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Recession Plane For Residential Building of Kathmandu

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Abstract

Making a healthy, safe, modern, and ecologically balanced city perhaps is one of the big challenges in modern era. The population is creating pressure on land creating burden on land and utility services. Urbanization and the expansion of urban functionality with population growth is pressurizing the urban areas to build tall buildings since there is a shortage of land to accommodate the extra population and activities. Physical planning in developing now world is becoming a challenging task for the planning agencies though multi-dimensional approaches are followed to minimize the negative impacts to the environment as well as of whom those plans are created. Physical environment planning in urban centers is a major concerning issue in developing nations. The Light plane in the Byelaws of Kathmandu illustrates the relationship between two adjacent buildings separated by street. As a result, the adjacent buildings in remaining three directions are separated through setbacks only, which is short in comparison with road length and the fact that roads cover low area in the Kathmandu Valley, consequently, the buildings are stacked compact and buildings cast its shadow on adjacent buildings. Thus, in this Scenario, even if we create an energy efficient building, it will not perform to its creditability. Nevertheless, in addition, shadows of unplanned high rises have also negative impacts to human health, comfort living, block natural ventilation and/or reduces economic value of land, affects building design, orientation, landscaping. Furthermore, it was found in the research that through the concept of Recession Plane, the solar insolation can be gained throughout the year and contribute in thermal energy saving upto 8% effectively.

Keywords

Light Plane, Recession Plane, Shadow Analysis, Simulation

1. Introduction

About 40% of the global total final energy consumption is consumed by building sector comparison to other economic sector all over the world and are responsible for global warming. [1]. In Nepal, the energy consumption by residential sector is 45%, transport sector is 29.9%, industrial sector is 14.1% and commercial sector is 10.8%. [2]. The starting point for buildings to become minimal energy consumers is by minimizing their energy demand. Also, we can achieve this through maximizing use of renewable resources.

Sun is the closest star from the Earth and hence solar energy is the fundamental as well as primary source of energy which governs Earth's climate and atmosphere. " The national average solar insolation of Nepal was found to be 4.66 kWh/m2day (16.776 MJ/m2day). And, Yearly mean daily solar radiation of Kathmandu was found to be 16.499 MJ/m2day." [3]

The thermal sensation experienced is highly correlated to the intensity of solar radiation, orientation of windows, and surface reflectance from the walls. Furthermore, thermal comfort in occupied spaces is important for building occupants. A study on buildings in Pacific Northwest shows that more than 83% of the occupants said they relished day light and sunlight in their rooms.[4]

"A LIGHT PLANE is a plane constructed from points on a boundary surface or a road surface, the angle of inclination of which is measured from the horizontal, at right angles to a site boundary and in towards the site so that the height of building does not obstruct the light and ventilation of property on the other side of the road." [5]

"A RECESSION PLANE is a plane constructed from points on or above boundary surface or a road surface, the angle of inclination of which is measured from the horizontal, at right angles to a site boundary and in

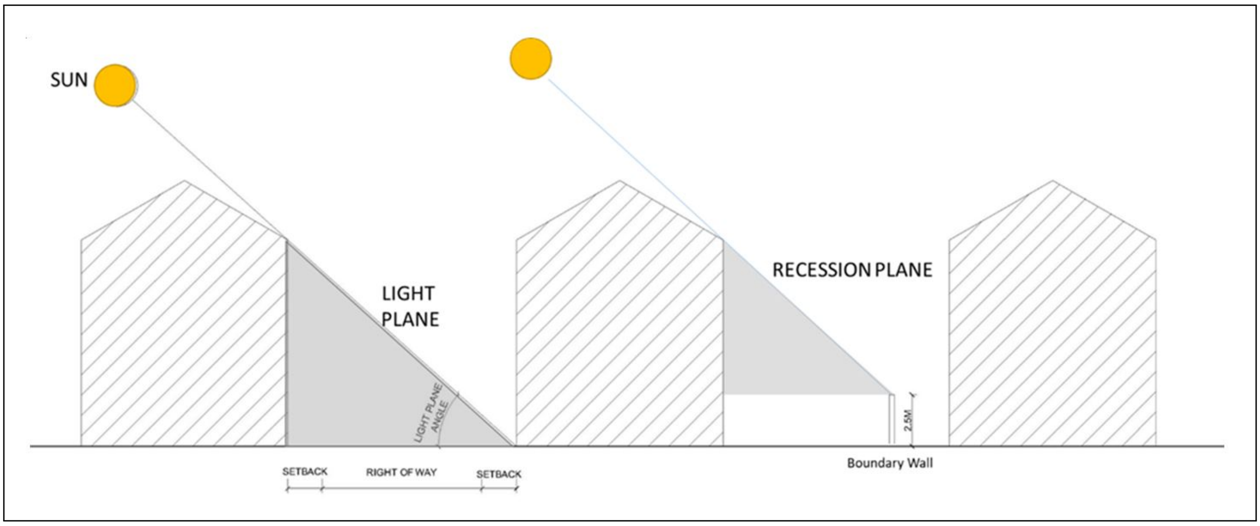


Figure 1: Light Plane and Recession Plane

towards the site." [5]

