# ENERGY EFFICIENT DESIGN & PLANNING OF SMALL SETTLEMENTS AS A SUSTAINABLE BUILDING APPROACH

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## Summary

In the present day context energy plays an important role in every pursuit of life. In a country like India, where economy is rising at a rate of more than 8 percent per annum, the need of energy is also increasing manifold, particularly with the coming up of MNCs & Real Estate developments. Design & planning of buildings and settlements can play a major role to curtail the energy demand and thus can help in achieving the global objective of sustainable development.

In India the majority of the areas come under composite climate and our buildings are often designed without taking enough consideration of climate. If we can place our built areas under shade for majority of times by virtue of design & planning, we can save lot on energy bills. From the studies, it is shown that 40% of energy needs can be reduced by only designing the buildings with proper specifications & placing them in a best orientation. In a study for Delhi region, the orientation of buildings if kept with longer axis as East –West i.e. major façade facing North & South and shorter facades on East & West, the building performs best for thermal comfort. If it is tilted 15 to 20 degree north then it also gets the advantage of air movements. Further having higher building blocks on south side rows, we get the advantage of the shadow on north side blocks by the movement of sun from east to west. This pattern of planning gives the maximum advantage of energy saving. In the paper, the design & planning approach to save energy for a small settlement for a 5000 population has been discussed as a strategy for sustainable building development.

## 1. Introduction

Energy in all forms is vital to sustain life. In housing it is used for cooking, heating, cooling, illumination and to run various gadgets. In the light of large demand of energy over the last 10-15 years and its short supply,, building industry in India has become quite energy conscious. Further the program on Global security and sustainability has given priority to the areas like conservation and sustainable development. Here we are more concern with conservation of energy in built environments. It is also necessary for sustainable development as the sources of non-renewable energy are limited and getting depleted day by day. The alternative sources of energy could be biogas, biomass, solar energy, wind energy, hydropower etc. For sustainability we have to depend on renewable sources of energy which are available in abundance and non-depletable in nature.

Now a days every country is very much conscious about the use of energy. As per a study in USA the energy consumption in buildings accounts for 36% of country's energy supply and energy use is growing at a rate of 3.3% a year. Heating and cooling equipment consumes 42% of all building energy use at a cost of $ 81 billion. A passive solar design can save as much as 50% on heating bills for only 1% more construction cost. These facts illustrate the capability and importance of passive solar building design with respect to conservation of both energy and money. Apart from general lack of norms and regulations, one reason that buildings are poorly adapted to the climate is lack of knowledge among building designers, whether an architect or engineer or town planner.

In the field of passive solar architecture related to individual buildings many research works have been done. Some studies have been carried out on tree shade effects on residential energy use at California using different type of trees (e.g. shape, size) and location around buildings. Tree shade reduces summer air conditioning demand and increases winter heating load by intercepting solar energy that would otherwise heat the shade area. Similarly studies are available on shading of windows, their designs etc. In all studies the effects have been limited to single building only. In this paper the impact of energy conservation has been studied at a settlement level with different planning patterns through design of buildings, their orientation and distances among the buildings of different heights for shading effect.

In India two solar houses have been constructed in Ladakh. A NGO, Ladakh Environment and Health Organization (LEHO) has taken the first step at 3500 m above sea level for designing a building using

passive system of heating. They introduced solar buildings in Ladakh with the help of a France based NGO, Geres. Similarly few buildings with passive features have been constructed in the plains of North India at Delhi & Gurgaon etc. to save the energy loads. The seminars / conferences are being held by various concerned departments to reduce the transmission / distribution losses and to use low energy saving devices & equipments like fuse less systems etc. In this background a project was under taken to achieve energy conservation through design and planning of small settlement.

## 2. Methodology

The methodology adopted involves finding out the physical requirements for a settlement of 5000 population for which energy requirements are to be analyzed. This includes the various types of residences, education facilities, recreation facilities and shopping facilities. Then area of the site is to be find out considering an assumed density of population.

