 with the need of higher investment costs and greater developments in technology and policy.

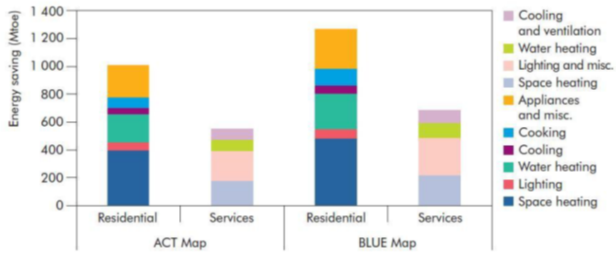

Figure 3: Energy saving potentials in different scenarios by use [3]

The biggest energy saving potential for residential sector lies in space heating, water heating and appliances [3]. However, space heating and lighting provide the highest energy saving opportunity for commercial sector [3]. Also, Figure 6 shows that residential buildings have more energy saving potential than commercial buildings as parallel to table 1.

4.2 Smart Buildings

The world is facing some challenges and opportunities as a result of changes in society and technology [5]. While changes in technology and society are shaping our future, the important point is new buildings should be appropriate to respond for all issues which come with changes [5]. Clements-Croome (2004) defines smart buildings as the one that is sustainable, healthy, and technologically aware in order to satisfy the requirements of users and business while dealing with changes in environment as being flexible and adaptable. The author mentions that background of smart buildings consists of sustainable issues, social change and technological developments including information and communication technologies, robotics, smart materials.

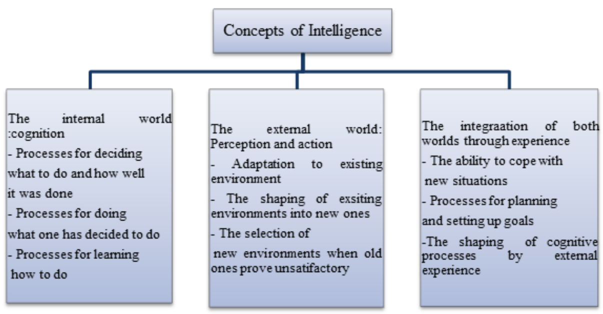

Figure 4: Components of Intelligence [6]

Main attributes that a smart building should have are determined by Atkin (1988) in three points:

- SBs should ”know” what is occurring inside and immediate outside.
- SBs should ”decide” the most efficient way to provide required environment for the users.
- SBs should ”respond” instantly to the need of users.

4.3 Historical background of Smart Buildings

Sinapoli (2010) states that smart building concept was started to be discussed in the early 1980s. The author refers to a New York Times article, published in 1984, which mentions intelligent buildings as a new generation which is nearly able to think. The author notes those buildings were combination of just building management and telecommunications [7]. The intelligent building pyramid which was created during European Intelligent Building Study by researchers is given in Figure below.

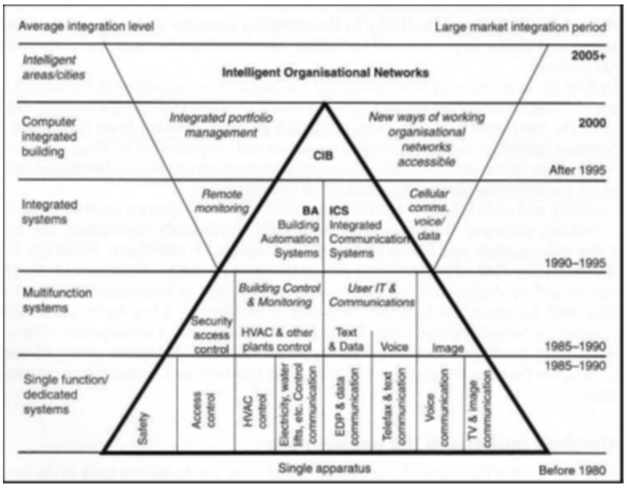

Figure 5: Research Methodology Flowchart

As Clements-Croome (2004) mentions this pyramid is not intended to define intelligent buildings, but it defines integrated and automated building: the type of intelligent buildings which highlights the utilization of information and communication technology. The author also notes the pyramid has turned out to be a notable landmark in the short history of progress in smart building concepts. The pyramid divides smart building system after 1980 into 5 stages as follows:

- Single function dedicated systems (1980-1985)
- Multi-function systems (1985-1990)
- Integrated systems (1990-1995)
- Computer integrated building (after 1995)
- Intelligent areas (2005+)

4.4 Key aspects in Smart homes

4.4.1 Communication Networks in smart Building

All SB technologies are part of networks since they communicate with each other or control elements which are used for monitoring, managing, and providing services [7]. On the other hand, media network systems which society is very familiar with, include television casting, radio casting, telephone line, internet, video conference, audio-visual entertainment, various services based on internet, fax, word processing, data base access, entrance videophone, computers, cameras, speakers, media players, monitoring devices etc. [8]. It can be said that those media network systems are widely prevalent even in conventional buildings since computer usage and network connection in between computers and other digital devices are indispensable for not only workspace but also daily life in modern context.

4.4.2 Audio-visual network

Audio-visual network includes various equipment’s and materials, multiple technical standards, and rapidly changing technologies such as computer, video player, projector, sound system, radio, camera, lighting system, tablet and derivatives, remote network via internet etc. [7]. It is possible to access, monitor and manage audio-visual devices remotely with cell phone, notebook or tablet even far from building with telecommunication or internet connection. Sinapoli (2010) categorizes the main constituents of audio-visual systems as:

- Audio and visual sources
- Processing and management
- Destinations (speakers and displays
- System control

4.4.3 Sensors

In the broadest definition, a sensor is a device, module, or subsystem whose purpose is to detect events or changes in its environment and send the information to other electronics, frequently a computer processor. Or simply put, Sensors are devices that sense a physical stimulus and convert it into a signal [9]. One example of a sensor that provides HVAC systems with useful data is a duct static pressure sensor, which measures the amount of resistance against the air flowing through a duct. A duct static pressure sensor contains a sensing element that reacts to physical changes—in this case, static pressure. The sensor transmits an electrical signal that indicates a change in duct static pressure. Building operators can use these static pressure readings to control the HVAC systems to operate at a particular duct static pressure, and can even use the measurement to identify HVAC system faults [10].

4.4.4 Intelligent Controls

Various researches were focused on in the 1990s. The main research trends in the field of advance energy and comfort management controls were emerged.

- Learning based methods including artificial intelligence, fuzzy systems and neural networks - fuzzy with conventional controls, adaptive fuzzy neural network (ANFIS) systems, etc.;
- The model based predictive control (MPC) technique, which follows the principles of the classical controls;
- Agent based control systems.

4.4.5 Energy Performance in smart buildings

While energy performance in buildings are already related with the terms green, sustainable, high-performance and many others; smart technologies comes with adaptive and responsive abilities to enhance and extend the concerns mentioned in those terms. According to Barnett and Browning (2007), criteria that sustainable building should follow can be described as;

- using the land appropriately
- using water, energy, lumber, and other resources efficiently;
- enhancing human health and productivity;
- strengthening local economies and communities;
- conserving plants, animals, endangered species, and natural habitats;
- protecting agricultural, cultural, and archaeological resources;
- being nice to live in; and being economical to build and operate

4.4.6 Security and safety in smart buildings

Wang (2010) states security and safety systems present for resisting against fire, damage, unauthorized entry, theft and any other dishonest, illegal or criminal acts in order to protect the property, life, materials and facilities. Safety systems include; fire prevention, evacuation management, earthquake detection, gas and water detection, and electric safety [8].

- Fire Prevention
- Security: Anti Burglary System and perimeter Protection
- Earthquake detection
- Access control systems

4.5 Smart Building Technologies (Active systems) for energy performance

Intelligent active systems are building elements which able to adjust itself due to internal or external changes in order to achieve required comfort level. Active systems which are mostly mechanical and electronic devices, generally requires energy but ideally it is desired that intelligent active technologies with minimum energy use has impacts on reducing energy consumption in a building[1].

4.5.1 Building Automation System

Building automation system (BAS) which is also known as Building Management System (BMS), is one of the major smart building systems [11]. Wang (2010) states BAS refers to combination of various computerized building control systems including a wide range from control elements with specific objective to independent remote terminals or even to complicated systems with central computer terminals.BAS is more than existence of different systems, main logic behind it is artificial intelligence and analysis/response algorithm. As Wang (2010) mentions, BAS functions for monitoring, controlling and managing all services including HVAC, electrical systems, lighting systems, fire systems, security systems, lift systems and water systems as seen from Figure 6.

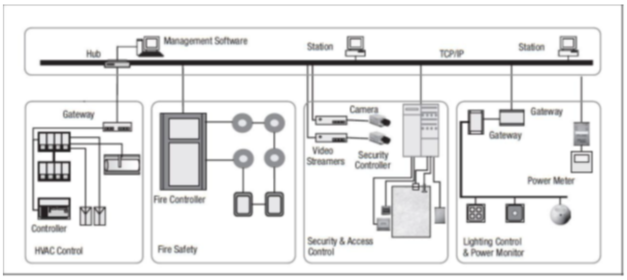

Figure 6: Integrated Building System [11]

4.5.2 HVAC systems

It takes an enormous amount of energy to condition air and then distribute it throughout a building. Smart heating, ventilation, and air conditioning (HVAC) systems use multiple sensors for monitoring and control. Software interprets information from various sensor points to optimize the HVAC system's operation while improving occupant comfort. Smart HVAC controls can limit energy consumption in unoccupied building zones, detect and diagnose faults, and reduce HVAC usage, particularly during times of peak energy demand.