2. Literature study

Two basic social impetuses, the desire to live together and the conviction to build structures ever larger, have affected the development of historical urban life. Today, modern skyscrapers (tall buildings) in many ways the symbol of modern life, introduce modernity and wealth to a city. However, tall buildings, although they are mostly well-known symbolic figures of metropolises, have been criticized since their first development. Primarily, opponents to tall building construction cite their huge mass as contrary to human nature; with their excessive energy consumption; the extra pressure they cause on city infrastructure; and the exacerbation of already difficult issues such as traffic and parking. [6]

Further, opponents object to their unnatural indoor conditions that adversely affect occupant health, and their role in the lowering of the economic viability of surrounding land by blocking the light, air, and view . Tall buildings block the sun of their surrounding environment and change their 'solar access', properties. Reduction at sun light is an important issue for energy efficiency, vegetation, and daylight properties of indoors.[7]

With the growing interest in sustainability, the use of sunlight has begun to play a major role in building design and green architectural strategy. Designation of the solar access of a region or a building is vital for design issues such as the determination of basic design goals, development of first schemes, optimization of the building's energy efficiency, integration of solar active systems, and taking proper vegetation plans . [6]Sustainable buildings are designed according to the promise that they will have the same solar exposure for the life of the building, even though this is not a permanent fact of developing cities.

Although 'solar access guarantee for lifetime' has vital importance for the future of green buildings energy dynamics, this subject is still not a design issue at urban planning. Regulations force designers to use solar energy effectively in new construction and there are many advancements in solar technologies that integrate with the architecture, but all these are meaningless if a consistent level of sunlight cannot be ensured over the life of a building.

2.1 Shadow And Shading

Shadow is a dark area or shape produced by a body coming between rays of light and a surface.

The effects of shading by one building upon another can be either positive or negative depending upon the site-specific circumstances of the properties involved. A potential benefit of shading for adjacent structures may be a cooling effect gained during warm weather. Negative consequences of shading include the loss of natural light for passive or active solar energy applications or the loss of warming influences during cool weather. Factors influencing the relative impact of shadow effects are site-specific and include differences in terrain elevation between involved properties, the height and bulk of structures, the time of year, the duration of shading in a day, and the sensitivity of adjacent land uses to loss of sunlight. [8] Shadows cast by structures vary in length and direction throughout the day and from season to season. Shadow lengths increase during the "low sun" or winter season and are longest on December 21-22, the winter solstice. The winter solstice, therefore, represents the worst-case shadow condition and the potential for loss of access to sunlight that a project could cause is greatest. Shadow lengths are shortest on June 21-22, the summer solstice. Shadow lengths on the spring and fall equinoxes, March 20-21 and September 22-23 respectively, would fall midway between the summer and winter extremes. building materials prevents the high energy consumption rate. [8]

2.2 Shadow Analysis

Shadow analysis describes the process or methods by which the magnitude of shadows casted by a stuff can be determined. It also means the study of casted shadow and shadow domain of a building on its surroundings in a daytime or for certain days of a year. This shadow profile varies time to time and orientation of the substance towards the light. The shadow analysis also includes these factors to describe a complete package of shadow domain on the surface over the time. Thus, shadow analysis can be defined as a method that formulate and interpret the casted shadow by a stuff considering the factors like solar angels, azimuth, orientation etc. to determine the domain of shadow.

2.3 Building Bye laws

"Building bye laws are the regulations that are generally made by local governments or the municipal departments of governments, with the intention of controlling urban development in harmony with that envisaged in the Master Plan and for ensuring structural safety, public health and hygiene." [9]. The different kinds of norms are Right of way, Light plane, Setback, FAR, ground coverage Height of building, and so on.

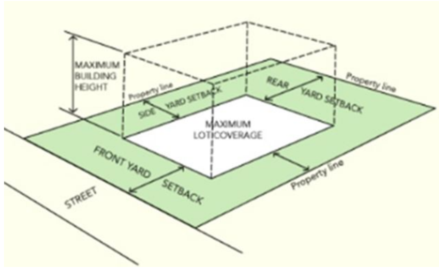


Figure 2: Building Envelope

2.4 Set Back Lines

A line parallel to and within the plot boundary set down by the relevant Authority, beyond which no construction is permitted. [9]

2.5 Building Height

In the case of flat roofs, the vertical distance measured from the center of the access road up to the highest surface of the building. In the case of sloped roofs whether gabled or single, if roof slope is greater than 25-30 degrees the height shall be the vertical distance measured from the center of the access road to the midpoint along the slope of the roof. In the case of the sloped roof with less than 25-30-degree pitch, the height shall be the vertical distance measured from the center of the access road to the eaves of the roof. [9]

