



## M2-Urban and Regional Planning UE8 Research training



### Sustainable Urban Energy in Existing Urban Pattern

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#### ABSTRACT

The densification of existing urban pattern seems to be better solution for the present energy crisis. But, this paper investigates about the urban form has a role in accessing renewable energy (solar). It under gone a literature review about the similar researches and a case study approach for an existing urban pattern. From the analysis it demonstrates that the urban form has more influence in getting solar energy than the general densification. It suggests that, for increasing building density without compromising the solar energy access, the exposed surface area also mutually increased with the building density.

#### 1. Introduction

At present more than half of the world population lives in the urban areas, the urban seems like an economical growth point for its countries development. The level of urbanisation in all part of the world is still under progress and in some places it is rapid urbanisation. Urban development is inevitable and essential. In the other hand urbanisation is major reason for the green gases emission, consumption of non-renewable energy, ecological decays, poor quality of life etc, so it leads the urban area us unsustainable in economical, social and environmental.

Always there was a say “Urban areas are economical engines”, yes urban areas are economical engines, but this engine requires more energy to run its buildings, transportation and services, it consumes more energy (renewable and non renewable) emits green house gases and pollutes the environment. Because of the emissions the air quality declined (poor quality of life), it causes the urban sprawl (poor quality of life is also one reason for urban sprawl). Then providing the service to the sprawl areas again it consumes energy and leads to more carbon emission.

So managing this scenario, there were several solutions founded, in this important measure to reduce the energy consumption and GHG emissions are densification of existing urban area and compact development for the future development, it is in macro level. At micro level building should follow the thermal regulation and built the low energy consuming new buildings. Densification of existing urban area involves various steps to adapt, but the prior purpose is to reduce the energy consumption and achieve energy sustainability. For achieving sustainable energy does the urban form has role in getting renewable energy (solar energy)? If it is yes, then existing urban pattern relation to the solar radiation examined, after building densification may processed.

Aim is to Study the possibility of achieving energy sustainability in the existing urban pattern in the context of solar radiation. So this paper analyse firstly urban form and its relation of accessing solar energy. Secondly that it examines the densification really meet the purpose of getting access the renewable energy to achieve energy sustainability or not. Hypothesis is: (An urban form plays an important role in solar radiation than Architectural shapes).

## 2. Methodology

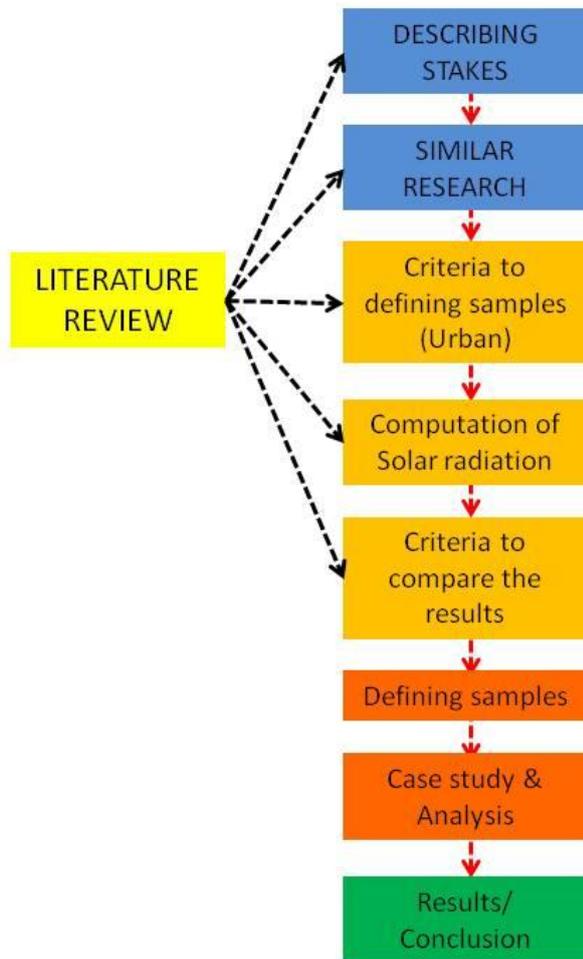


Table 1. Methodology

## 3. Literature review

### 3.1 Describing stakes

#### 3.1.1 Sustainability

There are several definition for sustainability, some important definitions are

- “Sustainable development is development that meets the needs of the present without compromising the ability of future generations to meet their own needs.” WECD, 1987).
- Sustainable development is concerned with the development of a society where the costs of development are not transferred to future generations, or at least an attempt is made to compensate for such costs. (Pearce 1993).
- Sustainability is the capacity to endure. For humans, sustainability is the long-term

maintenance of responsibility, which has environmental, economic, and social dimensions, and encompasses the concept of stewardship, the responsible management of resource use. (Wikipedia)

A universally accepted definition of sustainability remains elusive because it is expected to achieve many things. On the one hand it needs to be factual and scientific, a clear statement of a specific “destination”. The simple definition "sustainability is improving the quality of human life while living within the carrying capacity of supporting eco-systems", [1] though vague, conveys the idea of sustainability having quantifiable limits. But sustainability is also a call to action, a task in progress or “journey” and therefore a political process, so some definitions set out common goals and values. [2] The Earth Charter [3] speaks of “a sustainable global society founded on respect for nature, universal human rights, economic justice, and a culture of peace.”

#### 3.1.2 Sustainable Urban Planning

Urban planning that optimizes the use of the built environment, transportation system, energy, water and land, while aiming to minimize the negative impact of the community on the natural environment. Sustainable urban development may be defined as a process of synergetic integration and co-evolution among the great subsystems making up a city (economic, social, physical and environmental), which guarantees the local population a non-decreasing level of wellbeing in the long term, without compromising the possibilities of development of surrounding areas and contributing by this towards reducing the harmful effects of development on the biosphere. Sustainable urban development: definition and reasons for a research programme- Roberto camagni

#### 3.1.3 Sustainable energy

Energy efficiency and renewable energy are said to be the twin pillars of sustainable energy. Some ways in which sustainable energy has been defined are:

"Effectively, the provision of energy such that it meets the needs of the present without compromising the ability of future generations to meet their own needs. ...Sustainable Energy has two key components: renewable energy and energy efficiency." – Renewable Energy and Efficiency Partnership (British)

"Dynamic harmony between equitable availability of energy-intensive goods and services to all people and the preservation of the earth for future generations." And, "the solution will lie in finding sustainable energy sources and more efficient means of converting and utilizing energy." – Sustainable energy by J. W. Tester, et al., from MIT Press.

"Any energy generation, efficiency & conservation source where: Resources are available to enable massive scaling to become a significant portion of energy generation, long term, preferably 100 years.." – Invest, a green technology non-profit organization.

"Energy which is replenishable within a human lifetime and causes no long-term damage to the environment." – Jamaica Sustainable Development Network.

### 3.1.4 Solar energy

Energy from the sun that is converted into thermal or electrical energy; "the amount of energy falling on the earth is given by the solar constant, but very little use has been made of solar energy"-[wordnetweb.princeton.edu/perl/webwn](http://wordnetweb.princeton.edu/perl/webwn)

### 3.1.5 Building space heating

Heating of rooms within buildings.

### 3.1.6 Passive solar heating

A building can be designed to provide natural heating from the sun's energy. A well-designed building can capture heat in the winter and minimize it in the summer by using heat absorbing building materials and positioning windows and shade structures where they will absorb or reflect the desired amount of heat from the sun.

### 3.1.7 Urban form

Urban form can be defined as the spatial pattern of human activities (Anderson et al., 1996) at a certain

point in time. In a general sense, it can be classified into three categories: density, diversity and spatial-structure pattern. The spatial structure of a metropolitan area, possibly defined as the overall shape, may characterise such land use phenomena as monocentric versus polycentric forms, centralised versus decentralised patterns and continuous versus discontinuous developments. In a broader sense, urban form may involve design category, such as block or site design (Cervero and Kockelman, 1997). In addition to the above land use characteristics, urban form, in a still broader sense, may concern transport spatial structure such as miles of expressway. Urban form can be viewed from various geographical scales and classified into such levels as metropolitan area, city and neighbourhood. The reason for this classification is twofold. First, some urban form variables operate only at certain levels, such as the jobs –housing balance variable.

Secondly, urban form variables (such as density) may carry different meanings at different levels and may differently affect human activities, such as travel behaviour. Because far less research and knowledge exist on urban form at the metropolitan level than at intermediate and low geographical levels, this research primarily focuses on metropolitan forms

Urban form is a term used to describe the physical elements within a city. It refers to the arrangement, function and aesthetic qualities of the design of buildings and streets, which overlay the land use and transport system (Mead et al, 2006, p110). [4].

From these definitions, those relates to the spatial structure of the urban area, which denotes the shapes of the streets, building heights, plot coverage, open spaces etc will be taken in to the account on this study.