4.5.3 Plug Loads

A plug load is the amount of energy drawn by a device plugged into an electrical outlet. Plug loads include the hundreds of types of portable office and miscellaneous equipment in buildings. In existing buildings, smart plug load controls consist of auto-controlled receptacles and power strips that rely on time scheduling, motion sensing, or load detection to completely cut off power to equipment that is not in use. Some smart power strips can sense the primary load, such as a computer, and operate peripheral devices accordingly. For centralized control, plug load schedules can be programmed into lighting and building management systems (BMS).

4.5.4 Electrical installations and lighting

Smart lighting consists of advanced controls that incorporate day lighting and advanced occupancy and dimming functions to eliminate over lit spaces. Smart lighting systems can be controlled wirelessly and scheduled into lighting management systems. Wireless controls facilitate easier retrofits, while lighting management platforms let user's access controls through web-based dashboards. Lighting can be turned on, off, or dimmed with a building automation or lighting control system based on time of day, or on occupancy sensor, photo sensors and timers. One typical example is to turn the lights in a space on for a half-hour since the last motion was sensed. A photocell placed outside a building can sense darkness, and the time of day, and modulate lights in outer offices and the parking lot.

4.5.5 Window and Shadings

Smart window systems manage the amount of solar heat and daylight that enters the building. Systems consist of passive and active window glazing and films that respond to changes in sunlight or temperature, and auto-controlled shades that are scheduled to operate at specific times of the day to control light levels and solar heat gain. In retrofits, smart shading technologies have the greatest energy-savings potential in buildings with untinted, single-pane windows. The smart shades rely on sensors that measure indoor and outdoor ambient temperatures or the sun's position and radiation, automatically adjusting their height to manage the amount of light and heat entering the building. When added to a lighting retrofit project to maximize daylighting, smart shades offer an additional 10 percent energy savings in lighting energy use [9].

4.5.6 Connected Distributed Generation and Power

Distributed energy resources (DER) consist primarily of energy generation and storage systems placed at or near the point of use and provide power independent of the grid. Examples of DER include combined heat and power, solar photovoltaics and other renewables, and battery and thermal storage. DER relies on communications and control devices for efficient energy dispatch; adding a smart inverter to the DER gives its smart functionality. Smart inverters are software controlled and help manage onsite energy generation and storage. They allow for continuous two-way communication between the DER and the electric grid and can immediately respond to load signals, electricity rates, demand response events, and power outages.

4.5.7 Human Operation

Operators can interface with a smart building through computer dashboards-user friendly interactive displays of building operations and energy use. As for building occupants, they can use mobile apps to control some workspace functions such as lighting. Apps can also display individual occupants' energy use and recommend ways to reduce consumption. In Occupancy mode, the BAS aims to provides a comfortable climate and adequate lighting, often with zone-based control so that users on one side of a building have a different thermostat (or a different system, or sub system) than users on the opposite side. Some buildings rely on occupancy sensors to activate lighting or climate conditioning. Given the potential for long lead times before a space becomes sufficiently cool or warm, climate conditioning is not often initiated directly by an occupancy sensor.

4.6 Passive Design Strategies

Passive design strategies have been mentioned in various studies related to green buildings, sustainable buildings, high-performance buildings etc., while passive strategies at urban scale are also effective on the energy performance of building but this section focuses on just building scale strategies for the sake of this study. According to Brophy and Lewis (2011), bioclimatic heating, cooling, day lighting and energy strategies must be considered at early design stages with architect's other priorities for energy efficiency; since energy consumption can be reduced by as much as 20-35percent at no cost with designing the right form in the right orientation. Although, some mechanical systems seem essential in buildings for energy efficiency; their use should be challenged and energy conservation should be the first option.

4.6.1 Site planning

Site planning which includes orientation, neighborhood density, topography and green spaces is able to bring energy saving by means of heating, cooling, ventilation and daylight [12]. According to site situation and climate, orientation which is also related with building form and envelope should be properly considered. As Brophy and Lewis (2011) mention, south facing façades and glazed areas are beneficial by employing passive solar heating for the buildings in which heating load is dominant. In addition, the authors state overheating can be prevented by shading if needed on south; while it is possible but difficult to shade east and west façades effectively because of sun angle.

For cooling, orienting building and designing glazed areas to minimize solar overheating is one of the strategies, while adequate daylight should be considered to minimize internal gains from electric lighting since glazing locations and sizes are important for daylight. The authors note that water features may be used for evaporative cooling and shading by vegetation or devices can be used for preventing overheating, while directing wind properly to reduce cooling load is also useful. In addition, ventilation which can be provided naturally by properly oriented opening windows is not only a part of cooling but also a need for internal air quality in any climate [12].

4.6.2 Building Form

Designing spatial organization and the form correctly at the beginning has important effect on energy saving, while changes are difficult or even impossible sometimes and both financially and environmentally costly after building is built [12]. Some strategies which are related with the form depends on controlling solar gain and wind to reduce energy consumption as;

- zoning and orienting spaces properly,
- finding optimum shape for building mass,
- designing sunspace, courtyard and atrium,
- adjusting surface to volume ratio and window wall ratio,
- taking ventilation and infiltration into consideration
- locating openings properly
- adjusting surface areas at different directions according to climate conditions,
- using buffer zones and thermal mass,
- Employing overhangs, arcades, shutters and canopies to shade the envelope.

4.6.3 Building Envelope

Mediating the effects of climate on the occupants and the energy systems of building, collecting and storing heat, redirecting light, controlling air movement, and generating power are duties which are expected from building envelope in terms of energy, while any building enclosure is already responsible for keeping out wind, rain and damp, letting light in, conserving heat and proving security and privacy [12]. The authors mention some strategies for envelope design which may include solid, translucent and transparent elements as;

- modify envelope according to different orientations for heating, cooling and daylight strategies
- design envelope to achieve thermal comfort by means of thermal mass and insulation
- avoid thermal bridge and infiltration
- provide controlled energy efficient ventilation with heat recovery
- integrate appropriate passive components to advance the efficiency by considering potential thermal collection and storage
- consider glazing ratio and position
- consider thermal solar and light transmission properties of materials

5. Research Region- Kathmandu Valley

Kathmandu, the capital and main political and economic center of Nepal, lies in the bowl-shaped Kathmandu valley, a natural region, which contains some of the oldest human settlements in the central Himalayas. The valley includes four main cities, Kathmandu Metropolitan City, Lalitpur Sub-Metropolitan City, Kritipur Municipality and Bhaktapur Municipality. The valley covers an area of 900 square kilometers (347 square miles) [13]. The valley is experiencing an extraordinary rate of population growth, mostly in Kathmandu. An indication of this accelerated growth can be seen by the rate of growth of Kathmandu district, which is estimated to 4.71 percent per year [13]. The fastest decadal population growth rate is found in Kathmandu district which is 61.23 percent (CBS 2011).

5.1 Energy Issue in Nepal

More than 87 percent of Nepal's total energy demand is currently met by traditional energy sources such as fuel wood, agricultural residues and animal waste. (WECS, 2006) Likewise, about 90 percent of total energy is consumed in households. Various studies show that the feasible potential is about 83 Giga-watt (GW), of which about 42 GW is considered as technically and economically viable. The actual generation capacity of hydropower is limited to only 0.64 GW (NEA, 2008), due to the lack of necessary investment. Besides hydropower, there is a thermal generation of electricity capacity of about 53 Mega-watt (MW), which is not in regular operation (NEA, 2008). Nepal Electricity owing to the energy problems, the current demand of energy is not meet even to its minimum level. The load shedding (temporary shutdown of electricity supply in phased timing in different areas of the city) faced by the city people for a long period confirm to the fact that energy supply is inadequate, though it has been drastically minimized recently. Furthermore, accessibility of energy and use of locally produced energy will also determine how vulnerable Kathmandu is for its energy needs.