To calculate the energy requirements of a settlement the number of residences, their design, specifications, orientation and design of other buildings like shopping, schools etc. are all important. The requirements of different buildings adopted in the study for a population of 5000 persons are :

### 2.1 Requirements

1. No of houses - 1000 @ 5 persons / family
2. EWS[i]/LIG[ii] houses - 600
3. MIG[iii] houses - 230
4. HIG[iv] houses - 170
5. Primary school - 1
6. Nursery school - 2
7. Convenient shops - 2

i EWS Economically weaker sections
ii LIG Low income group
iii MIG Middle income group
iv HIG Higher income group

The number of low category houses has been taken as 60 per cent of the total houses as majority of the population in India belongs to this section of population and as a policy government also want that in any urban housing scheme major share of houses should be assigned to low income group people. The other building requirements are also kept as per prevailing planning norms in India. The density of population has been assumed as about 125 persons / acre or 315 persons /hectare. This comes out to about 50 houses per acre assuming 5 person per family and total requirement of land comes about 40 acres or 16 hectares approximately. Accordingly a plot of 400m x 400m has been theoretically selected for the study point of view.

### 2.2 Architectural Design

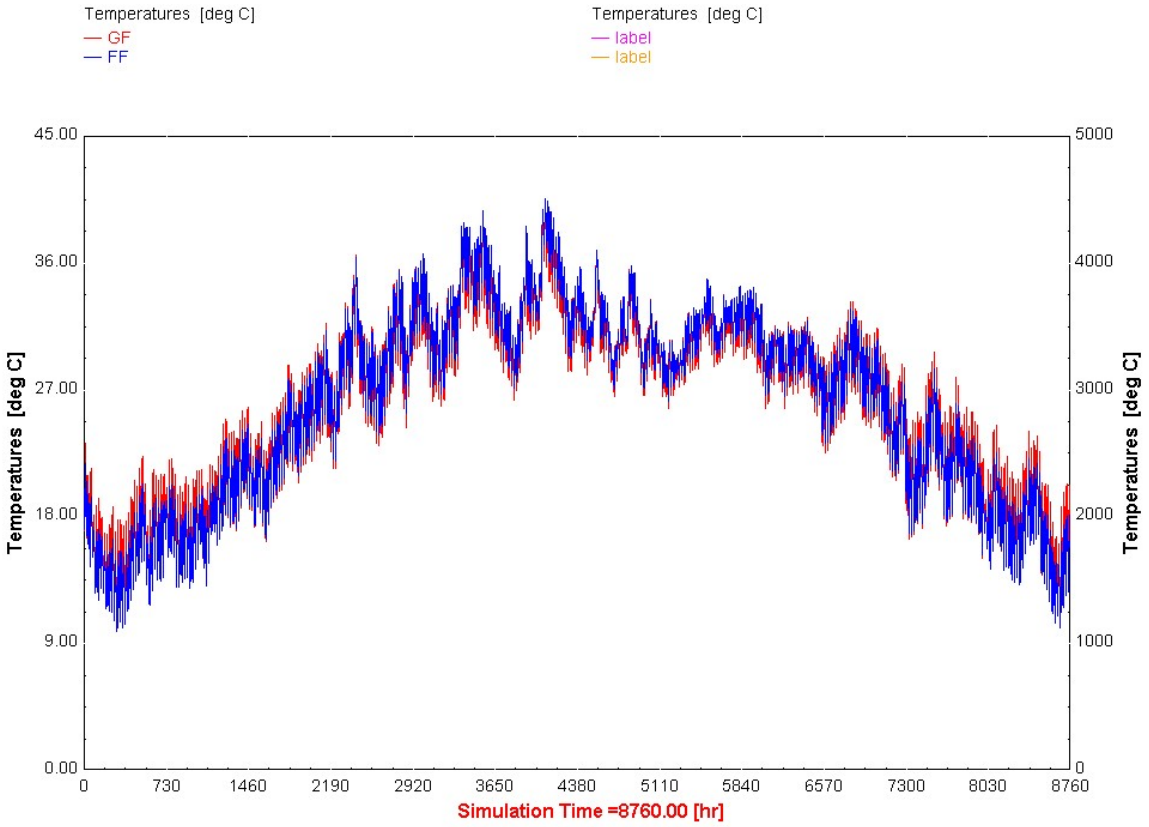
To calculate the energy load of a building their architectural design and specifications are important consideration so the designs for various categories of houses, a primary school, a nursery school and a shopping center have been developed. The areas for LIG, MIG and HIG houses have been taken as 36.00 sq.m., 72.0 sq.m. and 108.0 sq.m. respectively. The areas for primary and nursery schools are 421.65 sq.m. and 90.74 sq.m. respectively. Shopping complex with 20 Nos. of shops has been designed with area of one shop as 12.00 sq.m.