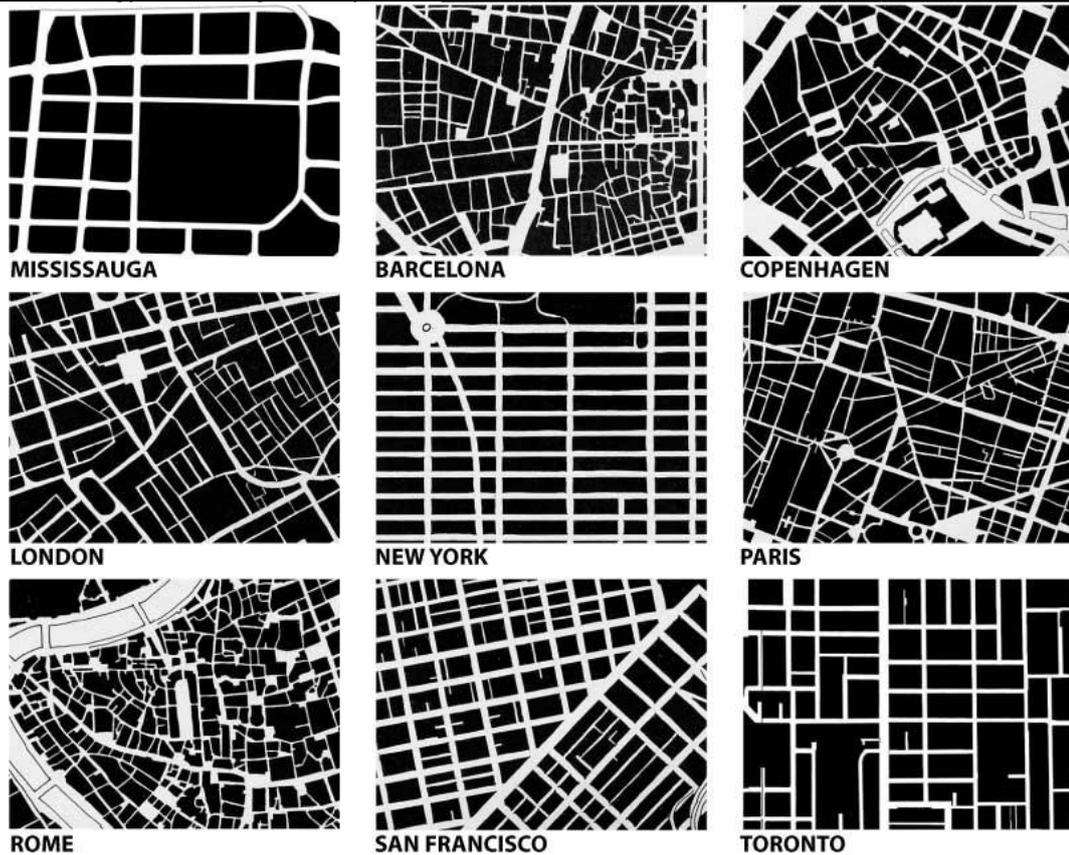


Figure 1: Comparison of world cities urban forms [5]

### 3.1.8 Urban compaction movement

Urban sprawl has become a global phenomenon, with the growth of cities across the globe reaching unprecedented standards in recent decades. Cities have expanded to such a degree that they are becoming unmanageable and inefficient in terms of service delivery, travel times for commuters and, in many instances, inequality for many of its residents. The movement has also come about in terms of concerns raised by environmental action groups as the concrete jungle encroaches on nature.

The ‘symptoms’ which led to the identification of unsustainable urban sprawl included a dominance of single family homes in cities, which was linked to the perception of safer and better living environments, especially for the young family raising children. This was and is still to a certain degree being weighed against denser inner city environments, which are more heterogeneous, diverse and vibrant. The connotations for such active more enclosed and dense environments are that they become unhealthy, aesthetically displeasing and dangerous. But on the other hand, more sprawled cities added to longer travelling distances, times and costs, increased levels of pollution and additional costs to consumers and suppliers due to greater distances. This not only impacts on the living areas and environments of people, but also causes economic slumps in the inner

city environments as suppliers follow consumers to places of residence to ensure higher levels of accessibility to their products, also playing on the ‘convenience’ factor for the customers. The inner city experience has become obsolete in many parts of the world due to this residential and economic flight to the suburbs.

In response to these broad issues outlined above, the Compact City Movement has evolved and support for this movement has increased throughout the developed and developing world. “This concept has emerged primarily in response to the widely acknowledged need to find more sustainable models for the towns and cities of the developed world” (Burton, 2000, p1969). A range of definitions has been developed for the idea of the ‘Compact City’ but these entire have the same gist of relatively high-density, mixed use developments, which promote and enhance efficient public transport systems and increase the quality of life of residents in cities across the world.

This process of achieving urban compaction usually involves intensification of activities, consolidation of activities and uses and the densification of strategic residential locations, which usually adds to intensification and consolidation of activities. These activities also usually involve the re-use of brown

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field land parcels, the more intensive use and re-use of existing urban buildings, infill development and increases in residential densification in new and existing buildings where alterations and additions can occur. (Harrison, 2003; Burton, 2000; Oelofse, 2003; Todes, 2003; Irurah & Boshoff, 2003).

Across the globe, the town planning response to these strong ideas of urban compaction has been the introduction of 'planning tools' such as urban growth boundaries, infill developments, incentives for densification, urban corridors, strategic transport planning and strategic infrastructure investment programmes. Many of these ideas have been incorporated into local planning initiatives.

The movement towards more compact cities is driven by the need for more sustainable human environments and urban sustainability. The focus has not only fallen on the urban morphology but also on the aspect of social equality, especially in the developing world. (However, this is also applicable to the developed world and its deep division of social classes).[12]

#### 3.1.9 Urban densification

Urban densification is increase the number of people or buildings or activities or habitation or facilities or all in the existing per unit area of urban space. Mostly the densification means residential densification. Residential densification has many connotations – mostly negative in nature. The negative connotations usually associated with it are that high density creates 'bad' living environments. This is accompanied by some misconceptions, as outlined in the Guideline Document for Higher Density Residential Development, prepared for the Housing Department of the EMM (p10, 2005):[12]

- Low densities result in higher quality living environments, whereas higher densities result in less desirable, low quality urban environments.
- Higher density environments are associated with limited housing options, in particular high-rise, cramped buildings.
- High densities are associated with low-income groups and low densities with high-income groups.

Issues to be considered in the application of density policy are summarised as follows:[12]

- The cost, availability and location of land
- Transportation and accessibility

- Socio-economic issues (household sizes, lifestyle)
- Environmental considerations
- Cultural issues
- Political position of government (local and national)
- Infrastructure planning (availability)
- Geological Constraints

#### 3.1.10 Urban microclimate

Several authors (Fuggle and Oke, 1970, Oke, 1976, Givoni, 1989) have investigated the urban climate and, particularly, the heat island effect within the urban dome. Less explored has been the urban microclimate, characterising the urban canopy, i.e., the layer of atmosphere enclosed within the street canyons up to the buildings' roof height (Oke, 1981) The form and layout of buildings as well as the streets' section and orientation, and the size and shape of all urban open areas, affect mainly the urban canopy microclimate. Hence, more investigation is needed on this field in order to evaluate the interactions between the geometric characteristics of the urban texture and the most important microclimate factors: solar radiation and air movement.[6]

#### 3.1.11 Solar radiation

Solar radiation interacts with the urban fabric at various levels. Canyon geometry of streets and building's shapes and layout induce different shading patterns. In addition, surface physical characteristics (material, colour, texture) affect solar absorption, and differing spatial and time solar exposures cause differential surface temperatures and, therefore, generate convective building-street thermal exchanges (Givoni, 1989). Since ancient time, Mediterranean civilisations laid out their cities in accordance with solar orientation and used surface colours and materials to maintain indoor comfort conditions. The "cul-de-sac" street layout, typical of the Muslim cultures and diffused in the whole southern Mediterranean area, allows for deep shadowing both at street level and on the buildings' facades. This characteristic, together with the white colour of building, provides for optimum cooling of indoor spaces (Scudo, 1997). Such an aggregated urban pattern characterises most of the European coastal and hill towns founded in the Middle Age, even though that feature was originated more for defensive purposes and economy of space rather than for climatic reasons.

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Building solar access within the urban fabric depends on both spatial and temporal factors. Spatially (synchronously), it depends on the ratio of the street width to the building height, while temporally (diachronically), is affected by the layout of buildings within the streets' grid and, therefore - in the case of a normal pattern layout - on the geographic orientation of the grid. Most of the European cities' parts developed after the Middle Age as well as the Jeffersonian American towns were laid out following a normal pattern. In cities' normal layout based on a Roman grid, i.e., with the main axes (cardo and decumanus) oriented approximately as the compass axes, the degree of time solar exposure of buildings depends mainly on the direction along which they are located. A more balanced solar exposure of buildings, less direction dependent, is obtained by a diagonally oriented normal pattern layout such as the Spanish one.

The assessment of the degree of insolation for a given urban fabric can be easily done, particularly in cities with a normal pattern layout, using graphical tools such as solar charts, shading mask protractors, and P.E.G. shading profiles. Calculating the solar radiation incident on the whole surface of a given urban fabric as well as its effect on the surface temperatures and the convective exchange rates is much more complex, and requires simulation tools not yet available for urban microclimate analyses.

#### 3.1.12 Microclimate and urban planning

The fast and often unchecked urban sprawl characterising the post II World War period, has nullified any attention to the connection - which was explicitly or implicitly present in the Modern Movement and in the pre-modern era - between urban form and microclimate. The increase of the urbanised world population, the decrease of land available for building, and the deterioration of the ancient building stock, are all factors which have posed a serious challenge to a climate conscious urban planning, particularly in the mostly densely populated metropolitan areas of the world. Economically profitable land use and maximum built-to-ground exploitation, are the far highest priorities for urban developers rather than solar and wind access or protection.

The new global climate change crisis might have, hopefully, a positive effect also on the possibility of re-founding urban planning according to a new climate- and energy-conscious approach.

“The global effort for sustainability will be won or lost in the world's cities where urban design may

influence over 70% of people's ecological footprint.” (Wackernagel-2006)

#### 3.1.13 Compacity: Impact of the shape factor

According to Ratti et al. (2005), the following non-dimensional quantity is an interesting descriptor of urban texture:

$$C = \sum_{\text{buildings}} \frac{A_{\text{ext}}}{V^{2/3}} \quad [1]$$

Where C is often called the compacity;  $A_{\text{ext}}$  is the external surface area; and V is the building volume. The author prefers the term 'shape factor' to 'compacity' because the higher the value of C, the less the building fabric is compact in the intuitive sense. C defines the amount of exposed building envelope per unit volume and can be used in a number of different applications. Its relevance to the energy consumption of buildings, however, must be considered carefully.

Minimizing heat losses during the winter requires minimization of the surface-to-volume ratio, but this implies a reduction of the building envelope exposed to the outside environment, thus reducing the availability of daylight and sunlight and increasing energy consumption for artificial lighting and natural ventilation. The higher the shape factor, the higher the energy needs for heating in colder climates [7].