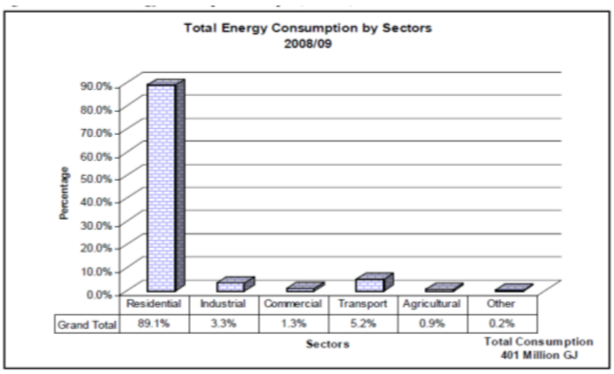

Figure 7: Sectorial Energy Consumption in Nepal(2008/09)

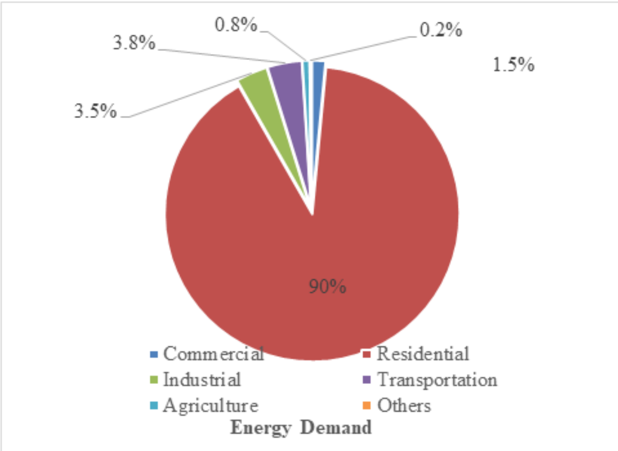

Figure 8: Energy Demand by Sect. in Nepal 2005

5.2 Bylaws of Kathmandu Valley

Building bylaws of Apartment housing construction in Municipalities and urbanizing VDCs of Kathmandu Valley area as follows:

- Minimum road width adjoining the construction site
- Ground Coverage: 50 percent
- Floor Area Ratio (FAR): 3 (3.5 outside ring road)
- Minimum area of open land surface: 20 percent
- Other open space: 30 percent
- Set back: 6m on the road side and 4m on the other three sides
- Height: 2*(setback on the other side of the property + road width + setback of proposed building)
- Distance between two blocks must be at least 6m
- Parking space for the each building unit over 80sq.m must have at least 1 car, 2 motorcycle and 2 cycle parking and for units below 80sq.m it should have 1 car, 4 motorcycle, 4 cycle parking per 4 building units (DUDBC, 2064)

5.2.1 Climatic Analysis of Kathmandu Valley

Climate of a place depends on several geographic factors but it is mainly attributed to topography and altitude. Nepal experiences extremities of hot and cold climate in flat plains in Terai and in the Himalayas respectively. Based on altitude, Kathmandu falls under Warm Temperate Zone where the climate is pleasant. However, the study of climatic data collected from the Meteorological Department for Kathmandu airport point out that the climate of Kathmandu is sub-tropical temperate, characterized by slightly hot summer and cold winters. Kathmandu lies at an altitude of 1350 meters and experiences all the four seasons: summer, autumn, winter and spring.

The climatic data of Kathmandu has been collected for the climatic analysis and the data range from years 2001 to 2016 have been computed for climate summary. The calculations of degree hours and wind speed have been done in climate consultant as shown in figure below. The average of the maximum and minimum monthly Mean temperature is found to be 30.24 °C during the month of June while 3.17 °C during the month of January respectively as shown in the Figure below. The average hour of sunshine is about 6.3 hours and it varies between 3.3 hours to 8.4 hours. The sun path diagram, figure 3.10, shows the solar altitude angle and azimuth angle for different time of a day for any month of a year. The sun's angle at noon during equinox (March 21 and September 22) is 62.3°, summer solstice (June 22) is 85.8° and winter solstice (December 22) is 38.8°.

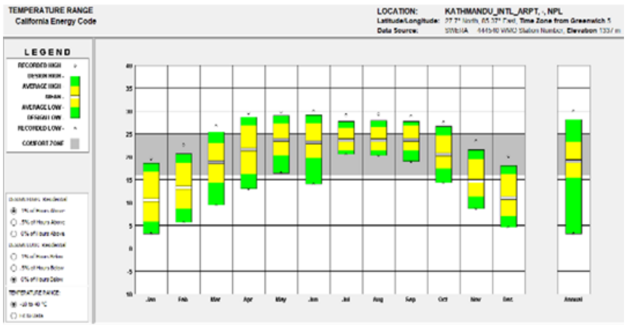

Figure 9: Annual Temperature Range for Kathmandu Valley

5.2.2 Psychrometric Chart

Psychrometric chart is a graph used to find temperatures, relative humidity and used to design and analysis of air conditioning systems, heating, cooling system. It can depict human comfort in relation to temperature and humidity. The chart ascertains a process whereby a designer can match solutions to climatic conditions when climatic data of a given site is plotted on the chart. Based upon monthly average temperature and humidity, different zones are plotted to indicate design requirements for a given place. The Psychrometric chart for Kathmandu is shown in figure below. The plot demonstrates that for most of the months, passive solar heating strategies should be implemented. December through February requires conventional heating in addition to passive solar designs. October, April and May need passive solar design for most of the period but seemingly fall under "comfort zone" as during daytime temperature is comfortable while nights are still slightly cold. Similarly, June to September is slightly off the "comfort zone" where provisions for air movement, internal gains and shading are highly demanded.

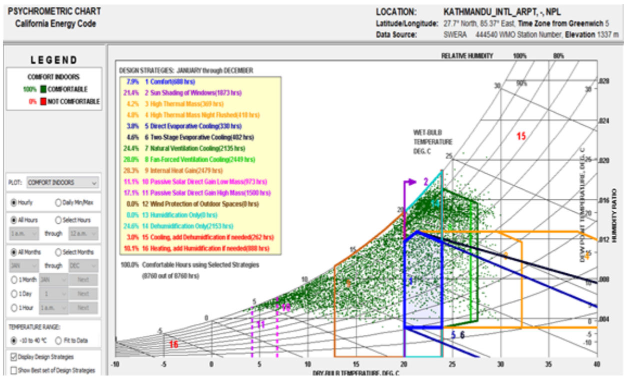

Figure 10: Psychrometric Chart of Kathmandu

6. Design Process

6.1 Site selection for the energy performance evaluation

In the study, impacts of Passive and active systems with use of smart technologies will be investigated on a base-case building by adding various smart building elements and passive strategies on it with computer based building energy simulations. The base case model will be a very close replica of the existing building with its existing conditions. Type of the building used in this study is a multi-residential building since literature review points out that residential buildings has not only highest amount of energy consumption but also highest energy saving potential among building types. And study also shows that the technological cost can be very high for single residence but can be feasible for multi-residential residence. The apartment buildings selected are a Guna Colony Tower building located in Sinamangal, Kathmandu and LP Apartment located in Lazimpat, Kathmandu. The study will include of the study of the various energy related elements in both the apartment buildings.

6.1.1 Site 1: Guna Colony Tower

This particular apartment building is located on the residential cum commercial zone at Sinamangal, Kathmandu as shown in figure 24 with multi-storey houses surrounding the area. The Guna Colony tower lies at the road connecting old baneshwor to Sinamangal chowk can be accessed from either Sinamangal chowk or Old Baneshwor chowk.

Figure 11: Guna Colony Apartment: Front view

The apartment complex consists of the two towers. The two towers are identical in design and orientation. Each tower consists of the 8 apartments in each floor and the apartment selected for our detail analysis is Type-A and Type-B apartments which are identical in design in context of room planning but differs in terms of the opening. The Type-A apartment has exterior face and opening to exterior towards north and east while the Type-B apartment has opening on exterior east face and inner courtyard on west as shown in figure below. The Eleven storey building was constructed with reinforced concrete structure by using tunnel formwork system. It represents a good example for temporary construction in Nepal over the last decade with arrangement of windows, spatial design and construction method with shear walls. The total area of a Type-A and Type B apartment is 1532.4sq.ft.

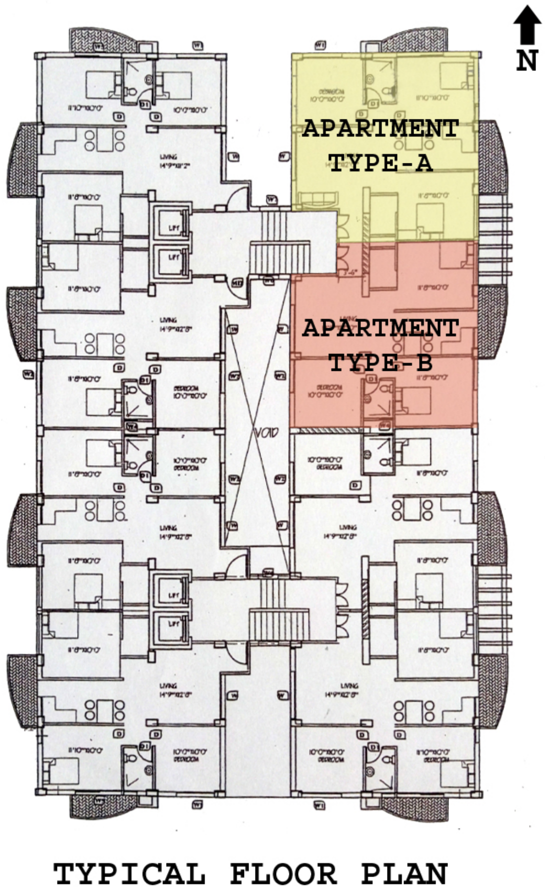

Figure 12: Guna Colony Apartment: Typical Floor Plan

6.1.2 Energy auditing of Two selected apartment type

Table 2: Energy auditing of the lighting fixture

S. N	Types of Bulb	Total no.	Power rating (watt)	Power rating (kw)	Average usage (hr/day)	Season	Unit kWh /day	Unit kWh /year
1	Ceiling Light	24	24	0.024	6	All	3.456	1261
2	Wall Light	10	15	0.015	6	All	0.9	328.5
3	Tube light	8	40	0.04	6	All	1.92	700.8
4	Mirror Light	2	8	0.008	0.75	All	0.012	4.38
						Total		2295

The table above shows the types of lighting fixtures used in the apartment. The table illustrates the total number of fixtures used, its power rating in Kilowatt, daily usage hour per day, season of the year when maximum used, energy unit used in kilowatt hour per day and kilowatt hour per year. This gives us the total unit of energy consumption in the case study apartment per year. The total energy consumption by lighting for the typical apartment is 2295.12-kilowatt hour per year.