### 2.3 General Specifications

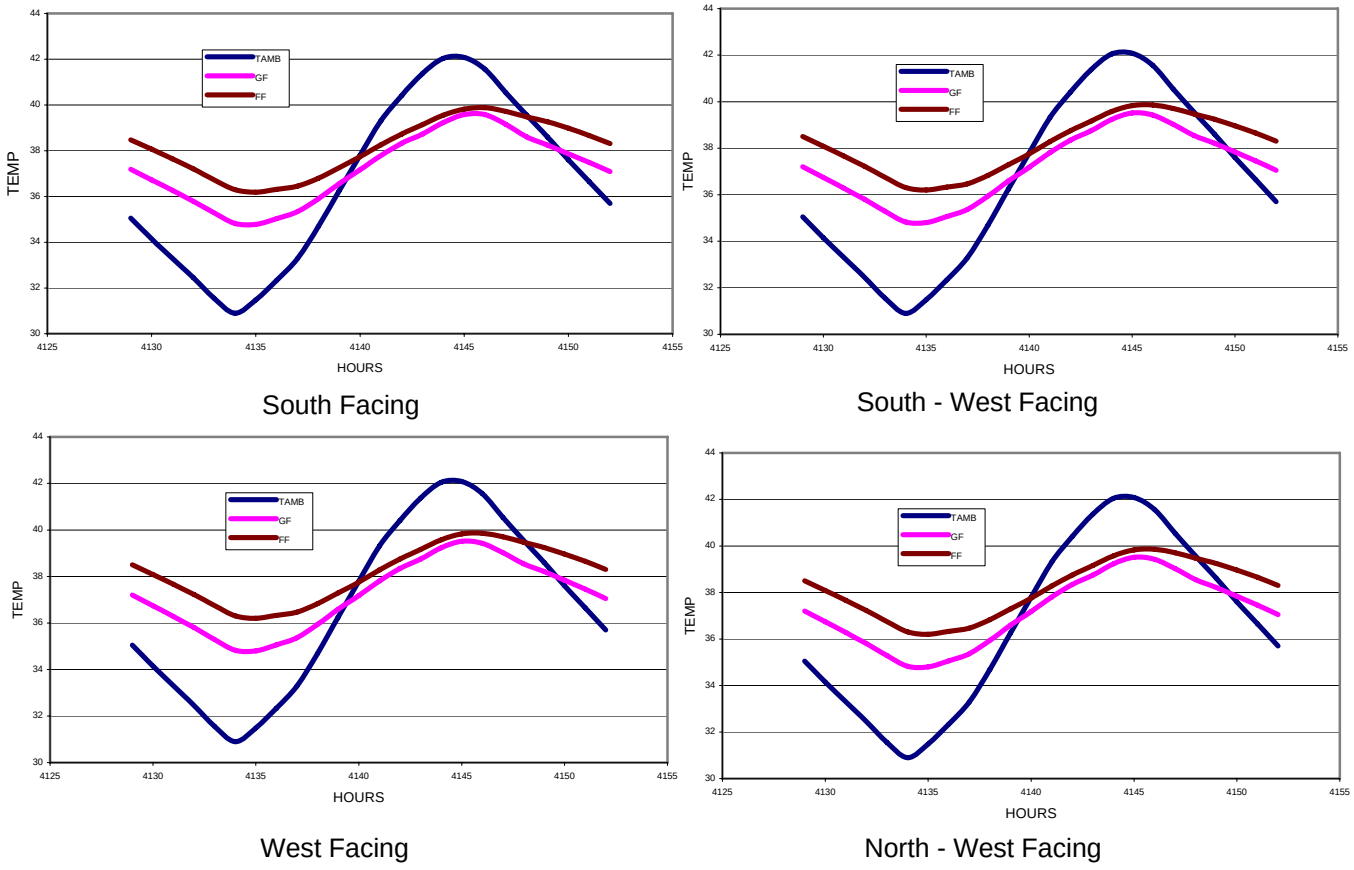
1. Brick work in cement mortar for 9” (23cm) thick brick walls and 4½ “(11.5cm) thick brick with ½ inch (10mm) thick cement plaster on both sides.
2. 4” (10 cm) RCC roof with 10cm thick mud fuska including insulating layer of tar felt, & 2” brick tiling.
3. 4 cm thick cement concrete flooring on 7.5 cm lean concrete in two room set.
4. 5 cm thick cement concrete flooring including 1.5 cm thick moisac finish and 7.5 cm thick lean concrete.
5. Windows with plane glass of 3 mm thickness with wooden frame.