### 3.2 Similar research/ Criteria for sampling/ solar computation and analysis.

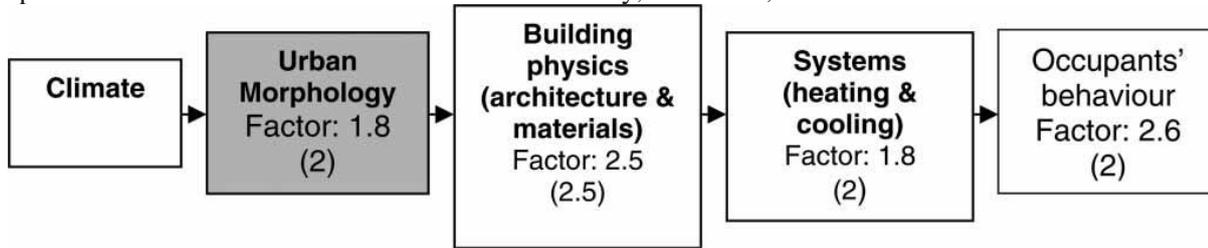
#### 3.2.1 Energy loads, CO2 emissions and building stocks: morphologies, typologies, energy systems and behaviour- Serge Salat

This research says that the existing building stocks are major energy consumers and CO2 emitters, depending on various factors namely urban morphology, architectural archetypes, construction technologies, energy systems and inhabitant behaviour. It is a large scale case study based on 96000 buildings in Paris, France. is the subject of detailed analysis of the existing residential building stock by comparing some environmental metrics of Paris's urban fabric with thermal energy consumption in buildings. The environmental metrics, such as building shape factor and passive volume (for natural ventilation and day lighting), are functions of urban morphology. This comparison of urban forms and heating energy consumption reveals some impacts of urban morphology and building typology on the energy efficiency in the different zones of Paris. The energy efficiency and CO2 emissions related to heating mode and inhabitant behaviour are separated from those linked to urban form and construction

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technology. Thus, a balanced view of the complex impacts of morphologies, typologies, energy systems, and inhabitant behaviour on energy loads and CO<sub>2</sub> emissions is presented, which allows for the optimization of urban form in terms of density,

building configuration, and morphology. Similar large-scale simulations can analyse urban form and the mix of building stock as well as the interaction of increased equipment efficiency, alternative energy mix, and inhabitant behaviour.



From this paper analysis on urban morphology, will be taken in to an account. The factors considered for energy efficiency is efficiency of the urban form and in particular its density as well as the set of parameters calculated below for three morphologies in Paris. Criteria taken for sampling is period of construction, that is traditional courtyard type (18-19<sup>th</sup> C), Modern fabric (1918-1980), Contemporary courtyard (1980- 2000) figure2.

	18-19 <sup>th</sup> C Traditional courtyard	1918-1980 Modernist fabric	1980-2000 Contemporary courtyard
	<ul style="list-style-type: none"> <li>•Very high building density</li> <li>•High FAR and high block density</li> <li>•Good ratio <math>V_p/V_t</math></li> <li>•Bad solar admittance</li> </ul>	<ul style="list-style-type: none"> <li>•High solar admittance, bad shape factor and low ratio <math>V_p/V_t</math></li> <li>•Very low building density, FAR and block density</li> </ul>	<ul style="list-style-type: none"> <li>•Medium building density</li> <li>•Medium block density and ratio <math>V_p/V_t</math></li> </ul>
Heating Energy density due to factors of urban morphology (GJ / year / m <sup>2</sup> )			
	0,21 GJ/year/m <sup>2</sup>	0,36 GJ/year/m <sup>2</sup>	0,20 GJ/year/m <sup>2</sup>

Figure2. Urban morphology and energy consumption for three samples of urban fabric in Paris. Due to urban morphology, the modernist texture consumes 1.8 times more energy for heating than contemporary or ancient urban block.

The indicators adopted mainly here is

- Impact of the shape factor ( compacity)
- Impact of passive volume

The higher the shape factor, the higher the energy needs for heating in colder climates.

In the comparison below of three urban textures, the value of the shape factor increases from the 18<sup>th</sup> to the 20<sup>th</sup> century. Traditional Paris courtyard buildings are more energy efficient due to their shape factor than modernist textures. The passive volume of Paris is much higher than that of high-rise modernist developments, and thus potentially more energy efficient.

### 3.2.2 Energy requirements of characteristic urban blocks- Mindjid Maïzia, Claire Sèze, Sébastien Berge, Jacques Teller, Sigrid Reiter, Raphael Ménard

The present article analyses energy requirements for heating and cooling typical urban blocks in the Region Ile de France. It provides a contrasted view on the incidence of compactness and urban organisation upon energy requirements and potential solar gains. From this article, the method adopted for sampling is analysed. Firstly from its literature Building simulation models By Steemers , the objective was to establish the relations between urban form and energy along with more detailed characteristics of buildings (thermal conductivity of external walls, window

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percentage etc.). The analysis was based on three geometric parameters: building depth, street prospect and urban compactness. Secondly, the urban blocks classifications by following parameters.

- ground floor area of buildings
- average height of buildings
- surface of external walls
- perimeter of the facade

Further

- discontinuous collective housing
- continuous collective housing
- dense individual housing and
- Dispersed individual housing.

Urban blocks which receive most solar gains (between 100 and 139.03kWh/m<sup>2</sup>/an) are dispersed individual housing types. It means that retrofitting existing dispersed individual housing blocks may be interesting for warmer climates provided that the potential for solar gains is effectively valorised. Very dense urban blocks perform quite badly in terms of potential solar gains.

In analysis author highlights that, for existing urban blocks, the benefits of compactness are much more limited than what is generally expected by policy makers. This is also true for potential energy gains over facades. Effects of compactness may be much more important for new buildings and new urban development's where building orientations can be optimised for solar gains though.

#### 3.2.3 Urban Form, Density and Solar Potential - Vicky Cheng, Koen Steemers, Marylene Montavon and Raphael Compagnon (2006)

This study comprises solar simulation of eighteen generic models; each represents a particular combination of built form and density. This paper examines the relationships between built forms, density and solar potential, with reference to three design criteria i.e. openness at ground level, daylight factor on building facade and PV potential on building envelope. The result shows the different effects of horizontal and vertical randomness on urban solar potential and it also reveals the interrelation between randomness, plot ratio and site coverage, which can provide helpful insights for planning solar cities.

The study was initiated by a research project concerning the sustainable urban design for Sao Paulo, Brazil. In the earlier stage of the project, the authors conducted a study to investigate the diverse influences of built density on urban daylight access and solar potential. The findings suggested that the two manifestations of density i.e. plot ratio and site coverage; do have different effects on the potential of urban solar resources. This research systematically and comprehensively evaluates the relationships between urban built form, density and solar potential with solar simulation of eighteen generic models.

Eighteen generic models representing a range of built forms and densities, compared for daylight performance and solar potential and these models can be categorized into four different built forms, three classes of plot ratio and two classes of site coverage. The four built forms correspond to different horizontal and vertical layouts, either uniform or random as illustrated in Figure 3. The form of a model is denoted by an expression (H, V), where H represents the horizontal layout and V represents the vertical layout. Hence, the four categories of built forms are: (uniform, uniform), (uniform, random), (random, uniform) and (random, random).

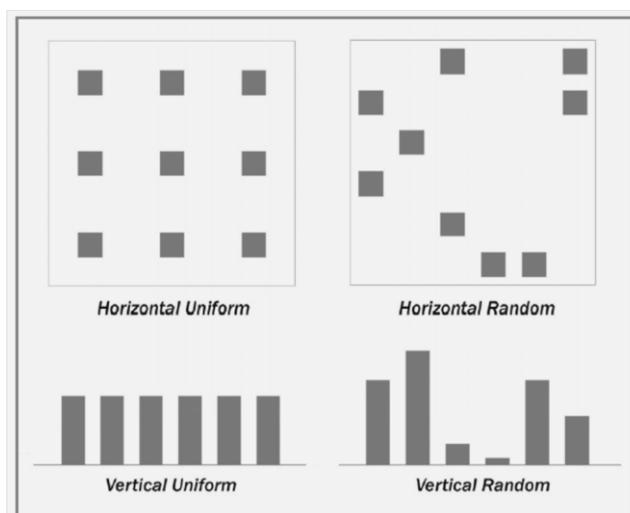


Figure3. Horizontal and vertical urban layouts

Densities are examined in two ways, i.e. plot ratio and site coverage: plot ratio is defined as the ratio of total floor area to site area, and site coverage is the ratio of building footprints to site area. Plot ratios representing three classes of density have been chosen for the study, and they are 1.4 for low density, 3.6 for medium density and 7.2 for high density.

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There are three indicators analysed in the study are.

- Sky view factor (is a measure of openness of a surface: a SVF of 1 means an unobstructed view of the sky and a SVF of 0 means a completely obstructed view of the sky.)
- Day light factors (daylight availability under average annual sky conditions)
- Solar potential (Solar potential for photovoltaic systems (PV), threshold for PV as set as  $800 \text{ kWh/m}^2$  for building facade and  $1000 \text{ kWh/m}^2$  for roof)

It suggests that, High site coverage is in general not preferable as it undermines daylight and solar potential on ground and building facade, however, the extensive roof surface provided by high site coverage development is a major source for high level solar radiation which makes it advantageous for PV application.

The significant improvement can be achieved, in terms of daylight and solar potential, by simply rearranging the layout of building blocks without reducing the amount of usable floor area.

Comparisons between good layouts at high plot ratio and poor layouts at low plot ratio reveal the possibilities to increase usable floor area and at the same time, maintain and even increase daylight and solar potential. The results contrast to the conventional assumption that increasing built density would lead to deterioration of the immediate environment, in relation to solar access and lessening the potential for renewable energy application at the urban scale.