Table 3: Energy audit of Electronic appliances

S. N	Appliance	Total No.	Power rating (kw)	Average usage (hr/day)	Season	Unit kWh/day	Unit kWh/year
1	TV-LCD/ LED (24")	1X2	0.06	5	All	0.6	219
2	Water Purifier	1x2	0.06	4	All	0.48	172.8
3	Laptop	1X2	0.15	4	All	2.4	438
4	Iron	1X2	1.2	0.25	All	0.6	219
5	Chimney	1X2	0.18	4	All	1.44	525.6
6	Mobile charger	3X2	0.005	3	All	0.09	32.85
7	Double size Refrigerator	1X2	0.074	24	6 months	3.55	639.36
						Total	**2246.58**

The table shows the energy audit of electronic devices in the case study of typical apartment. The appliances used are simple home appliances like LED TV, water purifier, chimney, double size refrigerator, laptop, iron and mobile charger. The maximum energy consumption is by two double size refrigerator and then by chimney. The total energy consumption of the typical apartment is 2246.58-kilowatt hour per year.

6.1.3 SITE 2: LP Apartment

The LP apartment building is located on the commercial zone at Lazimpat, Kathmandu as shown in figure 30 with multi-storey houses surrounding the area. The LP Apartment tower lies at the road connecting old Lazimpat chowk to Maharajgunj chowk can be accessed from the road passing through Radisson Hotel.

Figure 13: LP Apartment front view

The apartment complex consists of the two identical towers. Each tower consists of only 2 apartments in each floor as seen in the typical floor plan of the tower

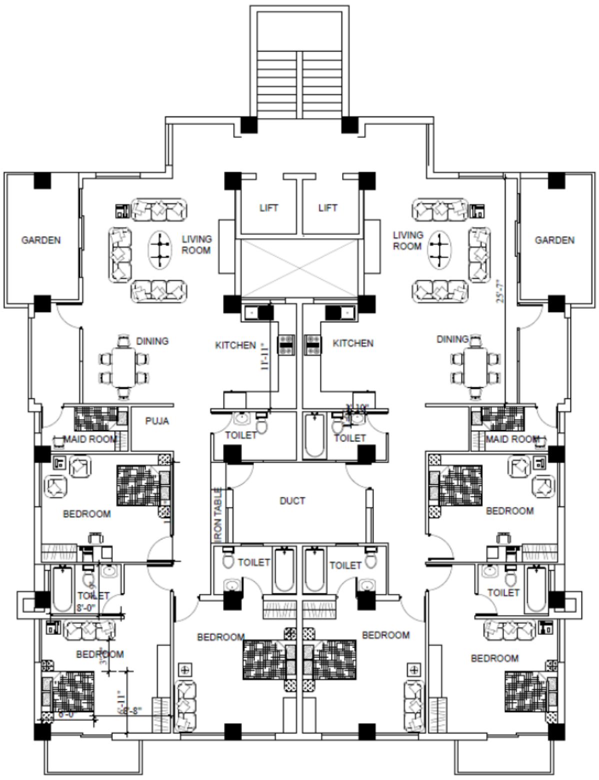

Figure 14: LP Apartment: Typical Floor Plan

which are identical in design in context of room planning but differs in terms of the opening. The 1st apartment has exterior face and opening to exterior towards east and while the 2nd apartment has opening on exterior on west face and has two inner voids in between two apartments as shown in figure below. The fourteen storey building was constructed with reinforced concrete structure by using tunnel formwork system. This 14 storied apartment building is very conveniently located and has 50 flats, each covering an area of 2050 sq. ft. Every floor is facilitated by elevator service and the complex has provisions for adequate parking space on the ground floor as well as in the basement.

Table 5: Energy audit of Electronic appliances

S.N	Appliances	Total no.	Power rating (watt)	Power rating (kw)	Average usage (hr/day)	Sea son	Unit kWh/ day	Unit kWh/year
1	TV-LCD/ LED (24")	1	60	0.06	5	All	0.3	109.5
2	Water Purifier	1	60	0.06	4	All	0.24	87.6
3	Laptop	3	150	0.15	4	All	1.8	657
4	Iron	1	1000	1	0.25	All	0.25	91.25
5	Electrical Chimney	1	180	0.18	4	All	0.72	262.8
6	Mobile charger	4	5	0.005	3	All	0.06	21.9
7	Double size Refrigerator	1	74	0.074	24	6 m	0.888	162.06
					TOTAL			1392.11

6.1.4 Energy auditing of Typical Apartment

Table 4 shows the types and no. of lighting fixtures used, its power rating in Kilowatt, daily usage hour per day, season of the year when maximum used, energy unit used in kilowatt hour per day and kilowatt hour per year in the apartment. This gives us the total unit of energy consumption in the typical apartment per year. The total energy consumption by lighting for the typical apartment is 1406.71-kilowatt hour per year.

Table 4: Energy auditing of the lighting fixture

S. N	Types of Bulb	Total no.	Power rating (watt)	Power Rating (kw)	Average Usage (hr/day)	Sea son	Unit kWh/ day	Unit kWh/ year
1	LED Ceiling Light	23	12	0.012	6	All	1.66	604.44
2	Wall Light	6	15	0.015	6	All	0.54	197.1
3	Tube light	6	40	0.04	6	All	1.44	525.6
4	Mirror Light	3	8	0.008	0.75	All	0.02	6.57
5	Chandeli er	1	200	0.2	1	All	0.2	73
						TOTAL		1406.71

Table 5 shows the energy audit of electronic devices in the case study of typical apartment. The total energy consumption of the typical apartment is found to be 1392.11-kilowatt hour per year.

6.2 Energy Simulation

The study uses computer-based energy simulations to assess the impact of active systems and passive strategies on energy saving for buildings. The software used for the simulation of the buildings in this research program is Energyplus with Openstudio. The energy model is prepared in the sketchup2017 which runs the openstudio engine to simulate the building energy through energyplus. EnergyPlus is a whole building energy simulation program that engineers, architects, and researchers use to model both energy consumption for heating, cooling, ventilation, lighting and plug and process loads and water use in buildings (Anon., n.d.) EnergyPlus is funded by the U.S. Department of Energy's (DOE) Building Technologies Office (BTO), and managed by the National Renewable Energy Laboratory (NREL).

Limitation

- The software makes use of the ASHRAE data and is more concentrated on the energy related components of America.
- Energyplus simulation is a complex software and needs years of study and practice to obtain the realistic scenario with its settings.
- The building components such as loads, equipment's, building materials types, etc. are limited and can only be obtained by building component library of NREL.
- The data availability in the context of Nepal is another limitation for the simulation in our case.
- And about the data available, the data format

acceptance by the energyplus is another limitation we face.

Energy Simulation Methodology

Firstly, the Base case module is developed using the existing building design features, climatic condition, electronic appliances and their schedules are used within the building. Then the energy simulation is performed. Secondly, the passive strategies that can help improve the energy performance of the building is added to the model and the energy performance is tested. Thirdly, as before the base model is selected and the active strategies including smart technology is added to the building and the energy performance is tested. And finally, both the active and passive strategies are added together on the base case energy module and the final energy performance is tested. And after all the test the energy performance is compared to find out the comparative potential of these strategies for saving energy.

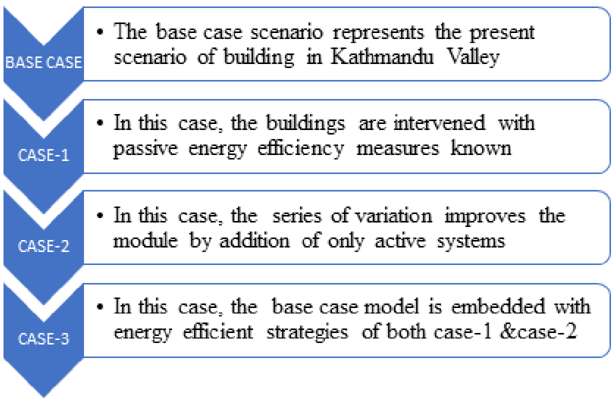

Figure 15: Methodology of Energy Simulation process

6.2.1 Base case model of Guna Colony Apartment

The base case module uses the actual scenario of the existing building with its original design features, materials used, weather conditions and the energy related features and equipment's used within the building. The base case module includes two apartment type: Apartment type-A and Apartment type-B. The details of the apartments can be seen above on the heading; Guna Colony Apartment. Below are the energy models in SketchUp in Openstudio with Energyplus which is rendered according to different types of spaces and thermal zones.