2.6 Solar Angle

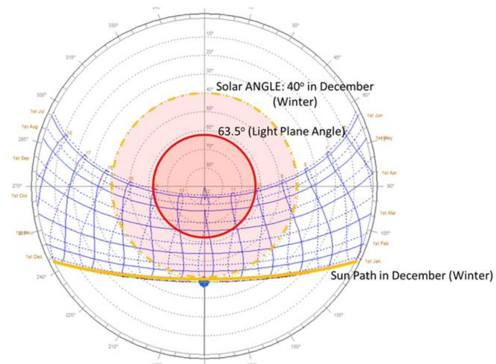


Figure 3: Solar chart and solar Angle of kathmandu Valley

Solar Angle varies according to different Orientation and time but, The Light plane illustrated in the Byelaws of Kathmandu does not explain nor refer the reason behind the light plane angle being 63.5 deg for Kathmandu Valley. According to the Solar Chart for Kathmandu valley i.e. figure 3, it illustrates that the light Plane angle of 63.5 deg, regulated in bye laws only serve the months from April to October, whereas the sunlight is primarily needed in November, December and January (Winter season). In these months solar angle is in range of 40 to 50 deg.

2.7 Solar Access

Solar access is the amount of solar radiation that reaches a building or the amount of direct solar energy on a building, and it is measured by the means of annual solar radiation and the amount of sunlight hour. [7] The solar rays that reach indoors reduce the demand for artificial light and heat energy and increase the property value by enriching the quality of space. Similarly, the access of sunlight in outdoor areas is necessary and valuable for the growth of vegetation, quality of public space, and the encouragement of social activities. Solar access and its continuity are vital for systems reliant on solar energy and for the development of solar technologies. Furthermore, access to sunlight enables the users of a building to perceive time and space by the sun's rhythmic movements. [10] In short, beyond its rationalist benefits, sun provides significant value in a built environment, both for the functioning of the building and for the people who use its spaces. Solar access depends not only on the design of a certain building but also on adjacent construction that can interfere with access to sunlight. Preserving access to the sun, then, by controlling environmental shadowing is a key concern for the future. [11]

As buildings have great mass, they reduce the solar access of their surrounding environment by overshadowing adjacent properties. Evaluating the effect of buildings on an environment's solar access will have great importance on the future adjudication of solar right regulations. [6]

2.8 Energy Simulation Software

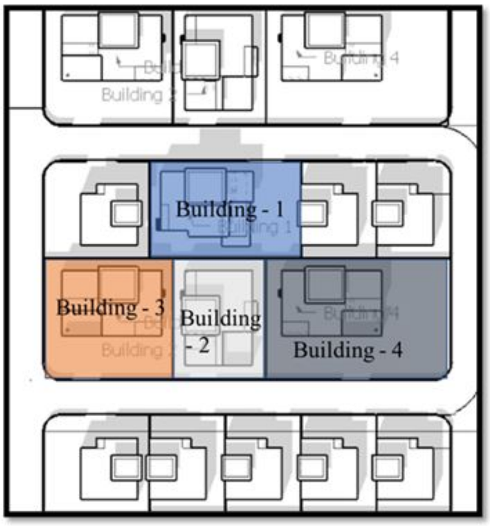
Autodesk Ecotect Analysis is an environmental analysis tool that allows designers to simulate building performance from earliest stages of conceptual design. This software has the ability to import climate data files, confirm longitude and Latitude, time zones, geographically locate and orient the site of the project, and weather impact on the building. Its software converts weather data, summer and winter solstice, spring equinox, shading design data, sunrise, solar noon and sunset data into the model. It provides 3D stereographic sun paths diagram onto the model. The software can perform thermal, ventilation and wind calculations.

We must manually update the thermal lag for different building material composition that are not available in ecotect. Ecotect can't do all building energy simulations, only for climate analysis, sun location visualization, daylight, shading, and basic thermal analysis, it does not work for ventilation simulation and the wind. The data availability in the context of Nepal is another limitation for the simulation in our case. There are very limited data about the climate zones and weather of various region of Nepal and almost no data about the building materials.

3. Research Context

3.1 Location description and reference house analysis

Figure 4: Master Plan



Kirti colony is located at the Chovar, Kirtipur at the distance of 10 km from Balkhu, Kathmandu. The main reason to choose it as case study is because as the built-up environment is developing and the concept of recession plane is difficult to implement in core area. The study area has been designed by CE Services Pvt. Ltd. And CE Construction is the main contractor. The total site area accounts upto 29695 sq. m (58-5-3-3). The colony houses 45 residential units with plot area of 235 sq. m. The case study area lies on planned Residential Sub Zone.

The entrance of the housing is N-S oriented. The building typology used in it is Modern Row housing with minimum of 1.5m setback. It is made up of Modern materials like Brick, cement, wood, steel, aluminium etc. The buildings are RCC framed structure with column size of 300 mm X 300mm. The external and inner wall of building is made up of 230mm and 110mm brick work with cement mortar (plaster) finish on both inner and outer side. Single-glazed wooden frame window of different size and wooden frame door of 100mm x 180mm are used.