Some of the implications specified report

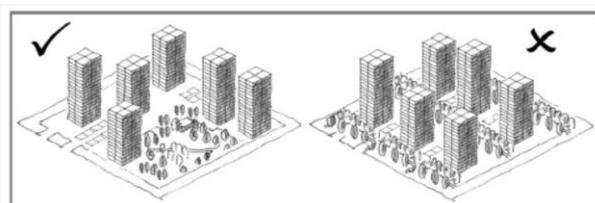


Figure 4: Horizontal randomness is preferable

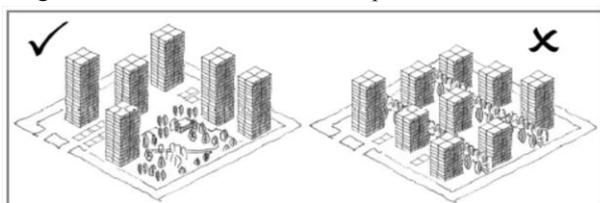


Figure 5: Low site coverage is preferable

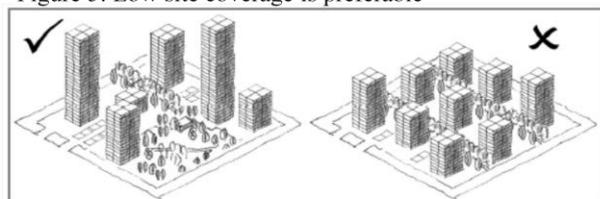


Figure 6: Vertical randomness is preferable

### 3.2.4 Compact cities in a sustainable manner

Vicky Cheng, Koen Steemers, Marylene Montavon and Raphael Compagnon (*2nd International Solar Cities Congress - Oxford 3-6 April 2006*)

In this paper author said about that the densification is generally assumed to exert negative impacts on urban daylight and solar potential, it demonstrates the possibilities to increase usable floor area and plot ratio without undermining the opportunities of daylight and solar applications. It analyse the diverse influences of built density on daylight access and the potential of two solar systems.

Background of this research is the rapid urbanisation and its causes of tremendous pressure on urban development, to cater expanding urban population the densifications seems a inevitable outcome, but increasing density which will lead to deterioration of environment in relation to solar access (day lighting), urban ventilation and accessing urban renewable energy potential. Under this problem, this paper concentrates to obtain a sustainable compact city model in day lighting and solar potential. It compares various theoretical built forms to explore the diverse effects of two different representations of built density i.e. plot ratio and site coverage (ratio of building footprints to site area) on urban daylight and solar potential. It then furthers the discussion by examining the performance of a range of existing building blocks in Luz, a city centre site in Sao Paulo, Brazil.

The study employs computational simulation to model sky view factor, daylight factor and solar potential in both theoretical and real existing urban built forms. Digital elevation modelling (DEM), an image processing of three-dimensional urban texture has been used to predict sky view factor at ground level. It involves first theoretical study and study of existing urban blocks.

In the theoretical study, Models representing three different types of built forms i.e. uniform skyline, pyramid skyline and random skyline are compared for daylight performance and solar potential. Each of the models consists of 25 buildings in a 5x5 square array. Apart from the model array, in order to imitate urban surroundings, two extra rows of buildings are placed along the peripheral; these buildings with random heights resemble the surrounding obstructions.

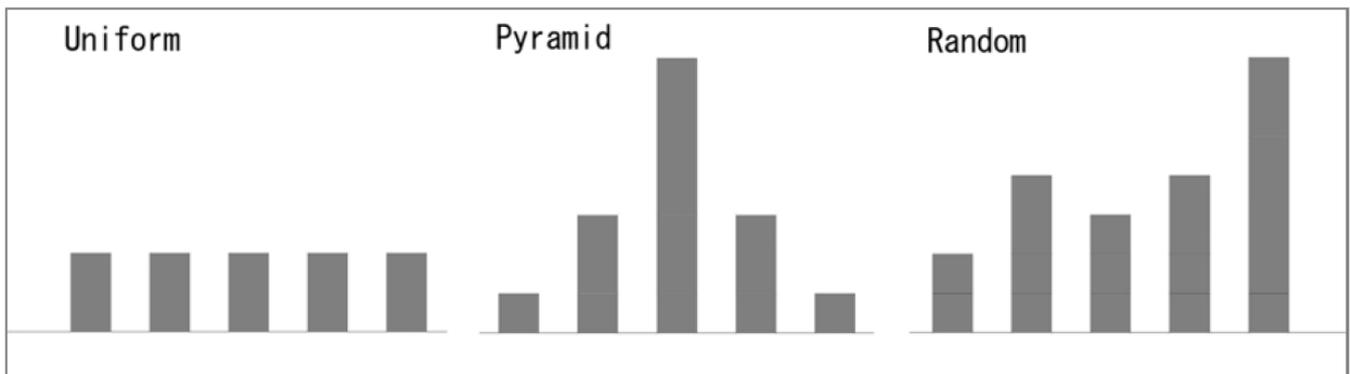


Figure7. Built forms representing different types of skylines

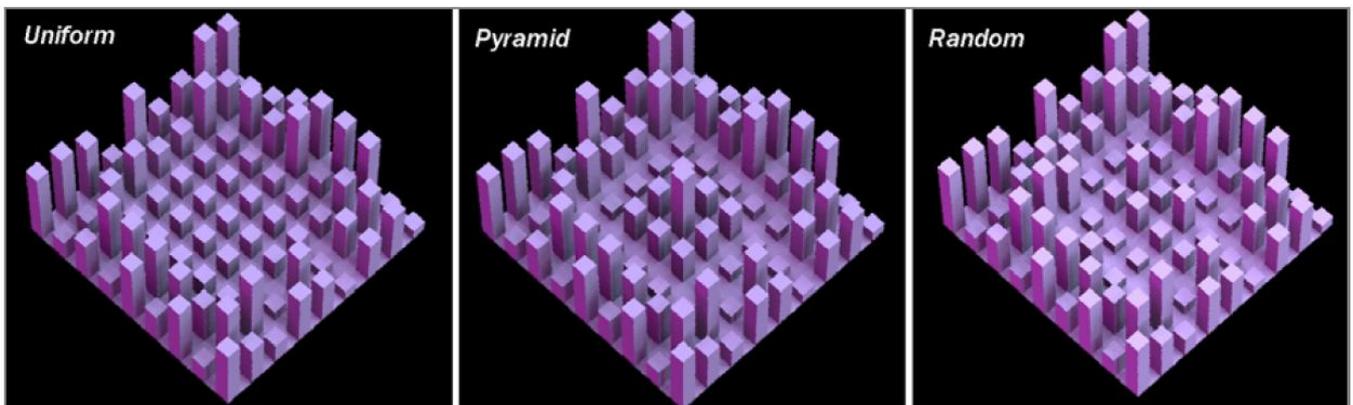


Figure8. Generic models for theoretical studies

#### Inference from the theoretical studies

- Sky view factor: ground level and building envelope, the average SVF in pyramid and random skyline configurations are about 5% and 9% higher than the uniform skyline configuration
- Day light factor: The average daylight factor of uniform, pyramid and random skylines are 0.26, 0.27 and 0.28 respectively, in other words, pyramid and random skylines provide 4% and 8% more daylight than the uniform skyline configuration.
- Solar potential: for thermal collectors (hot water supplies avg. 400kw/m<sup>2</sup>) and

photovoltaic systems (avg. 800kw/m<sup>2</sup>) have been computed for the three skyline configurations. The thermal potential of the uniform, pyramid and random configurations are respectively 16%, 22% and 27%; and the photovoltaic potential are respectively 0%, 1% and 1%.

Studies of the existing urban blocks include 11 urban blocks. These urban blocks represent a range of different built forms from compact high-rise to relatively flat and open layout, which provide a rich urban texture for understanding the influences of built density. Figure 9, shows all the blocks.

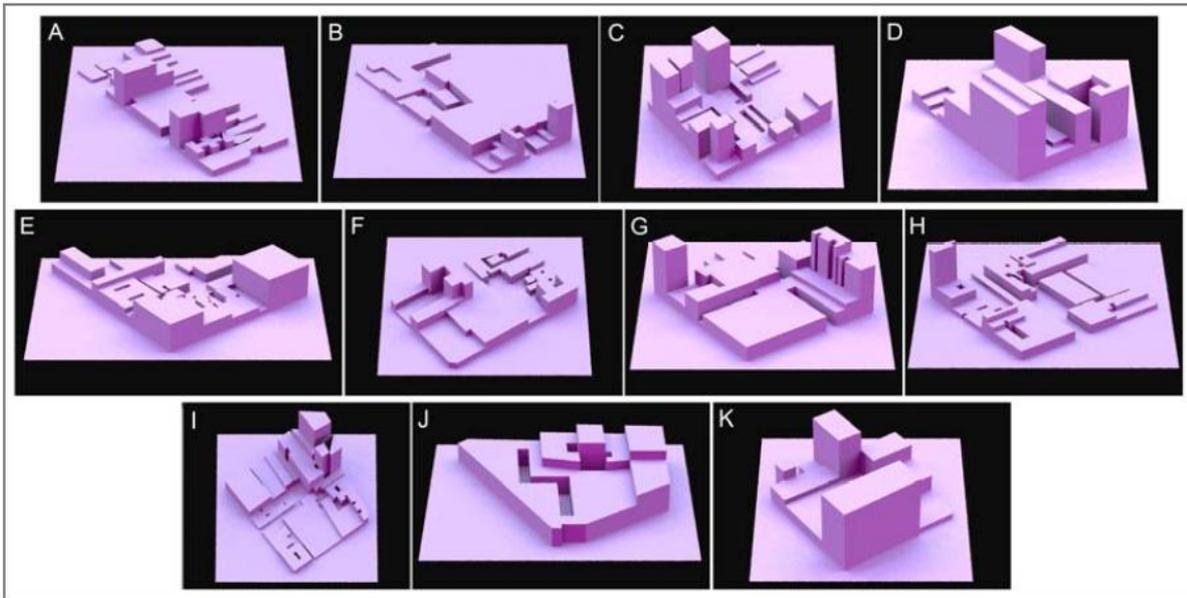


Figure9. Existing urban blocks in Luz, Sao Paulo, Brazil  
 From this models there are several indicators analysed are follows