### 2.4 Energy Considerations

For the above designed buildings energy flow have been calculated for 22nd June temperatures putting these buildings in eight cardinal directions and having 2 and 4 Storey developments by using TRNSYS software. The energy simulation curves have been prepared for Delhi Region. Annual simulation curve and simulation curves for 22nd June for LIG two storey house buildings have been shown for four cardinal directions i.e south facing, south west facing, west facing and north west facing in graphs 1 and 2. During temperature simulation process shading factor on the building surface is also required. For this purpose, software/program has been developed using FORTRAN programming language to calculate the shadows. It calculates the height of shadows on the opposite buildings placed at a given distance at different orientations of the building for different altitudes and azimuth of the sun at different hours of the day.




*Graph 1 Annual Simulation Curve LIG 2 storey house.*



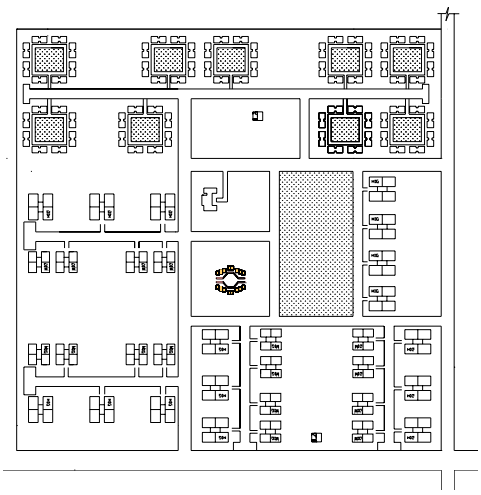

*Graph 2 Simulation curve for LIG 2 storey building for 22nd June.*

## 3. Layout Planning

Three layouts have been developed, two with normal / traditional type of clusters & road patterns having 4 storeyed walkup apartments for LIG group and 2-4 storey apartments for MIG & HIG group. Here the buildings have been placed in all the directions as depicted in FIG. 1 & 2.

The other layout has been developed considering orientation of all the buildings in E-W direction as longer side (facing north & south) because it consumes minimum energy. It is also depicted from the cooling load tables 1, 2 & 3 and corresponding histograms fig. 3, 4, 5 for LIG, MIG & HIG houses.

Further, while placing the blocks of buildings the height of blocks on the northern side rows have been reduced while of the blocks on the southern side has been increased to get the maximum advantage of the sun movement. It is reflected in the different design of residential clusters. Then these clusters have been grouped in a plot area of 400 m x 400m i.e. 16.00 hectare plot giving a density of 315 person / hectare or 126 persons / acre approximately. The development has been envisaged from 2 to 12 storeyed. The plantation of trees has been proposed on western side of clusters with a continuous belt of trees all round the boundary line of the site. The layout has been enclosed as Fig. 6.