3.2 Bye Laws

S.N.	Zone	Building Type	Land Usage Area	Maximum Height (Ft)	Maximum Floor	FAR
1	Planned Residential Zone	Vacant land upto 250 sq m	70 %	Light Plane		2
		Vacant land > 250 sq.m	60%	Light Plane		2

4. Methodology

The study uses both qualitative and quantitative methods. The qualitative methods are based on interpretation of literature on approaches to recession plane. Similarly, the quantitative method largely includes the study of solar angle, best fit time interval and shadow analysis modeling of the building. In this sense, the study is located within the pragmatic paradigm. In this, the interpretation of solar access uses interpretive paradigm whereas quantitative data, extensive solar analysis and energy performance modelling use a positivist paradigm.

The literature study was done through journals, and academic research works, from various sources including the internet. The collected data from the case study area included information about orientation, building envelope, openings, and fenestration. This helped to develop the base case model for these initiatives near the real building. The weather data file of Kathmandu was loaded in the simulation program and the indoor comfort range was formulated with the help of climate consultant. With the obtained data, energy consumption patterns of the base case building were analyzed using the Ecotect simulation program. Based on the simulation analysis, the results were obtained and discussed.

5. Data Set and analysis

5.1 Climatic data

This research is based upon simulation so for any simulation program to perform, a weather data must be input to give best results. By running the weather data of 10 years of Kathamndu in Climate Consultant software based on ASHRAE standard 55-2004 using PMV (Predicted Mean Vote), the output shows the warmest, coldest month and the comfort temperature range for Kathmandu. The hottest month is in May whereas January is the coldest month and the comfort range varies from 20.3^0C – 26.7^0C which has been shown in Figure 5. The thermal comfort was based on dry bulb temperature, clothing level (clo), metabolic activity, air velocity, humidity and mean radiant temperature.

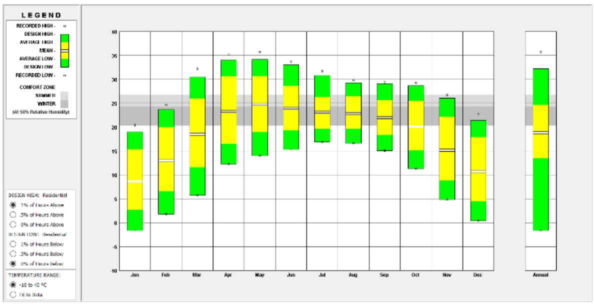


Figure 5: Comfort Range in Kathmandu

5.2 Building Simulation and Parameters

The Solar angle, shadow analysis and energy performance of the residential building was checked by the help of Ecotect simulation software. The base case energy model was created for performing solar access anaylysis, shadow analysis and thermal analysis under different parameters. Also, various different scenarios are prepared with alteration in recession plane angle, building material and energy-related elements that helps to optimize energy performance of the same building. The data assumptions made for thermal analysis was as realistic as possible according to the site conditions.

The following parameters were considered for internal design conditions of each floor level of the building:

- Comfort temperature band: 20.3^{0}C – 26.7^{0}C
- Lighting level: 300 lux
- Clothing: 0.60 clo (Trouser and shirt)
- Humidity: 60%
- Airspeed: 0.5 m/s
- No of people : 5
- Activity: Sedentary-70W
- Sensible Gain: 5
- Latent Gain: 2W/m^2
- Air Change rate: 2.0 ach (leaky)
- Wind sensisivity: 0.5 ach (Somewhat sensitive)