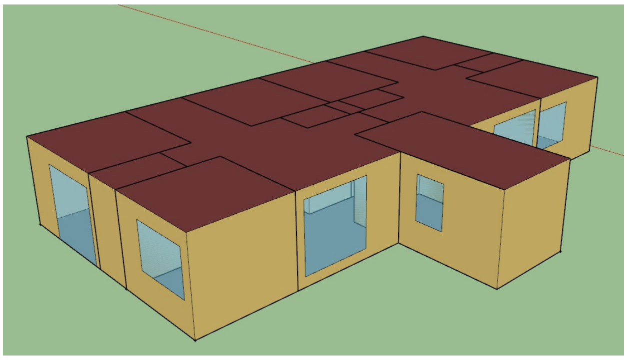

Figure 16: Energy model of Guna Colony Apartment in Sketchup- Openstudio with Energyplus

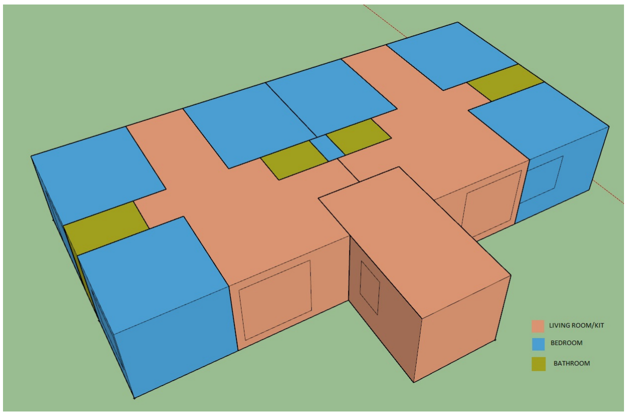

Figure 17: Energy model of Guna Colony Apartment render in terms of Space Type

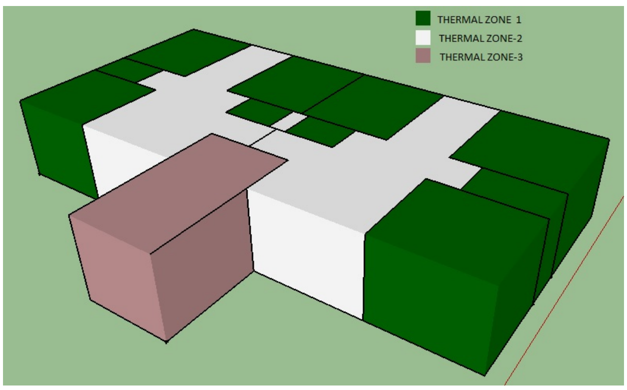

Figure 18: Energy model of Guna Colony Apartment render in terms of Thermal Zone

Table 6: Wall-window Ratio of base case model (Guna Colony)

	Total	North (315 to 45 deg)	East (45 to 135 deg)	South (135 to 225 deg)	West (225 to 315 deg)
Gross Wall Area [m2]	398.76	113.97	85.40	113.97	85.42
Above Ground Wall Area [m2]	398.76	113.97	85.40	113.97	85.42
Window Opening Area [m2]	31.76	8.64	10.66	1.25	11.20
Gross Window-Wall Ratio [%]	7.96	7.58	12.48	1.10	13.11
Above Ground Window-Wall Ratio [%]	7.96	7.58	12.48	1.10	13.11

Table 7: Zone Summary (LP Apartment)

DESCRIPTION	BEDROOM THERMAL ZONE 2	LIVING/KIT THERMAL ZONE 3	STAIRS THERMAL ZONE 1	Total
Area [m2]	75.96	51.14	14.7	141.79
Conditioned (Y/N)	No	Yes	No	
Part of Total Floor Area (Y/N)	Yes	Yes	Yes	
Volume [m3]	208.37	140.27	40.31	388.95
Multipliers	1	1	1	
Above Ground Gross Wall Area [m2]	201.83	152.98	43.95	398.76
Window Glass Area [m2]	17.63	11.62	2.51	31.76
Opening Area [m2]	17.63	11.62	2.51	31.76
Lighting [W/m2]	5.9289	3.3245	5.8125	4.9776
People [m2 per person]	22.79	5.42		11.11
Plug and Process [W/m2]	5.6069	1.9341	0	3.701

In base-case module, heating set-points are assigned according to ASHRAE 55-2004 standards for the calculations. Natural ventilation is employed by means of operable windows which are operated by user. It is assumed that the user will follow a certain routine and open windows at a specific time interval every day throughout the year. The specific time interval which is assigned according to occupancy period is 6:00am-10:00am and 6:00pm-10:00pm. This was based on the assumption the occupants will leave home at around 10:00 am in the morning to be at work at 10:30 am, and will return home around 6:00pm in the evening; it is also assumed that the occupants will not open windows as soon as they arrive home. Simulation number (SN) 1 deals with the base-case scenario with features given above. Since all neighbor units are same with base-case module, it is assumed that there is no heat transfer between neighbor units for all simulations; they are adiabatic zones. In addition to this, stairwell is also assumed as heated zone and considered as adiabatic in the simulations.

Table 8: Base Case Scenario Energy Usage per year (Guna Colony)

	Electricity [GJ]	District Cooling [GJ]	District Heating [GJ]	Total end use energy in KWH
Heating	0.00	0.00	10.98	2747.22
Cooling	0.00	7.77	0.00	2102.78
Interior Lighting	8.33	0.00	0.00	2313.89
Interior Equipment	7.56	0.00	0.00	2100
		Total	**End use**	**9263.89**

The table above shows the energy usage output produce by the simulation software where the energy usage of building in lighting and electric equipment are 2313.89Kwh and 2100Kwh respectively which is close to the value obtained from the energy auditing which are 2295Kwh for lighting and 2046Kwh for Electric equipment which is close range. Thus, the data obtained from the manual energy audit calculation and simulation matches approximately, which helps to authenticate that the model is very close to the real case scenario. Also, in the simulation an extra load output is shown namely; District heating and District cooling whose data are 2747.22Kwh and 2102.78Kwh respectively, which indicates the amount of heating and cooling energy that the is required to keep the building which the thermal zone set by the software.

6.2.2 Base case model of LP Apartment

The base case module uses the actual scenario of the existing building with its original design features, materials used, weather conditions and the energy related features and equipment's used within the building. The base case module includes two apartments as shown in the typical floor plan above. The details of the apartments can be seen above on the heading; LP Apartment.

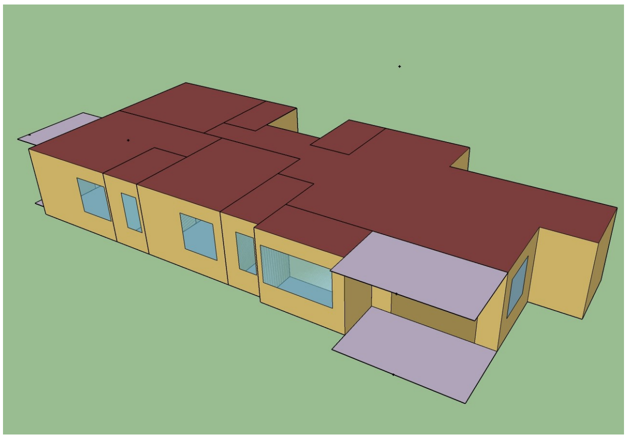

Figure 19: Energy model of LP Apartment in Sketchup- Openstudio with Energyplus

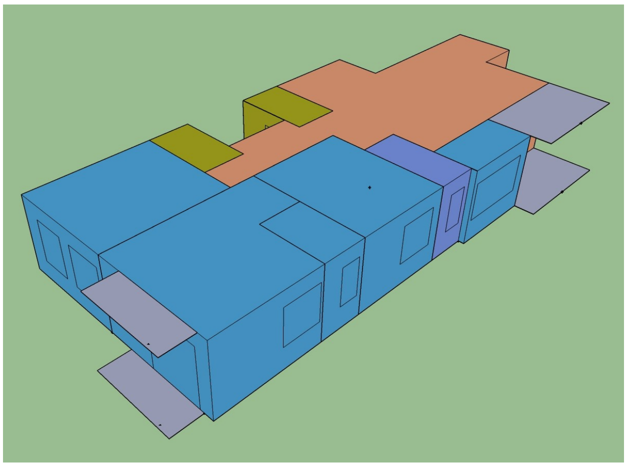

Figure 20: Energy model of LP Apartment render in terms of Space Type

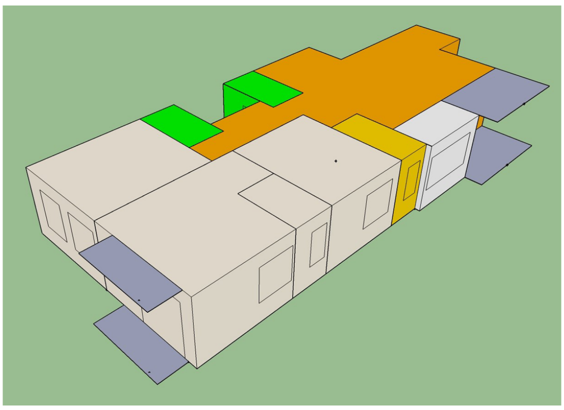

Figure 21: Energy model of LP Apartment render in terms of Thermal Zone

Table 9: Wall-window Ratio of base case model (LP Colony)