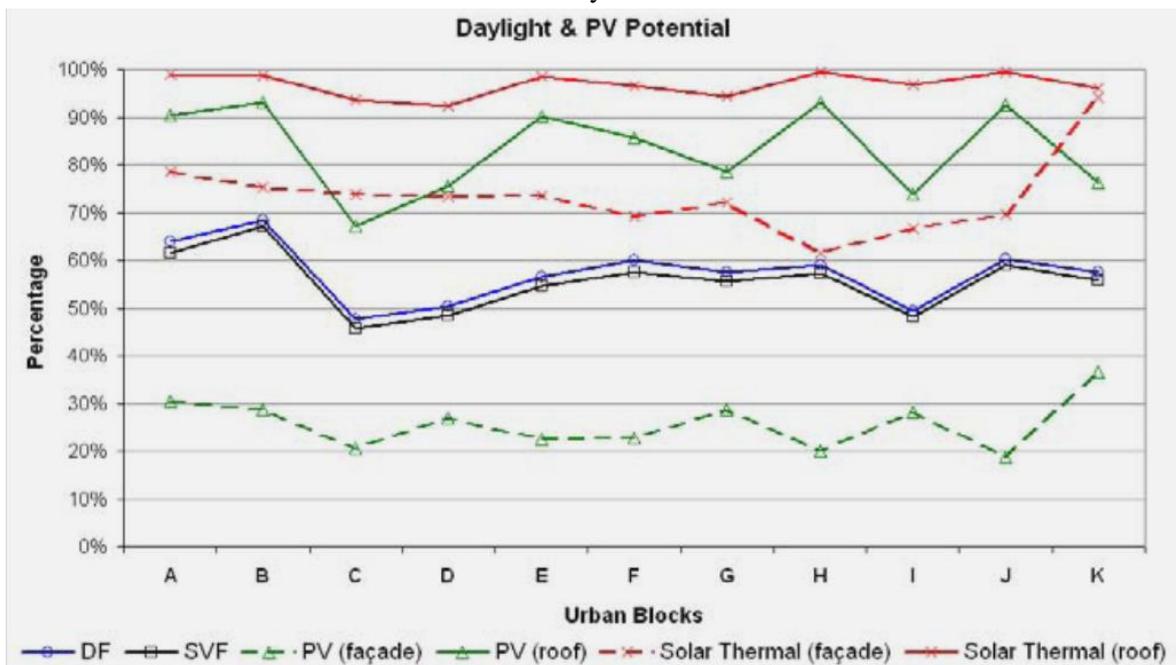


Figure10. Daylight and solar potential of the urban blocks

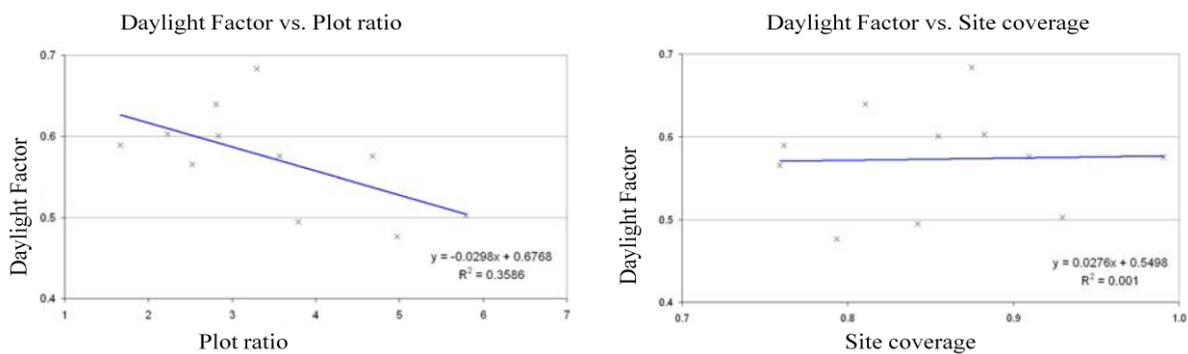


Figure11. Daylight factor and built density.

The result suggests that density is not a better indicator for day lighting factor.

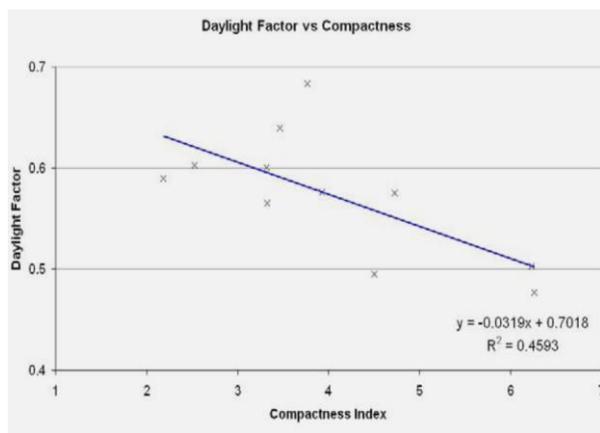


Figure12. Daylight factor and compactness index

The Compactness Index is defined as the ratio of plot ratio to site coverage, in other words, it represents the ratio of total floor area to building footprint i.e. the average number of floors. Figure 12 shows the correlation between compactness index and daylight factor; the result shows good correlation ( $R^2=0.46$ ) and the outcome outperforms that obtained with plot ratio alone.

In the conclusion, the daylight and solar potential of an urban development are primarily determined by the amount of solar radiation that falls on the surfaces. In this sense, there are two parameters i.e. the vertical and horizontal obstruction angles, which could be influential.

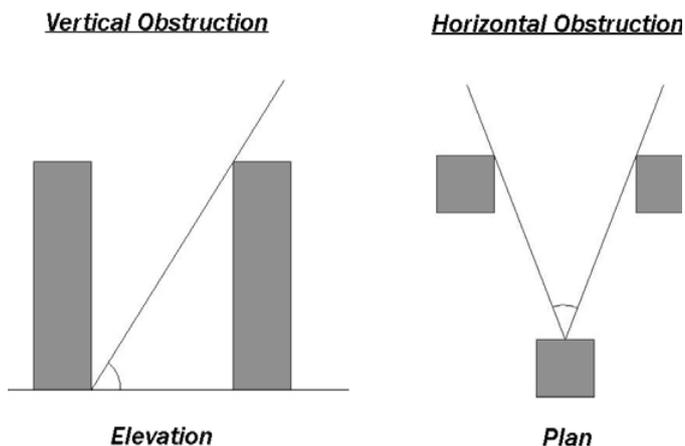


Figure13. Vertical and horizontal obstruction in urban setting

The discussion on skylines, plot ratio and compactness index are more related to vertical obstruction whilst those studies on site coverage and unobstructed façade area are more relevant to horizontal obstruction.

This study shows that varying skyline configuration has better performance than uniform skyline configuration, in terms of daylight access and solar

potential. Furthermore, it suggests that the effect of built density on urban daylight and solar potential is not straightforward. It has been demonstrated in the theoretical studies that, with a simultaneous decrease in site coverage, it is possible to increase the usable floor area and plot ratio without reducing the opportunities of daylight and solar applications. After all, the key message of this paper is that the intention for densification and the concept of sustainability are not mutually exclusive. Given proper urban design and layout, compact cities can be a respectable solution to rapid urbanization.

### 3.2.5 Energy and the city: density, buildings and transport- Koen Steemers

This paper establishes the relative magnitudes of building energy use in comparison to transport, and points out the interrelationships between the two in the context of the cities and of a temperate climate. The main part of the paper assesses the building energy trends and implications of urban form, with a particular reference to the effect of varying density, and presents strategic findings. It calls for continued research and development, particularly in the field of modelling the urban microclimate as a function of design, as well as comfort research with an emphasis on outdoor comfort. Urban microclimate and comfort are the themes of this paper.

This paper made case study at UK, first urban density: transport vs. building energy. In UK the transportation consumes less energy than the buildings.

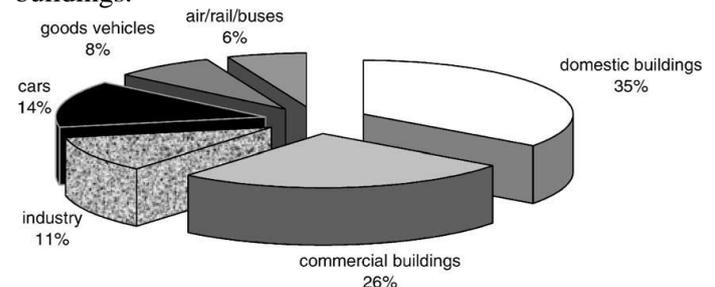


Figure14. Energy use breakdown for London

The energy demand in housing is dominated by space heating, which on average accounts for 60% of the total energy. There are some possible way to reduce this consumption are

- (i) By increasing building depth;
- (ii) By increasing building height or reducing spacing (i.e. changing height: width ratios between buildings);
- (iii) By increasing 'compactness' (e.g. apartments instead of detached housing, where the building depth and height characteristics may theoretically remain unaffected).

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In the urban texture analysis, it analyse the energy performance of buildings is linked to the quality of the urban environment, the LT urban combine analysis tool is adopted (400m X 400m) and some various assumptions made like (detailed characteristics of individual buildings, such as glazing ratio, U-values, systems, etc) primary is urban form. The base-case urban form is altered by adjusting the building heights so as to produce a range of urban densities from half to double the existing. The energy consequences of increasing the average obstruction angles are significant, for example, 108 increase in obstruction results in approximately 10% increase in energy (Fig. 15). For a density range of plot ratios from 1.25:1 to 5:1 the results show that doubling the density typically increases energy consumption by in the order of 25% for this whole section of the city.

The optimising the glazing ratios in response to the level of obstruction reduces the effect, so that doubling the density now results in a 21% increase in energy.