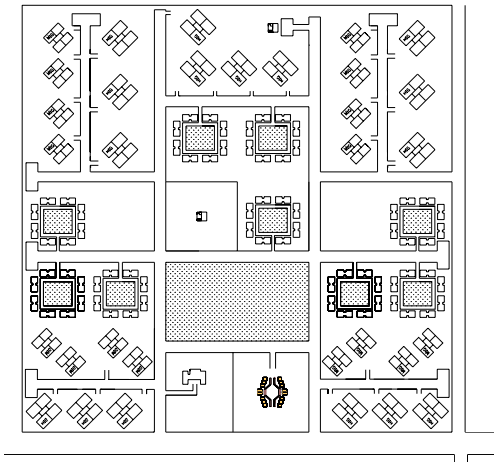


**Legend**

- **Area of the plot**
  **16 hactare/40 Acres**
- **LIG Houses = 576**
- **MIG Houses= 256**
- **HIG Houses = 168**
  **Total = 1000**
- **Primary School – 1**
- **Nursery School – 2**
- **Shops – 16**
- **Neighbourhood Park – 1**
- **Tot lots – At cluster level**
- **Density 25 DUs/Acre**
- **Type of Development 2 to 4 Stories**

*Figure 1 Settlement layout plan for a neighborhood of 5,000 population, Alternative – I*

The energy conservation in a settlement is a function of so many things because a settlement comprises of houses, community buildings and services. As the study was specifically to conserve energy through planning patterns and land uses, it is important to understand the concept of planning pattern and land uses taken in the study.



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- **Shops – 16**
- **Neighbourhood Park – 1**
- **Tot lots – At cluster level**
- **Density 25 DUs/Acre**
- **Type of Development 2 to 4 Stories**

*Figure 2 Settlement layout plan for a neighborhood of 5,000 population, Alternative – II*

Table 1 Cooling Loads (kw) for LIG Houses in Different Directions

| Direction | 2 Storey Development | 4 Storey Development |
|---|---|---|
| N | 3.32 | 4.846 |
| NE | 3.795 | 5.826 |
| E | 3.686 | 5.618 |
| SE | 3.73 | 5.7 |
| S | 3.258 | 4.757 |
| SW | 3.811 | 5.858 |
| W | 3.687 | 5.62 |
| NW | 3.772 | 5.785 |

Table 2 Cooling Loads (kw) for MIG Houses in Different Directions

| Direction | 2 Storey Development | 4 Storey Development |
|---|---|---|
| N | 5.751 | 7.759 |
| NE | 6.282 | 8.845 |
| E | 6.088 | 8.434 |
| SE | 6.238 | 8.753 |
| S | 5.719 | 7.694 |
| SW | 6.302 | 8.884 |
| W | 6.089 | 8.437 |
| NW | 6.209 | 8.855 |

Table 3 Cooling Loads (kw) for HIG Houses in Different Directions

| Direction | 2 Storey Development | 4 Storey Development |
|---|---|---|
| N | 8.301 | 11.054 |
| NE | 8.919 | 12.305 |
| E | 8.598 | 11.652 |
| SE | 8.874 | 12.217 |
| S | 8.263 | 10.978 |
| SW | 8.933 | 12.342 |
| W | 8.6 | 11.656 |
| NW | 8.916 | 12.32 |