5.3 Scenarios modeling and results

- Existing Scenario

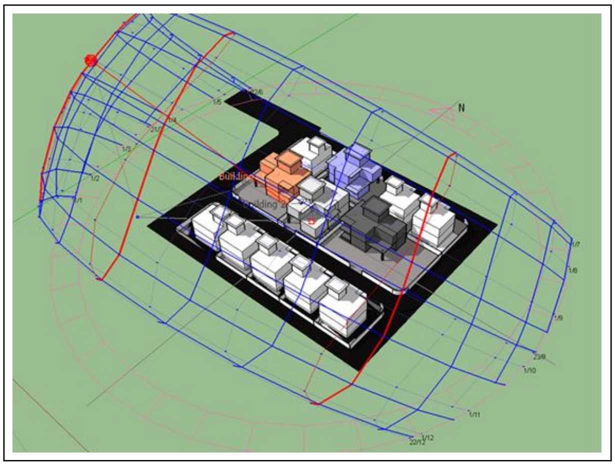


Figure 6: Energy model showing the annual solar path

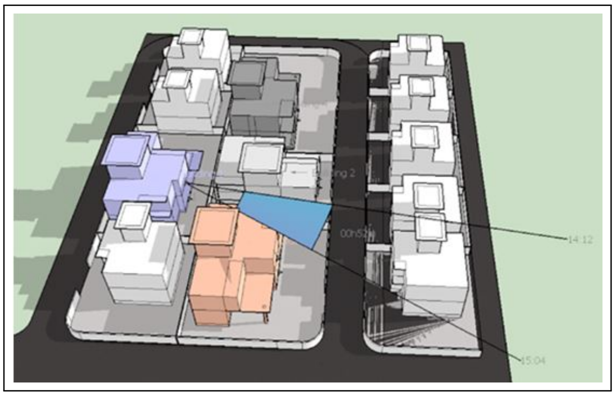


Figure 7: Solar Access in building 1 during winter

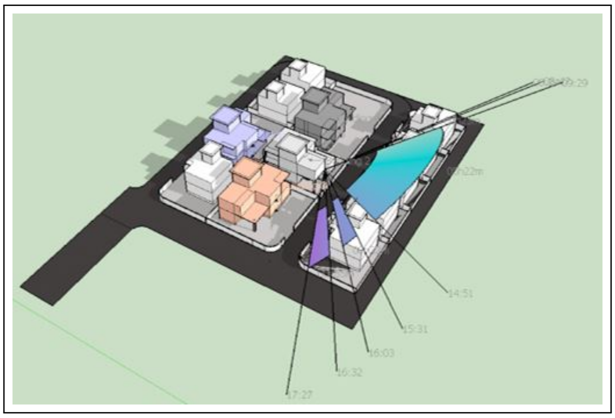


Figure 8: Solar Access in building 2 during winter

The figure 7 and 8 show that during Winter season, the ground floor of building 1 receives at an average of 40 minutes of solar insolation which is either in morning or on afternoon whereas the average daily sunshine hours is 9.5 hrs. Thus, only second floor received uniform solar insolation throughout the year. As a result, the annual heating and cooling load with contemporary building material and technology is 10017.726kWh whereas the annual heating and cooling load with energy efficient building materials is 5517.97kWh.

- Scenario 1 : Recession Plane (North-60^0, South-90^0, East-60^0, West-60^0)

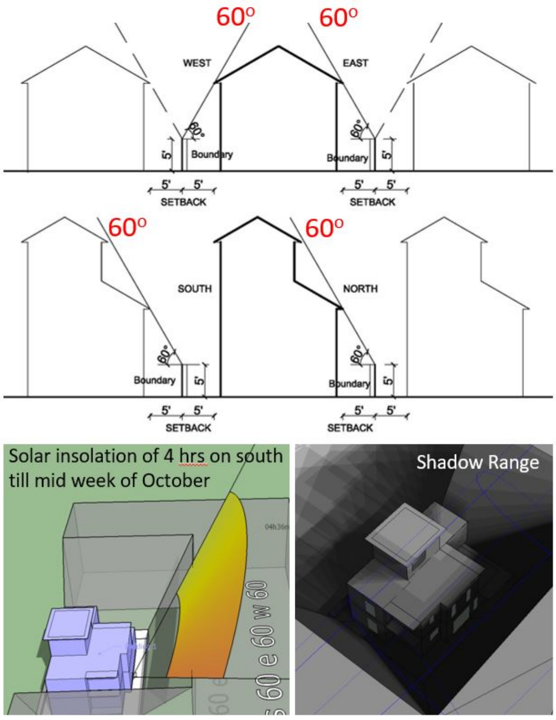


Figure 9: Simulation of scenario 1

In this scenario, the south façade has solar insolation of minimum 4 hours (10 am to 2pm) till mid of October. Similarly, the east and west façade have solar access in morning and afternoon. Thus, only second floor receives uniform solar insolation throughout the year as illustrated by shadow range. As a result, the annual heating and cooling load with contemporary building material and technology is 9715.025kWh whereas the annual heating and cooling load with energy efficient building materials is 5401.39kWh.

- Scenario 2 : Recession Plane (North-50^0, South-90^0, East-60^0, West-60^0)

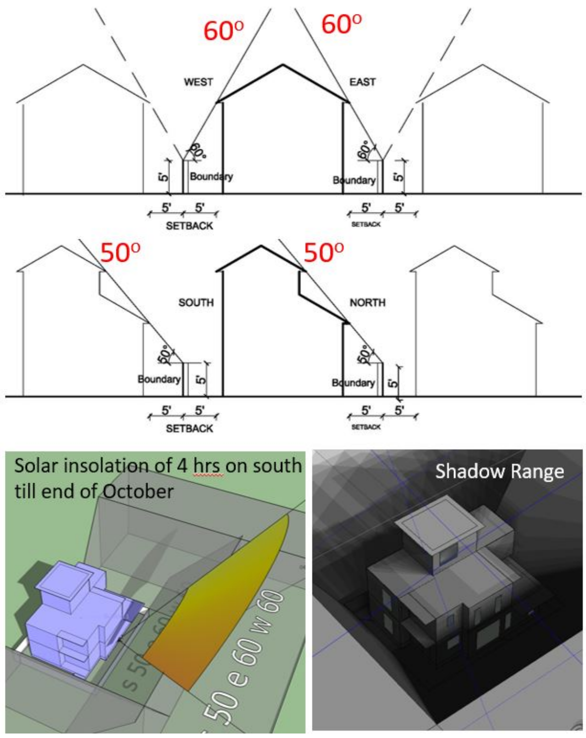


Figure 10: Simulation of scenario 2

In this scenario, the south façade has solar insolation of minimum 4 hours (10 am to 2pm) till the end of October. Similarly, the east and west façade have solar access in morning and afternoon. Thus, only first floor receives uniform solar insolation throughout the year as illustrated by shadow range. Consequently, the annual heating and cooling load with contemporary building material and technology is 9623.025Wh whereas the annual heating and cooling load with energy efficient building materials is 5314.98kWh.