	Total	North (315 to 45 deg)	East (45 to 135 deg)	South (135 to 225 deg)	West (225 to 315 deg)
Gross Wall Area [m2]	430.32	97.14	124.02	97.14	112.02
Above Ground Wall Area [m2]	430.32	97.14	124.02	97.14	112.02
Window Opening Area [m2]	19.03	2.32	8.86	5.89	1.95
Gross Window-Wall Ratio [%]	4.42	2.39	7.15	6.06	1.74
Above Ground Window-Wall Ratio [%]	4.42	2.39	7.15	6.06	1.74

Table 10: Zone Summary (LP Apartment)

DESCRIPTION	THERMAL ZONE 1	THERMAL ZONE 2	THERMAL ZONE 3	THERMAL ZONE 4	Total
Area [m2]	71.09	69.92	11.12	5.41	157.54
Conditioned (Y/N)	Yes	No	No	No	
Part of Total Floor Area (Y/N)	Yes	Yes	Yes		
Volume [m3]	216.67	213.11	33.89	16.49	480.16
Multipliers	1	1	1		1
Above Ground Gross Wall Area [m2]	163.85	176.7	59.58	30.19	430.32
Window Glass Area [m2]	4.22	12.48	1.16	1.16	19.02
Opening Area [m2]	4.22	12.48	1.16	1.16	19.02
Lighting [W/m2]	4.9236	3.8617	2.1585	1.1093	4.1262
People [m2 per person]	3.1	21.76	32.6		5.94
Plug and Process [W/m2]	4	3	1	0	3.2

In base-case module, heating set-points are assigned according to ASHRAE 55-2004 standards for the calculations. All the other features and schedule needed for simulation are set similar to that of the simulation model of Guna colony apartment.

Table 11: Base Case Scenario Energy Usage per year (LP Apartment)

	Electricity [GJ]	District Cooling [GJ]	District Heating [GJ]	Total end use energy in KWH
Heating	0.00	0.00	11.42	3172.22
Cooling	0.00	27.34	0.00	7594.44
Interior Lighting	5.44	0.00	0.00	1511.11
Interior Equipment	4.94	0.00	0.00	1372.22
		Total	End use	13650

6.2.3 First Scenario: Active Strategies

The first series of variation improves the module by addition of only active systems. All sensor-based operations for all systems can be limited by an operation schedule and also interrelated with other systems by means of BMS.

SN1 Linear/off (continuous/off) day lighting control is used. Addition of daylight sensor at the center of the space. This measure will add daylighting controls to spaces that have space types assigned with names containing the string in the argument. The lights dim continuously from minimum light output to maximum output as day lighting illuminance decreases but the lights will be switched off at minimum dimming point.

SN2 Reduce night time lighting load; Many buildings have lights that run unnecessarily at night. Turning these lights off at night can provide energy savings without impacting the day-to-day operation of the building occupants. This control system follows a different schedule for both weekdays and weekends. Another active system is the intelligent HVAC control, where the sensor detects the occupancy and the interior temperature and reacts to the thermostats.

SN3 Thermostat is set for each thermal zone and the HVAC will interact with the sensor within the thermostat to keep the temperature of the room within the wanted temperature range.

SN4 All Active strategies combined.

6.2.4 Second Scenario: Passive Strategies

The second series of variation improves the module by addition of only passive strategies. The strategies which are concern of early design stage are not fixed as the construction is done. The first passive strategy in the second series of variation is orientation which is directly related with solar gain, daylight, wind exposure and more.

SN5 Building is tested with South(S), East (E) and North (N) facing position.

SN6 Window/wall ratio is another passive strategy which is dependent to orientation, impact of the ratio is designed and tested in terms of orientation. As recommended by Mr. Susanne Bodach in his article Design guidelines for energy-efficient hotels in Nepal the wall-window ratio is selected; i.e. WWR South 40–60percent, WWR North 10–20percent, WWR East 10–20percent, WWR West 10–20percent for temperate Bio-climatic zone (1001m-1500m)

SN7 Insulation improvement of the building by addition of insulation material on the inner wall and providing the finishing with the calcium silicate board to improve the thermal properties of the room.

SN8 All Passive Strategies combined

6.2.5 Third Scenario: Both Passive and active Strategies

In the third series of variation improves the module by addition of both active and passive strategies exactly as detailed in the series above.

SN9 Combination of active and passive strategies

6.3 Simulation Result of Guna Colony Apartment

SN-1 Illuminance sensor Lighting control

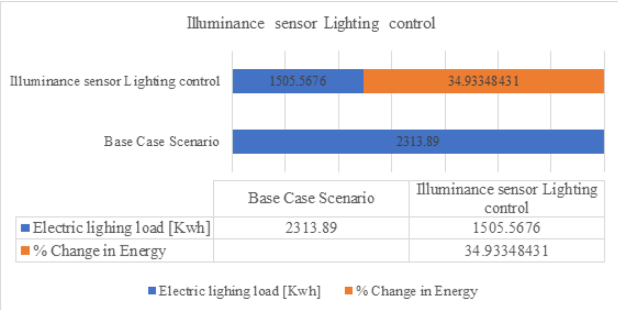

Figure 22: Comparison of electric lighting load by use of illuminance sensor lighting control (Guna Colony)

SN-2 Reduce night time lighting load

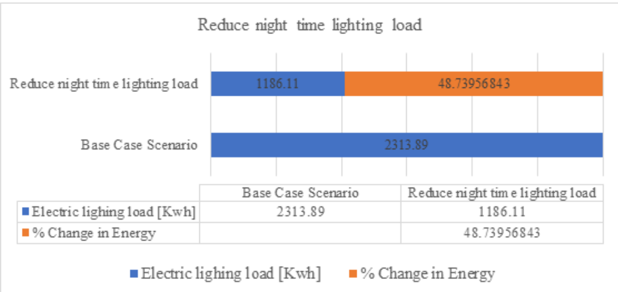

Figure 23: Comparison of electric lighting load by reduced night time lighting load (Guna Colony)

SN-3 Set thermostat schedule

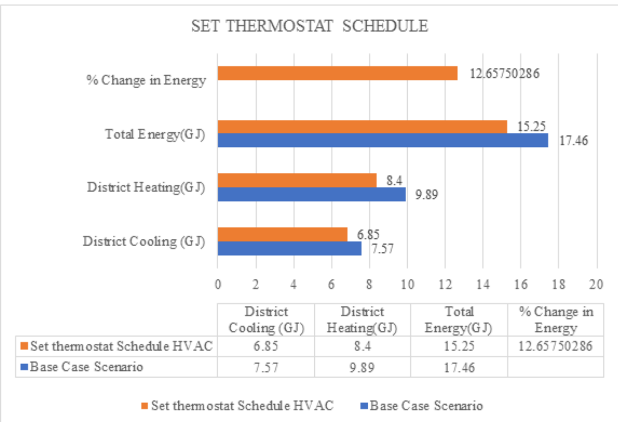

Figure 24: Comparison of result by setting thermostat schedule of HVAC (Guna Colony)

SN-4 Active Strategies

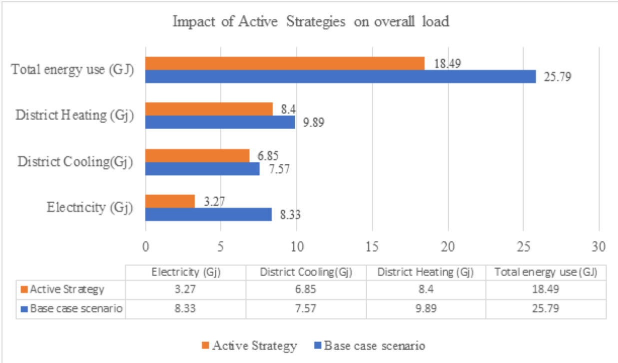

Figure 25: Impact of Active Strategies on overall load (Guna Colony)

SN-5 Orientation

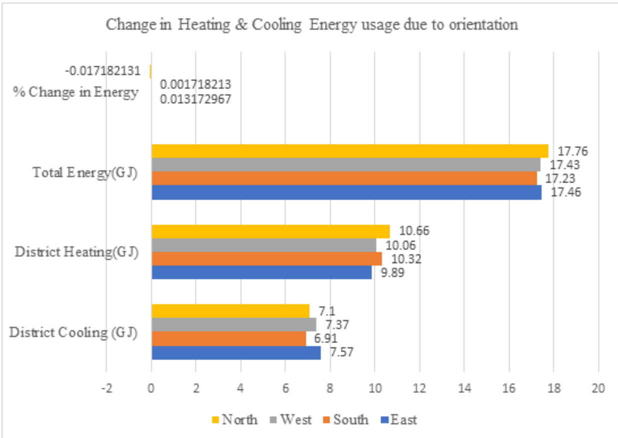

Figure 26: Change in heating and cooling energy usage due to orientation (Guna Colony)

SN-6 Wall-window Ratio

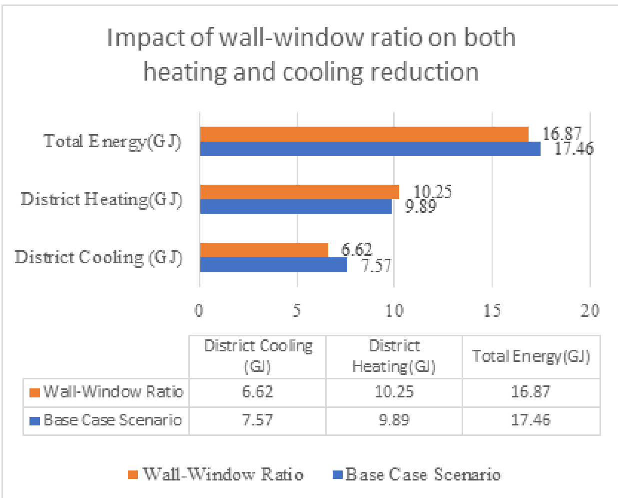

Figure 27: Impact of WWR on both heating and cooling reduction (Guna Colony)