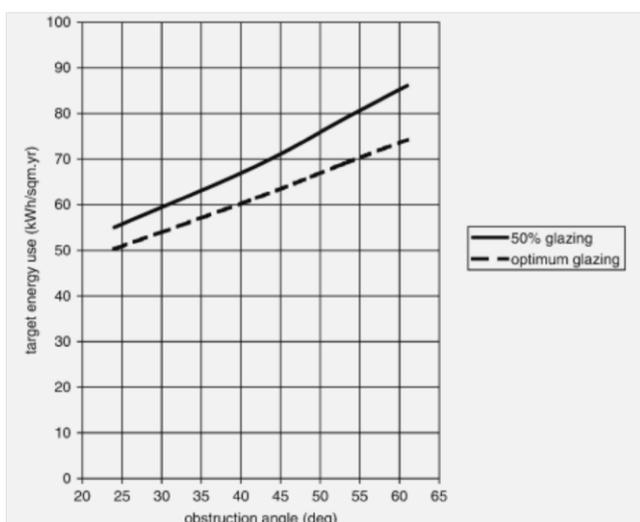


Figure15. Effect of obstruction angle on energy use for naturally ventilated offices on the London site

This highlights those other parameters, at the level of individual buildings, will change the relationship of energy to urban density, and that they should respond to the specific urban context. Glazing ratios in particular as they represent the main interaction between building and climate affect the energy performance and can be ‘optimised’ to minimise energy demand.

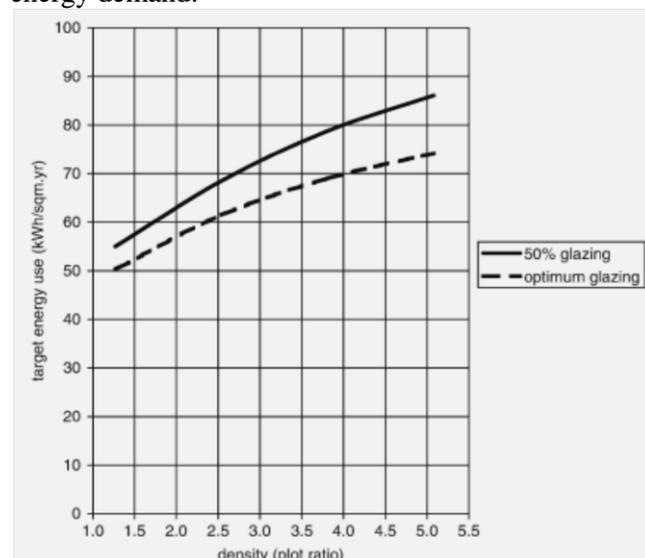


Figure16. Effect of density on energy use for naturally ventilated offices on the London site.

In conclusion the author states that “Towns and cities should be well designed, be more compact and connected, support a range of diverse uses within a sustainable environment which is well integrated with public transport and adaptable to change”.

It is not difficult to agree with this statement and its vision. What is important is to develop the necessary techniques to inform the balance, sequence and implementation of decisions to achieve the desired results.

**3.2.6 Inference from the case study**

Case study 1	Case study 2	Case study 3	Case study 4	Case study 5
Energy loads, CO2 emissions and building stocks: morphologies, typologies, energy systems and behaviour	Energy requirements of characteristic urban blocks	Urban Form, Density and Solar Potential	Compact cities in a sustainable manner	Energy and the city: density, buildings and transport
Context				
Existing buildings are major consumers of energy and (directly or indirectly) CO2 emitters.	Compact urban form’s implication on energy	Rapid urbanisation, un examined state of densification, Plot ratio & plot coverage	Rapid urbanisation, densification leads to deterioration of the environment, in relation to solar access, urban ventilation and less potential for renewable energy in urban scale.	Kenworthy’s curve transport energy Vs density, comparison of building with transport energy in temperate climate.

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Methodology				
Assigning factors. Selecting samples (traditional, modern, contemporary) urban fabric. <i>Indicators</i> <i>Compacity</i> <i>Impact of passive volume</i>	Assigning the samples from the existing urban pattern with the developed criteria's. Analyse the gains of each block's facade and roof.	Eight generic models with categories. Analysis and results of models with the <i>Indicators</i> <i>Sky view factor,</i> <i>Daylight factor, Solar potential.</i> All the findings compared with the existing model.	Three computerised theoretical model for different built forms with same density (only vertical variation) Analysis of the model with the <i>Indicators</i> <i>Sky view factor,</i> <i>Daylight factor, Solar potential.</i> Same analysis is compared with 11-existing models and results were compared	Analyse the energy consumption of different building types (uses) and suggestion for reduced energy consumptions. Urban texture analysis in existing block model adopted with the basic assumptions. Density of the building is increased by varying building heights, with this change in energy consumption is computed in relation to energy losses due to obstruction angle.
Results				
Modernistic urban fabric has higher energy consumption and higher CO2 emission.	Dispersed building type has more solar gain.	Randomness of the buildings block in horizontal, vertical and lower plot coverage is encouraged.	Day light factor and compactness ratio has better co relation with the density. Varying skyline improves the daylight potential.	Authors say better design of city has the value in energy sustainability.
Inference				
Limited samples for the urban fabric.	Analysed only the individual blocks, not with the surrounding blocks. Concentrated on the solar gain relation with facade and roof not with floor area.	In the proposal all the existing buildings are removed and redesigned new block. Implication of the surrounding was not taken into the account.	Selection criteria for existing blocks were not clearly mentioned. Varying skyline will affect the solar potential.	Models developed in the existing urban pattern and also examined with the same. Practical approach.

Table2. Inference from the case study

4. Assumptions and Criteria for Samples.

4.1. Criteria for defining urban form (samples).

There were two factors, seven criteria and two values for defining the samples are.

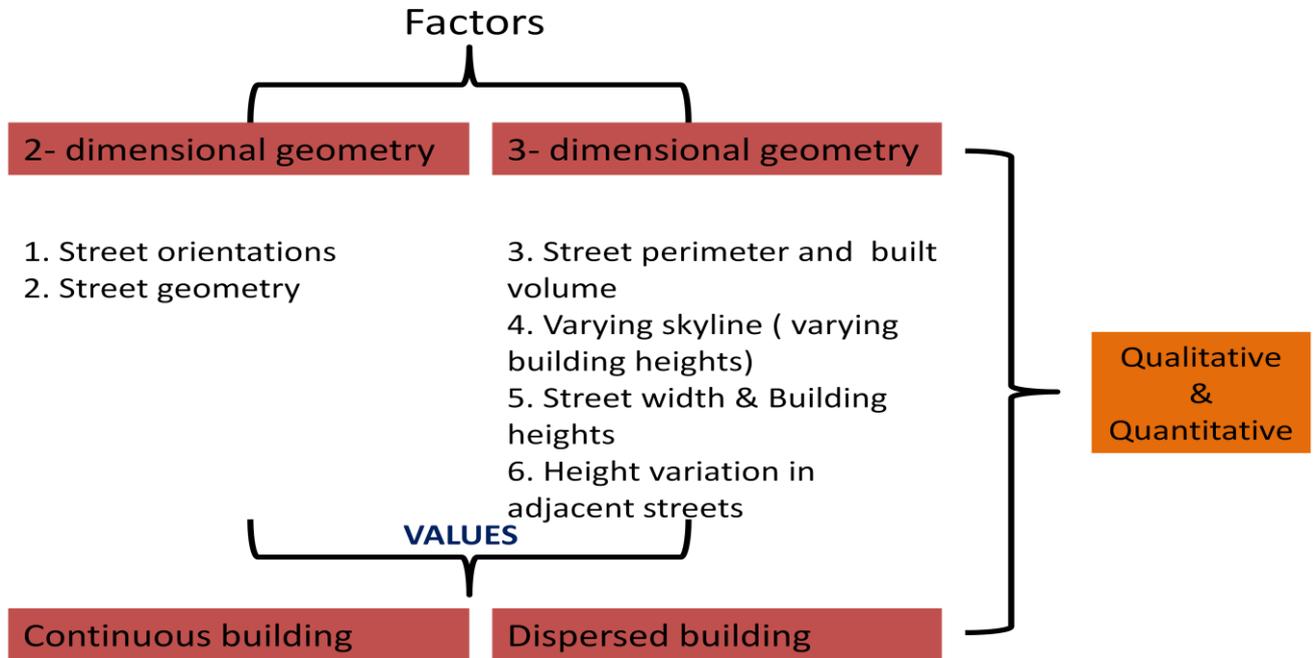


Table2. Criteria for defining urban forms

Criteria1. Street orientation

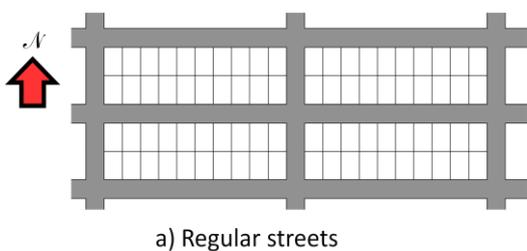


Figure17. a). Regular Street means, orientation of the street based on basic orientation (south, north, east and west).

Figure18. b) Angular streets

b). Angular street means, the street is oriented some angle other than basic orientation.

Criteria2. Street geometry

This criteria is based on geometry of the street normally the streets has a rectangular or square geometry and sometimes irregular geometry, where the geometry of the street has any impact on the solar potential.

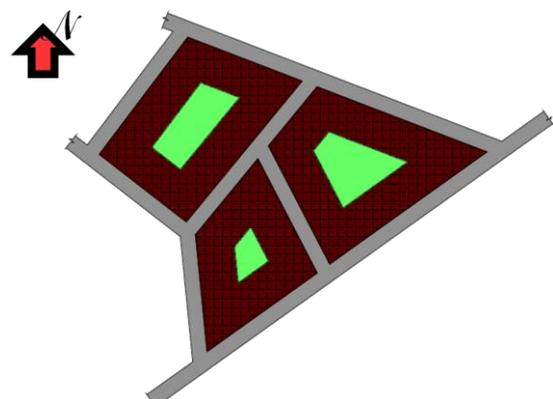
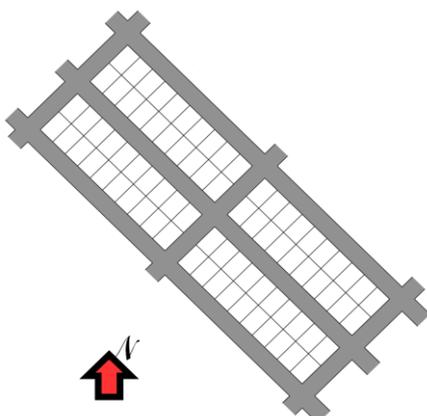


Figure19. a) Irregular street geometry (forms)

**Criteria3. Street area and built volume**

This criterion is based on relationship of street area in to the built volume.