- Scenario 3 : Recession Plane (North-45^0, South-90^0, East-60^0, West-60^0)

In this scenario, the south façade has solar insolation of minimum 4 hours (10 am to 2pm) till the mid of November. Similarly, the east and west façade have solar access in morning and afternoon. Thus, ground floor receives few hours of solar insolation throughout the year as illustrated by shadow range. As a result, the annual heating and cooling load with contemporary building material and technology is 9570.245Wh whereas the annual heating and cooling load with energy efficient building materials is 5235.029kWh.

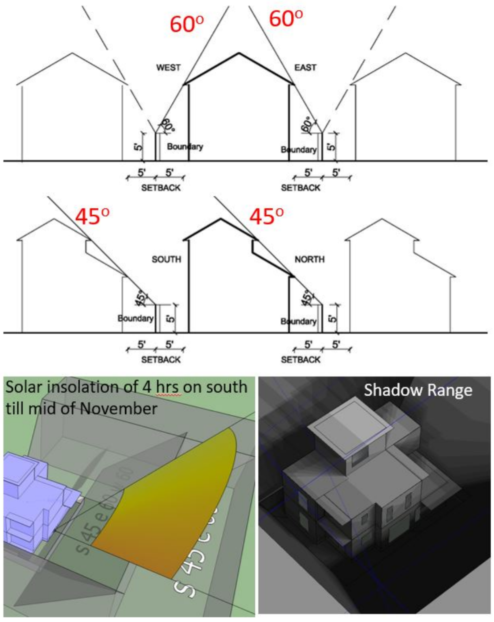


Figure 11: Simulation of scenario 3

- Scenario 4 : Recession Plane (North-42^0, South-90^0, East-60^0, West-60^0)

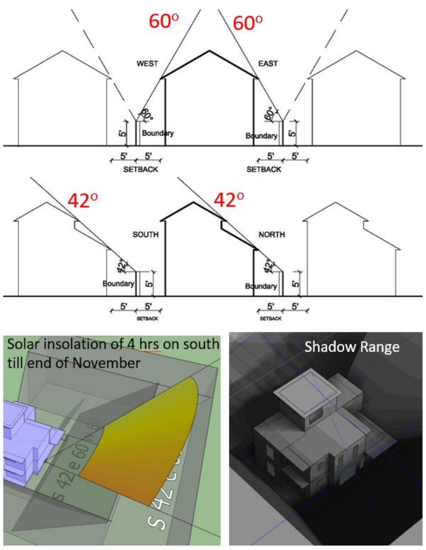


Figure 12: Simulation of scenario 4

In this scenario, the south façade has solar insolation of minimum 4 hours (10 am to 2pm) till the end of November. Similarly, the east and west façade have solar access in morning and afternoon. Thus, ground floor receives few hours of solar insolation throughout the year as illustrated by shadow range. Consequently, the annual heating and cooling load with contemporary building material and technology is 9516.159Wh whereas the annual heating and cooling load with energy efficient building materials is 5192.749kWh.

- Scenario 5 : Recession Plane (North-40^0, South-90^0, East-60^0, West-60^0)

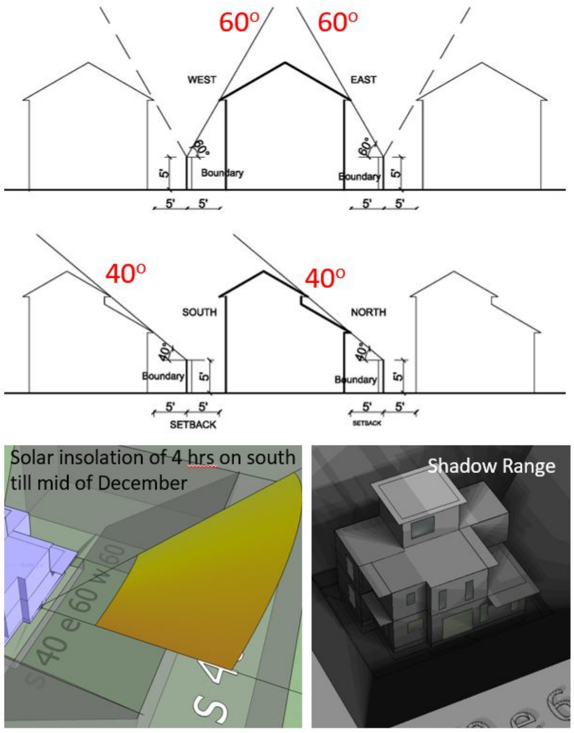


Figure 13: Simulation of scenario 5

In this scenario, the south façade has solar insolation of minimum 4 hours (10 am to 2pm) till the mid of December. Similarly, the east and west façade have solar access in morning and afternoon. Thus, ground floor receives solar insolation throughout the year as illustrated by shadow range. Therefore, the annual heating and cooling load with contemporary building material and technology is 9489.159Wh whereas the annual heating and cooling load with energy efficient building materials is 5154.27kWh.