SN-7 Exterior wall Insulation

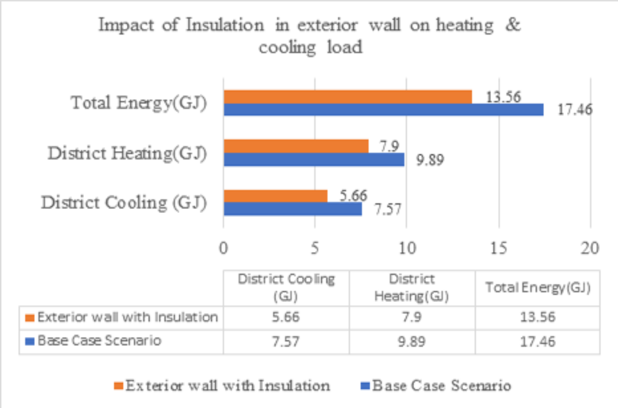

Figure 28: Impact of insulation in exterior wall on heating and cooling load (Guna Colony)

SN-8 Impact of Passive Strategies on heating and cooling load

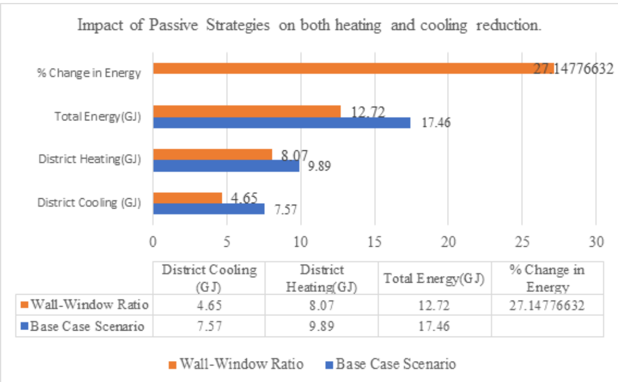

Figure 29: Impact of passive strategies on heating and cooling reduction (Guna Colony)

SN-9 Impact of Active and Passive Strategies

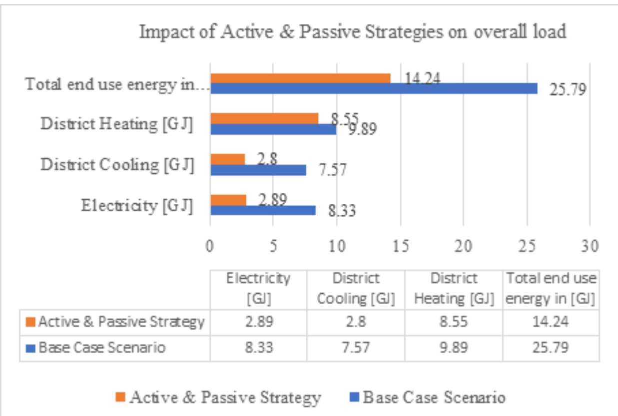

Figure 30: Impact of Active and passive strategies on overall load (Guna Colony)

6.4 Simulation Result of LP Apartment

SN-1 Illuminance sensor Lighting control

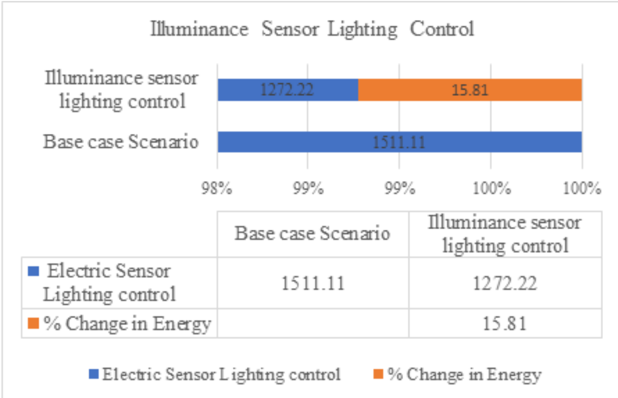

Figure 31: Comparison of electric lighting load by use of illuminance sensor lighting control (LP Apartment)

SN-2 Reduce night time lighting load

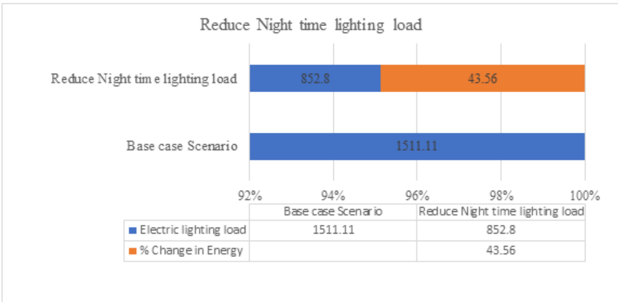

Figure 32: Comparison of electric lighting load by reduced night time lighting load (LP Apartment)

SN-3 Set thermostat schedule

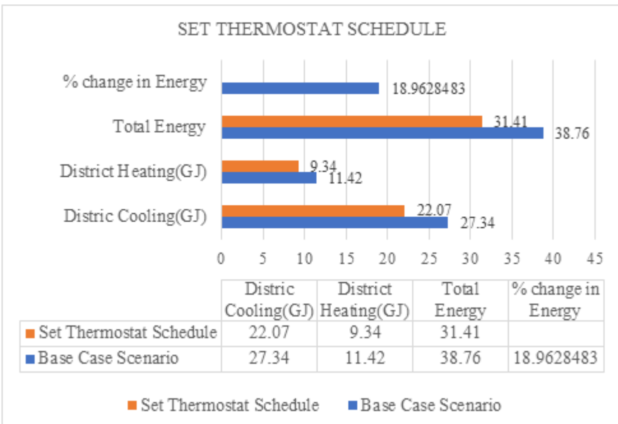

Figure 33: Comparison of result by setting thermostat schedule of HVAC (LP Apartment)

SN-4 Active Strategies

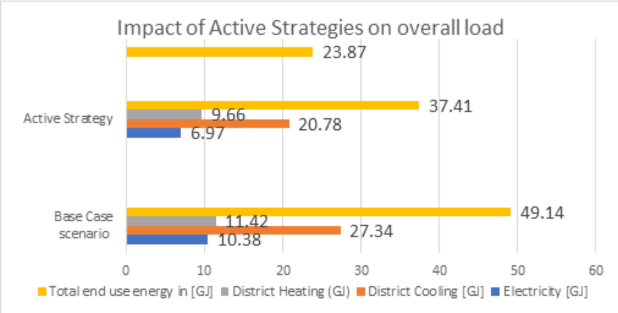

Figure 34: Impact of Active Strategies on overall load (LP Apartment)

SN-5 Orientation

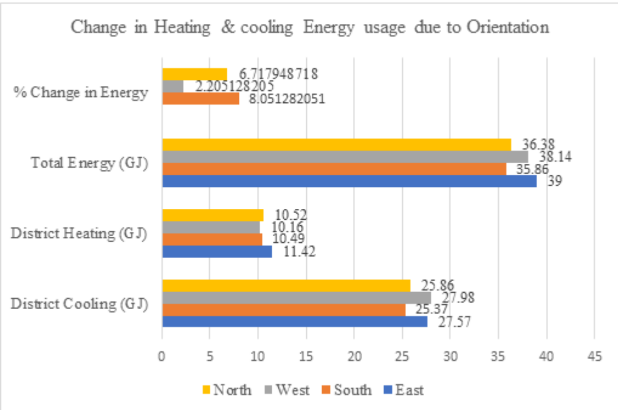

Figure 35: Change in heating and cooling energy usage due to orientation (LP Apartment)

SN-6 Wall-window Ratio

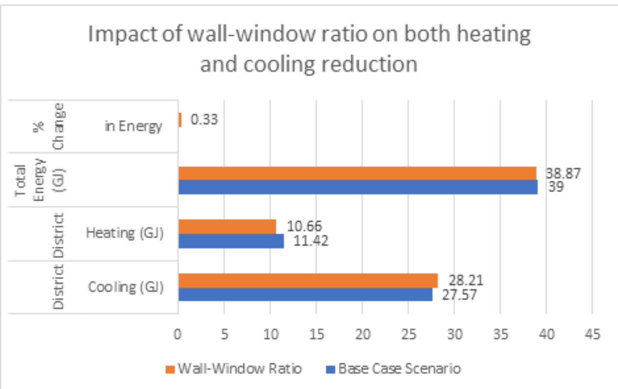

Figure 36: Impact of WWR on both heating and cooling reduction (LP Apartment)