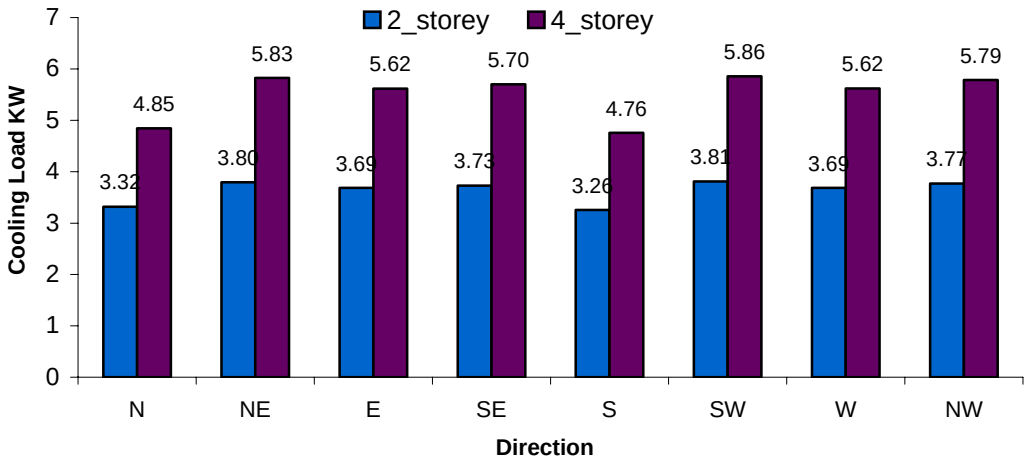


*Figure 3 Histogram for cooling load (kw) for LIG houses*

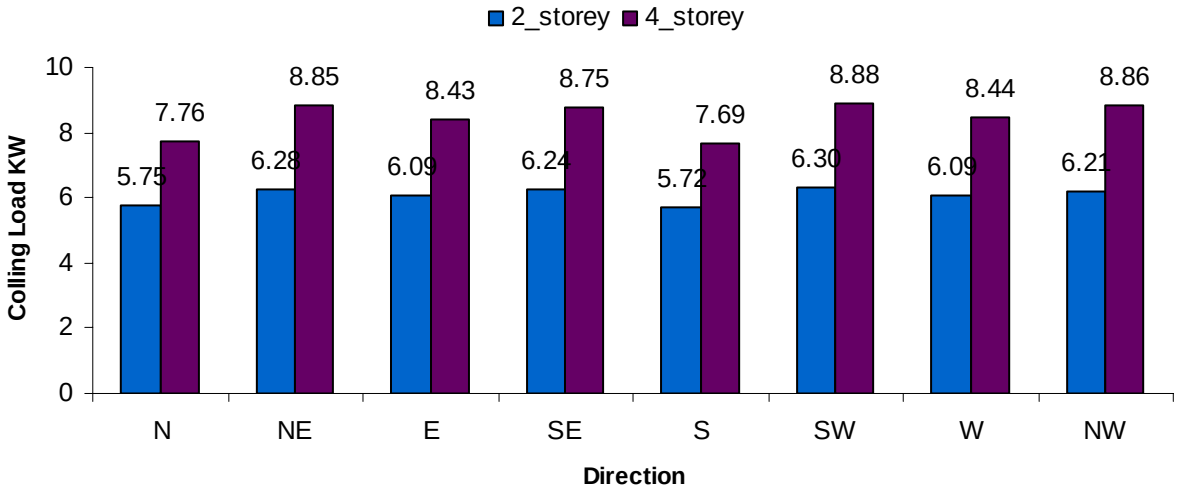


*Figure 4 Histogram for cooling load(kw) for MIG houses.*

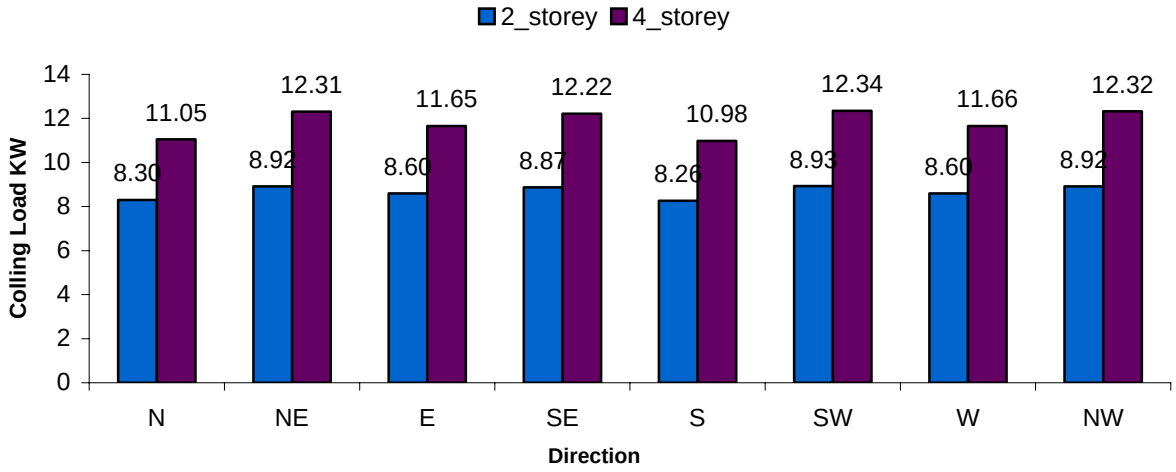


*Figure 5 Histogram for cooling load(kw) for HIG houses.*

## 4. Planning Patterns & Land Uses

Planning pattern at city level may be taken as an out come of major road patterns i.e. linear, grid, radial or a combination of these. At a small settlement level-planning pattern in general is the disposition of various buildings, in a locality in different fashion. This is the type of development in terms of height, number of storeyes and orientation of building blocks. The height or number of storeyes play an important role in conserving energy because in a multi-storeyed building more number of floors are in shade. The top floor can be provided with proper insulation. Placing the buildings with respect to each other in a space in terms of distances and directions is also very important because of various patterns of shadows displayed on the opposite or side buildings. Orientation also plays a role as north & south surfaces get negligible quantity of sunrays.