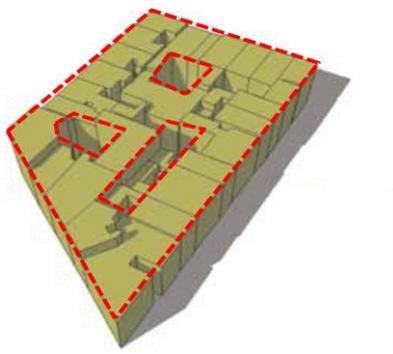


Figure20. Street area and built volume

**Criteria4. Varying skyline within the street**

Varying building heights of the buildings within the street has any impact.

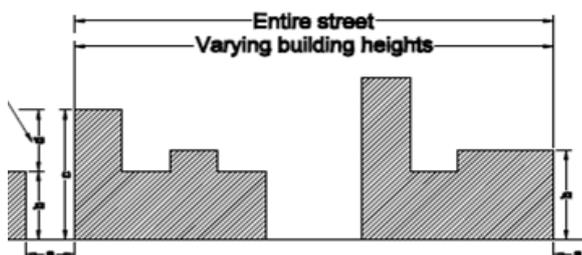
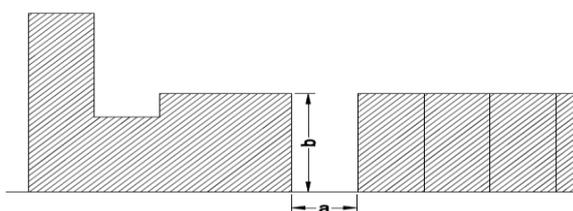


Figure21. Varying skyline within the street

**Criteria5. Street width & Building heights**

This is based the relationship of road width and building heights.

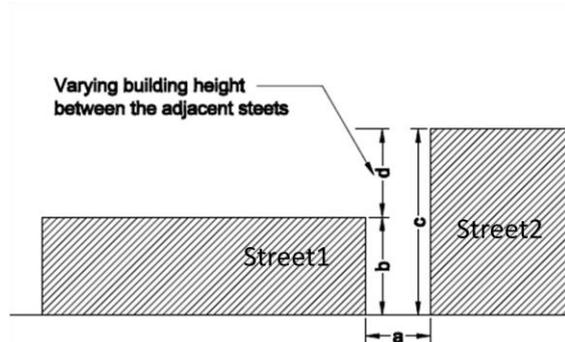


- a= street width
- b= building height of street 1

Figure22. Street width and building height

**Criteria6. Height variation in adjacent street**

Comparing the effect of variation of adjacent streets



- a= street width
- b= building height of street 1
- c= building height of street 2
- d= height variation between the streets

Figure23. Height variation in adjacent streets

**Values for defining the samples**

- Continuous building area
- Dispersed building area

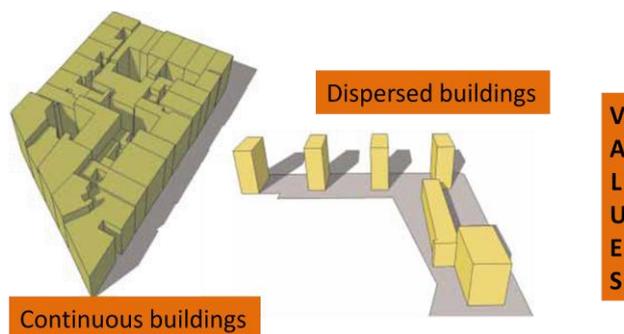


Figure24. Values for defining the samples

**4.2 Computation of Solar radiation**

For computing solar radiation the ecotect software is used for the modeling and analysis.

5. Case study part

5.1. Defining samples

There are seven samples selected in the Tours urban area.

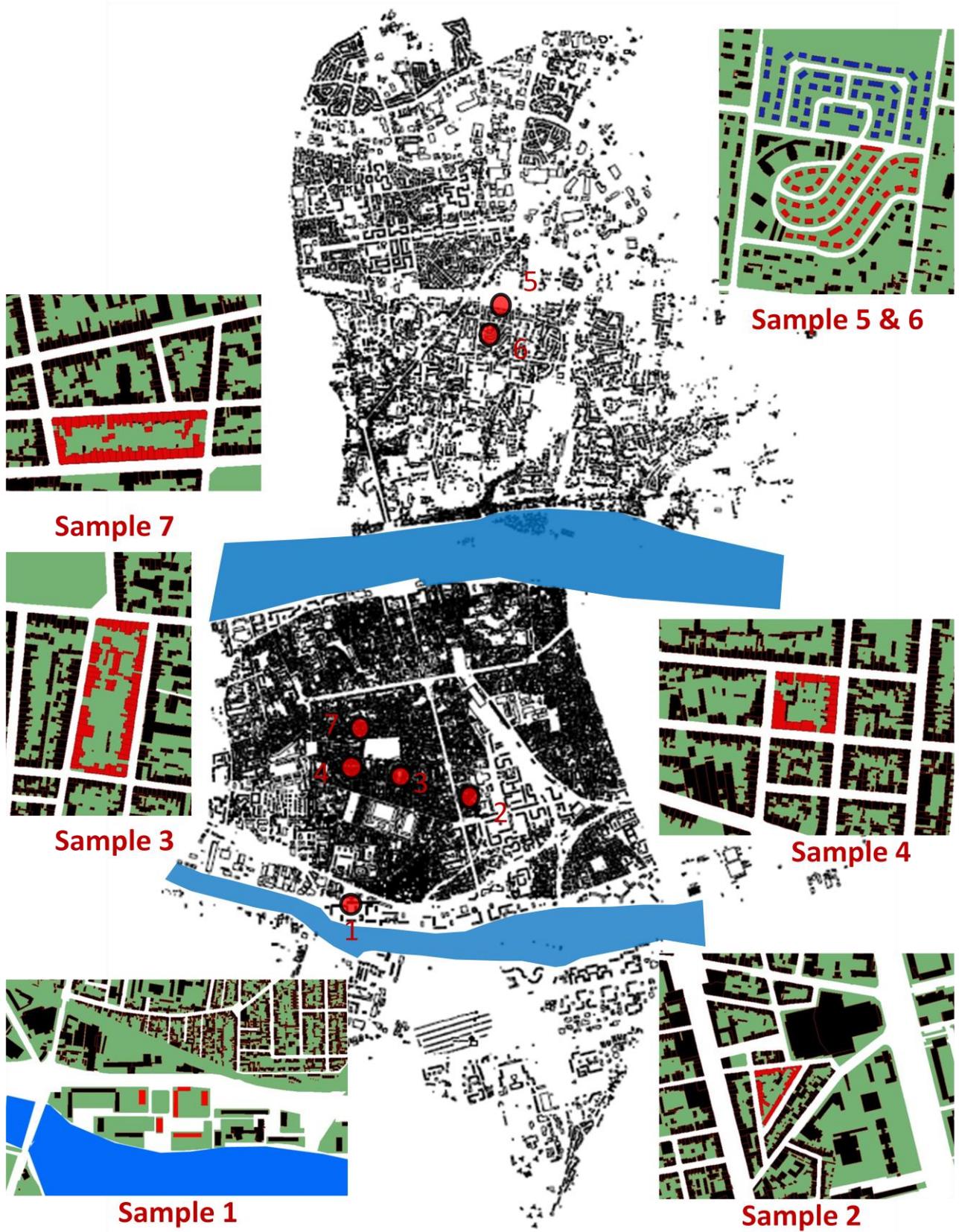


Figure23. Location of samples in the Tours map

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The sample1 defined as per the criteria1 (south and east orientation), criteria 6(varying building heights) with the value of dispersed buildings. Criteria2 (irregular geometry) with the value of continuous buildings the sample2 is defined. Sample3&4 is defined with the criteria1 (south and east orientation) and criteria2 (regular geometry) with the continuous buildings. Sample 5 is defined with the criterial1 (pre dominant orientation east-west & north-south) and value of dispersed buildings. Sample6 is with the criteria2 (different orientation) and the value of dispersed building. Finally sample7 faces north south orientation- criteria 1 with the value of continuous building criteria.

**5.2 Solar access simulation model**

**5.2.1 Sample 1:**

Solar simulation model, in this sample face both the north south and east west orientation.