- Scenario 6 : Recession Plane (North-60^0, South-90^0, East-75^0, West-60^0)

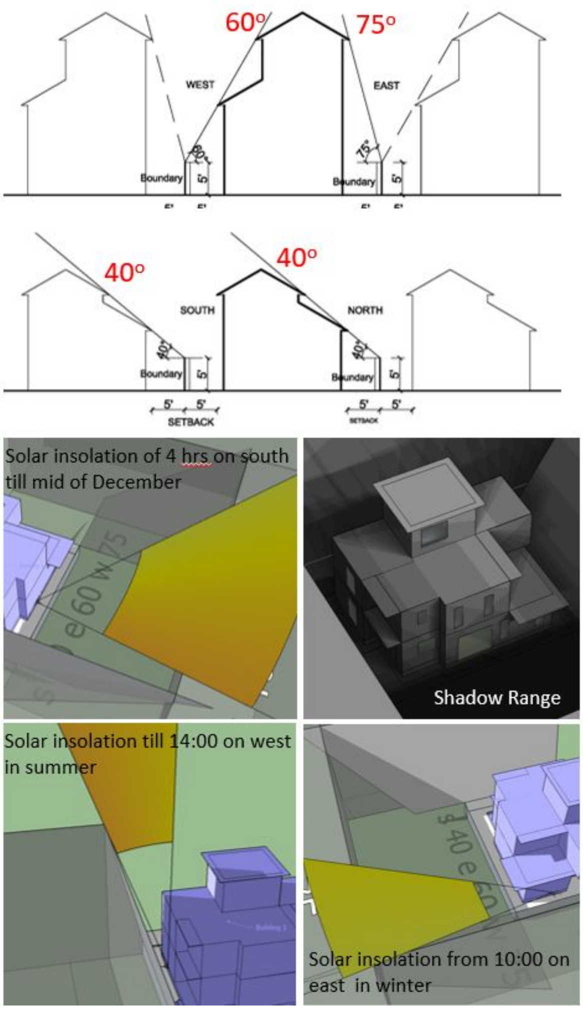


Figure 14: Simulation of scenario 6

In this scenario, the south façade has solar insolation of minimum 4 hours (10 am to 2pm) till the mid of December. In addition ground floor receives solar insolation throughout the year and the east façade also receives solar insolation from 10:00 in winter. On the other hand, the west façade receives solar insolation till 14:00 in summer as illustrated by shadow range. Consequently, the annual heating and cooling load with contemporary building material and technology is 9499.507kWh whereas the annual heating and cooling load with energy efficient building materials is 5167.168kWh.

6. Findings and discussions

The figure 15 illustrates that base case scenario has least solar insolation period in south and east direction, from (mid-April to mid-Sep) and (mid-Feb to mid-Nov) respectively whereas it cast shadows on west in summer. Similarly, scenario – 5, has maximum solar insolation period in south, east and west direction, from (Jan to mid Dec), (Jan to mid-Dec) and (Feb to Nov) respectively. While Scenario – 6 has maximum solar insolation period in south and east from Jan to mid-Dec, and also cast shadows on west in summer.

		Base Case Scenario	Scenario 1	Scenario 2	Scenario 3	Scenario 4	Scenario 5	Scenario 6
With contemporary building materials	Energy consumed per year	10017.73	9715.025	9623.025	9570.245	9516.159	9489.159	9499.507
	Energy Difference		302.701	394.701	447.481	501.567	528.567	518.219
	Energy Saved %		3.021654	4.062789	4.650107	5.2409	5.554415	5.461169
With energy efficient building materials	Energy consumed per year	5517.97	5401.39	5314.98	5235.029	5192.749	5124.27	5167.168
	Energy Difference		116.58	202.99	282.941	325.221	393.7	350.802
	Energy Saved %		2.112733	3.758107	5.323463	6.212401	7.581726	6.845892

Figure 16: Energy saved in optimised scenarios

The result obtained through simulation shows energy saving of optimized model scenario-1, scenario-2, scenario-3 and scenario- 4, scenario 5 and scenario 6 in comparison to base case scenario with Contemporary building materials to be 10017.726 kWh, 9715.025 kWh, 9623.025 kWh, 9570.245 kWh, 9516.159 , 9489.159 kWh and 9499.507 kWh respectively per year. Similarly, energy saving of optimized model scenario-1, scenario-2, scenario-3 and scenario- 4, scenario 5 and scenario 6 in comparison to base case scenario with energy efficient building materials to be 5517.97 kWh, 5401.39 kWh, 5314.98 kWh, 5235.029 kWh, 5192.749 kWh , 5124.27 kWh and 5167.168 kWh respectively per year.