The land use is a direct result of type of development or planning pattern. As we go higher we consume less space on ground and we reduces the land area for a particular land use like residential and get more open area as a more green/open land use for recreational activities i.e. parks, playgrounds, landscaping etc. for a better environment.

The distances and direction becomes significance because in a particular direction the building consumes less energy as compared to other direction. Further the distance & direction changes the shadow pattern of the blocks and the advantage of the shadows of higher buildings can be taken on the other buildings if higher blocks are placed in a fashion giving maximum shadow on the other blocks.


1. Shops
2. Primary school
3. Nursery school
4. LIG quarters
5. MIG quarters
6. HIG quarters

*Figure 6 Layout plan.*

## 5. Discussions and Findings

The results of the studies through temperature simulation curves drawn using TRNSYS for 22nd June indicate that orientation having lo nger sides on E-W direction is the best for energy considerations. So the orientation of the blocks of a building should be with E-W as longer side and facing north or south. The results for cooling load calculations for a LIG cluster planned in a traditional fashion of four storeyed development having 64 houses required a load of 40.78 KW while a cluster of similar houses planned in the proposed fashion requires a cooling load of 30.05 KW only i.e. a saving of 25% of cooling load. In these calculations the impact of shading has not been considered, if it is also taken in to account a saving of 35-40% of cooling load can be achieved easily. Shadow pattern studies show that maximum shadow on the buildings can be obtained on east & west surfaces placed against each other. This indicates that the surfaces of the building facing east and west should be put closer to each other to get the maximum advantage of the shadow. On north and south faces of the buildings there is hardly any shadow of opposite buildings. The shadows on south east & south west direction of blocks are generally thrown from the side blocks placed at an angular position on south side.

Further the higher blocks of buildings / residences can be put on southern side of the other buildings so that advantage of the shadow of these blocks from movement of sun from east to west can be taken on the southern side by the blocks situated at angular position i.e. blocks which are on the E / W sides of the immediate north side blocks. For example, if we take a cluster of houses (figure.7) as described above having six blocks in two rows A & B. Blocks of row B on south side are higher then blocks of row A on north.

The block No.5 is situated on southern side of blocks No. 1&3 of row A at angular position and both the blocks will get the advantage of shadow of block No. 5 on south. Similarly, the blocks No. 2&4 on north side would get the advantage of the shadow of south side block No. 6 which is higher and placed at an angular position. Now in this cluster of 6 blocks practically every critical side having undesirable heat gains is protected except the west and south-west sides of blocks No. 1&5 which can be taken care of by providing suitable landscaping / planting of trees.

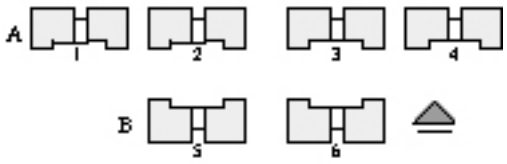


*Figure 7 Block layout.*

## 6. Conclusions

India is at a threshold of overall development including its economic and physical development. Physical developments include the design and planning of buildings and settlements where lot of energy is required as maintenance and in the process of material development. By proper planning and design energy of the order of 40 percent or more can be saved easily using proper specifications and orienting the building blocks in suitable direction. Study for Delhi region shows that if residential blocks are placed in east –west direction with 15 to 20 degree tilt on north side, the advantage of sun and air movement taken together and providing some insulation in roof finish can save the energy bill upto 35- 40 percent. This saving can further be increased if southern side blocks in the layout are taken of more height than northern side blocks which may provide shadow on northern side low height blocks with movement of sun from east to west. Thus we can contribute in achieving the broad objective of global sustainability by way of planning and design of buildings.

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