SN-7 Exterior wall Insulation

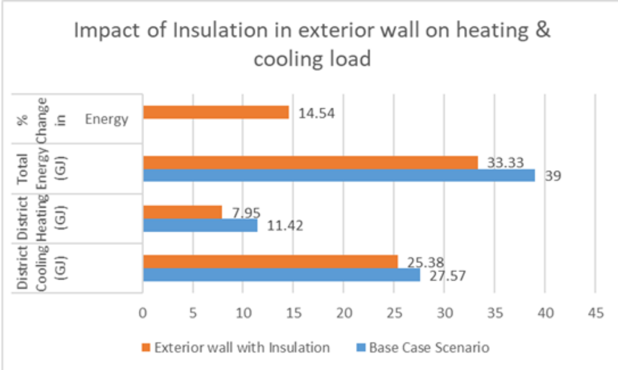

Figure 37: Impact of insulation in exterior wall on heating and cooling load (LP Apartment)

SN-8 Impact of Passive Strategies on heating and cooling load

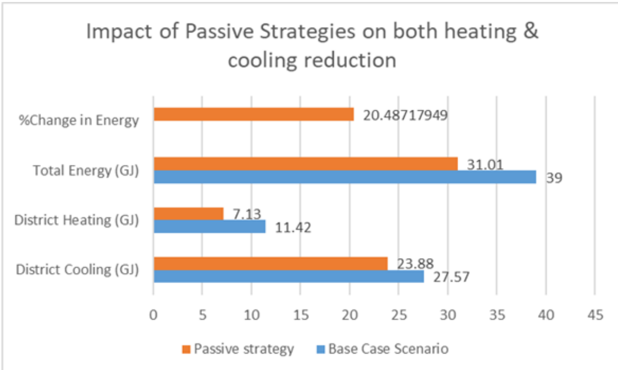

Figure 38: Impact of passive strategies on heating and cooling reduction (LP Apartment)

SN-9 Impact of Active and Passive Strategies

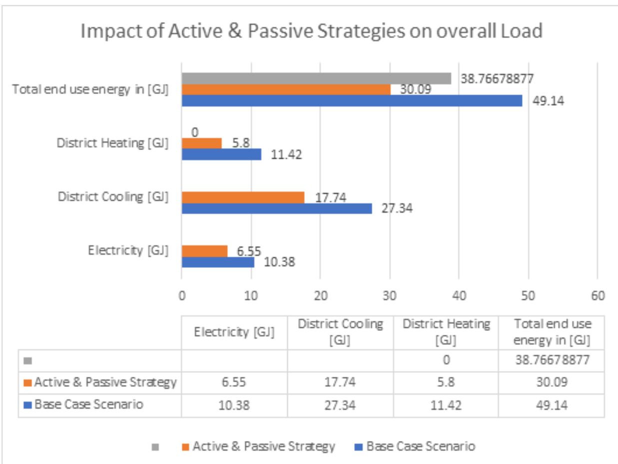

Figure 39: Impact of Active and passive strategies on overall load (LP Apartment)

7. Result and Discussion

The active and passive strategies imbedded in the base case module has resulted in no. of outputs since the energy saving capacity of each strategy is calculated separately and also in the combined order as passive and active strategies together as well.

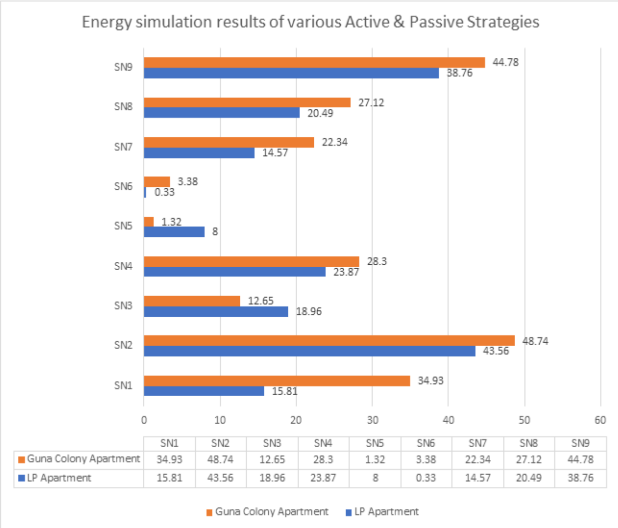

Figure 40: Overall results of the energy simulation

In the active strategies, the use of automation through use of sensors and schedule of lighting, electric equipment and occupancy are considered. The active strategies used in the simulation process for the study of the energy saving potential are Illuminance sensor lighting control and Reduced night time lighting load which shows the energy saving capacity of 35 percent and 48 percent of the lighting load respectively in Guna Colony Apartment and the energy saving capacity of 15.81 percent and 43.56 percent of the lighting load respectively in LP Apartment. Another active strategy used in the simulation process is Setting the thermostat schedule which shows the energy saving of 12.65 percent of the heating and cooling load in Guna Colony Apartment and the energy saving of 18.96 percent of the heating and cooling load in LP Apartment. And the overall energy saving of the active strategies all combined together shows the energy saving of 28percent of the total load in Guna Colony Apartment and the energy saving of 23.87 percent of the total load in LP Apartment.

In the passive strategies, the use of orientation of the building is considered as the apartment is replicated in various orientation thus the effect of orientation is checked where the result shows that the building facing south which is rotation of 90 degree clockwise of the base case module is the most efficient. But the improvement of the energy on the model due to this rotation is 1.3percent of the original energy in Guna Colony Apartment and 8percent of the original energy in LP Apartment. This shows that there is only minor change on the energy improvement in Guna Colony Apartment but one of the reasons for such small change is because of the large openings on all side except for the south face. But there is a significant change in energy saving in LP apartment because it has a very low wall window ratio and large no. of openings are only in I side of the apartment. Another passive strategy used in the simulation are wall-window ratio and exterior wall insulation which shows the improvement of 3.38percent and 22.34percent of the heating and cooling load in Guna Colony Apartment and the improvement of 0.33percent and 14.54percent of the heating and cooling load in LP Apartment which shows that the insulating the exterior wall has a significant effect on the heating and cooling load but wall window ratio does not show any significant change. The overall energy saving capacity of the passive strategies is found to be 27.12percent in Guna Colony Apartment and the overall energy saving capacity of the passive strategies is found to be 20.49percent in LP Apartment showing that the passive strategies are also highly effective to reduce the energy of the building.

Finally, the combination of both active and passive strategies imbedded into the base case energy model shows the overall energy saving in term of electric lighting and heating and cooling load of 44.78percent in Guna Colony Department and energy saving of 38.76percent in LP Apartment. This shows that both the active strategies and passive strategies are equally important in term of energy saving. But if combined together can help save a significant amount of energy in the multi-residential apartment buildings.

8. Recommendation

Residence sector being the major energy consumption sector within the building sector here in Nepal. So, it is very important to regulate this sector in terms of energy regulations to essentially develop a more energy efficient household and housing sector which can help minimize the overall energy consumption of the entire nation. In the developing country such as ours, such energy saved can be used in more productive sectors.

The above study shows that the large amount of energy can be saved through use of energy efficient strategies. The energy efficient strategies may include various passive strategies such as proper insulation, right orientation of the buildings and maintaining the wall window ratio which has been studied in above. Similarly, with the advancement of technologies, many efficient equipment, gazettes and fixtures has been developed. Some of the major recommendation that this study helps to put front for energy saving in multi-residential building are as follows:

- Energy Regulation must be developed for all building type specially the residential sector here in Nepal
- The minimum criteria in term of energy efficiency should be developed for any building to obtain a building permit.
- Some of the criteria that this study helps to focus are as follows:
- The minimum U-value of the exterior wall of the building should be set/item The wall-window ratio on the various façade of the building in term of their direction according to the geographical location should be set through thorough study.
- Orientation of the building with respect to the climatic zone and the micro climate of the area should be considered
- Use of sensor based smart electronic equipment should be motivated. Especially the owner occupancy-based sensor.
- Use of low energy consuming star rated equipment should be used

9. Conclusion

This study focused on the comparative impact of technological devices and traditional methods and also their energy saving potential. While smart buildings which become more popular day by day, present technological solutions for energy saving; some architectural designs have been used throughout the history to balance relation in between buildings and environment by employing free energy sources such as sun, wind etc. In context of Nepal a large amount of the energy is consumed by the residence sector, specially the residence of Kathmandu valley, it becoming the heart of Nepal. With the rise of housing demand in Kathmandu valley, the multi-residential apartment towers started to satisfy the housing need. And such a residential module which is a unit in an existing residential tower in Kathmandu is used as base-case module and various active systems and passive strategies has been tested on it. The output will be mostly based upon the simulation result generated with use of base-case module with different active system and passive strategies.

In the active strategies, the use of automation through use of sensors and schedule of lighting, electric equipment and occupancy are considered. In the passive strategies, the use of orientation of the building, insulation of exterior wall surface and Wall-window ratio is considered. Both the active and passive strategies shows a significant improvement in the energy usage of the building. The combination of both active and passive strategies imbedded into the base case energy model shows the overall energy saving of 44.78 percent in Guna Colony Department and energy saving of 38.76 percent in LP Apartment. This shows that both the active strategies and passive strategies are equally important in term of energy saving. But if combined together can help save a significant amount of energy in the multi-residential apartment buildings. Thus, can be concluded that the combination of the passive strategies with the smart active technologies can save up to about 40 percent of the energy usage in the normal condition. And finally, though the passive strategies used from the ancient of time for energy efficiency can be a leading factor to be considered while designing any building now but in the near future it is a technology which can help us take a giant leap in this sector and also very cheaply.

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