Finally, the scenario-6 shows solar insolation can be gained throughout the year and minimize the effect of solar radiation from west in summer with thermal energy saving up to 5.46% and 6.84% with contemporary and energy efficient building materials, respectively. The simulation result clearly shows that if recession plane is considered, it is possible to achieve solar radiation throughout the year and a significant reduction in energy consumption and energy, with possibility of utilizing solar energy that significantly better sustainability of environment.

7. Conclusion

The Solar Energy generates the life on the Earth, although 'solar access guarantee for life time' has vital importance for the future of green buildings energy dynamics, this subject is still not a design issue

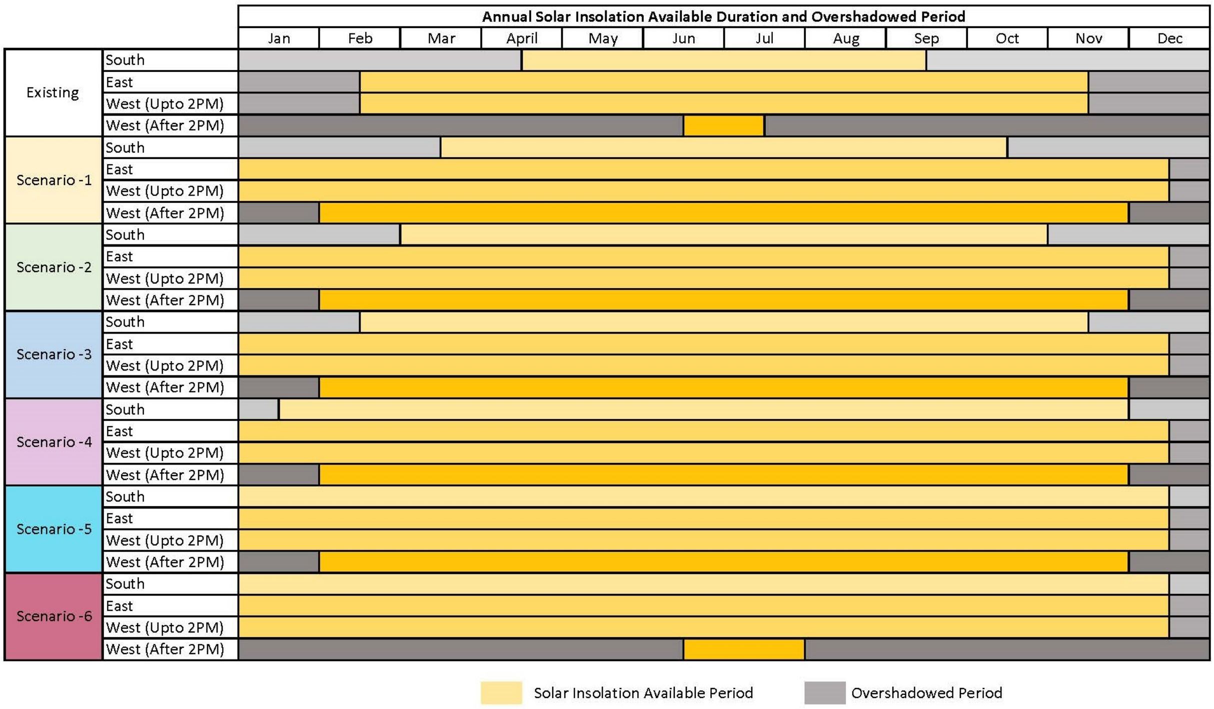


Figure 15: Annual Solar Insolation Available Duration and Overshadowed Period

at urban planning. Regulations force designers to use solar energy effectively in new construction and there are many advancements in solar technologies that integrate with the architecture, but all these are meaningless if a consistent level of sunlight cannot be ensured over the life of a building. Thus, Recession Plane portrays the close relationship between the buildings, solar radiation and surroundings. It gives necessary dimensions to the site so that it fulfils its own requirements without effecting its surrounding. Furthermore, the characteristics of open spaces between buildings have, an impact on the sustainable development of urban areas. Spatial arrangement and accessibility of these spaces, the quantity and character of greenery, and passive design strategies influence the functionality, the ecological stability of the area, hygienic life of residents, sustainable and energy efficient qualities. This research study shows the great potential of Recession Plane in optimizing the built environment. The Simulation results shows that scenario - 6 has feasible recession plane angle of (North-40^0, South-90^0, East-75^0, West-60^0) and solar insolation can be gained throughout the year and minimize the effect of solar radiation from west in summer with energy saving up to 6.84%. The recession plane can also be applied to public buildings and public spaces.

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