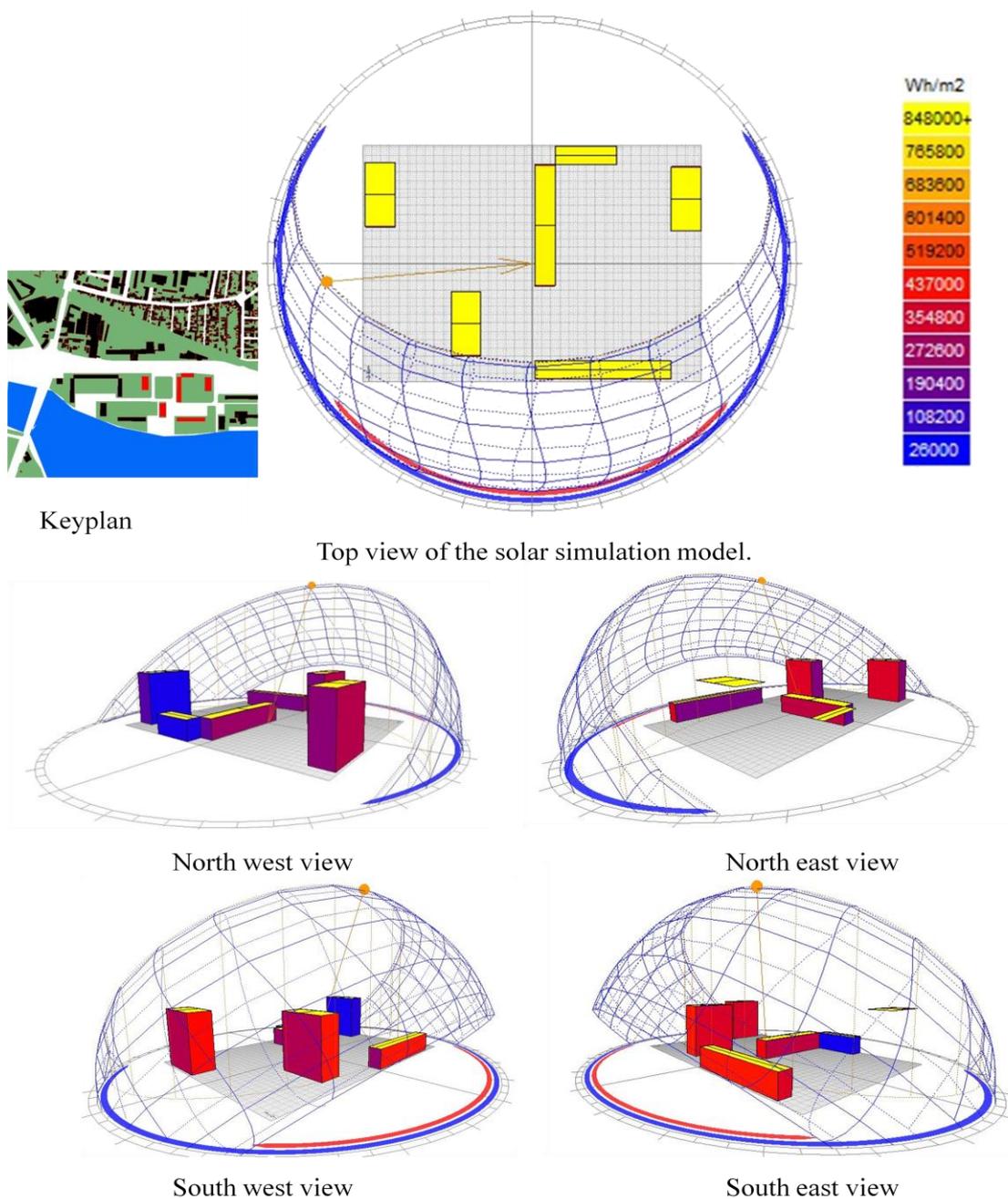


Figure24. Sample 1 solar simulation model.

Rest of all samples simulation model in the appendix 1 to 11

### 5.3 Solar access analysis

This analysis found the results for the daylight factor and solar potential factor of the samples are listed above and also the density factors for analyzing the best indicator. Overall all the roof area of all the samples has better performance over solar potential in Photovoltaic and solar energy production. Because the roof value of all samples are above 800kWh/m<sup>2</sup>.

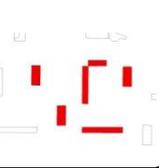
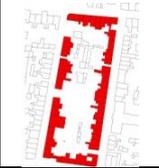
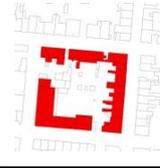
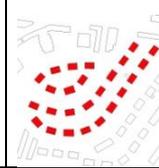
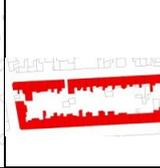
Name of the sample	Sample 1	Sample 2	Sample 3	Sample 4	Sample 5	Sample 6	Sample 7
Model of the sample							
Sample area in m <sup>2</sup>	35534.85	4462.45	11645.55	3945.6	33154	12771	7709
Total builtup area in m <sup>2</sup>	44478	3855.7	9310.48	4030.7	11385	4719	8707.32
FSI	1.25	0.86	0.799	1.02	0.343	0.369	1.12
Plot coverage	0.111	0.4	0.371	0.457	0.171	0.184	0.454
Wall surface area in m <sup>2</sup>	22034.7	3192.56	5361.35	2728.3	13824	6006	4974.71
Total wall surface area radiation in mWh	8194.41	1056.12	1720.21	877.01	4174.27	1775.11	1785.9
Wall surface area radiation per meter square builtup area in kWh/m <sup>2</sup>	184.23	273.91	184.76	217.58	366.64	376.16	205.1
Roof surface area in m <sup>2</sup>	3951.82	1787.85	4462.59	1804.08	5715	2528.4	3433.16
Total roof surface area radiation in mWh	3335.34	1529.31	3595.08	1540.68	4441.25	1780.54	2886.45
Roof surface area radiation per meter square builtup area in kWh/m <sup>2</sup>	74.98	396.63	386.13	282.23	399.09	377.21	331.49
Total radiation of the sample in mWh	11529.75	2585.43	5315.29	2417.69	8615.52	3555.65	4672.35
Radiation per metresquare of builtup area in kWh/m <sup>2</sup>	259.22	670.54	570.89	599.8	756.73	753.48	536.6
Ratio of wall surface area/ Builtup area	0.495	0.828	0.575	0.676	1.21	1.27	0.571

Table3. Summary of findings

There are some indicators analyzed in this study are

5.3.1 Wall surface area radiation per meter square of built up area Vs. Density

It correlates the built density parameters i.e. plot ratio and site coverage with wall surface radiation per meter square of built up area and results in Figure36. It appears that plot ratio has fairly good correlation with daylight factor ( $R^2=0.823$ ), whilst site coverage is not relevant at all ( $R^2=0.173$ ).

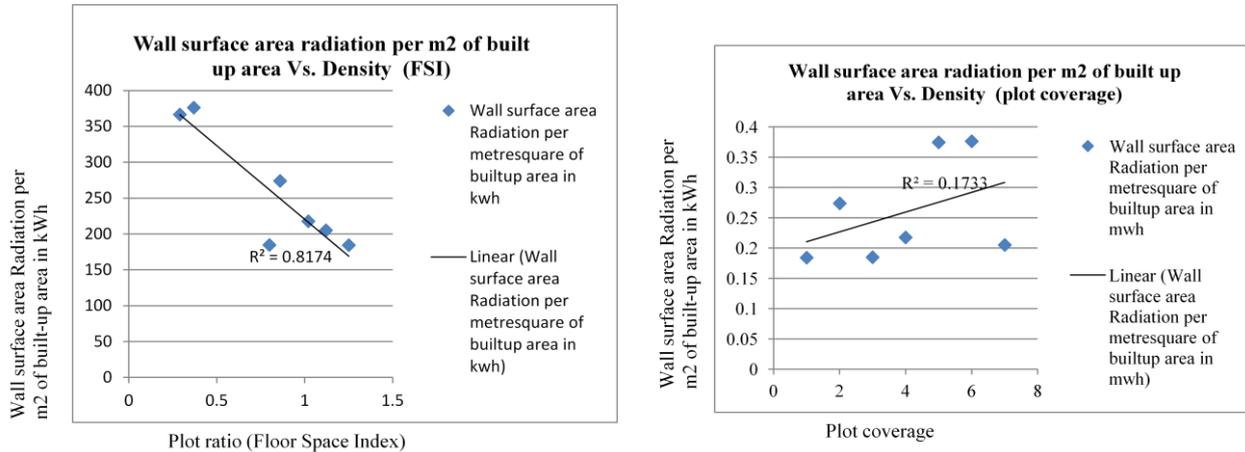


Figure25. Wall surface area radiation per meter square of built up area Vs. Density

Although the result suggests that site coverage alone does not influence very much the daylight factor, it does not mean that its effect is completely negligible.

Then, the Radiation per meter square area values are correlated with the compacity.

5.3.2 Solar potential (Roof surface radiation per metre square of built up area Vs Density)

Firstly the roof area radiation compared with FSI, then with the plot coverage finally with compacity.

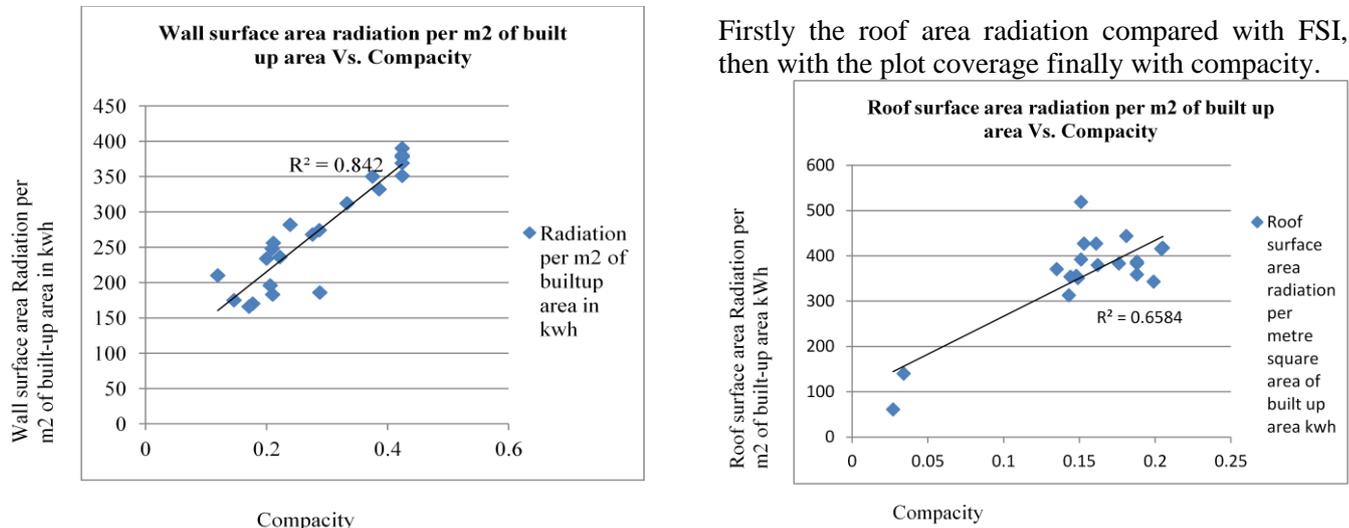


Figure26. Wall surface area radiation per meter square of built up area Vs. Compacity

Figure27. Roof surface area radiation per meter square of built up area Vs. Compacity

The results shows that the better correlation between the compacity and wall surface area radiation ( $R^2=0.842$ ). Therefore, the compacity, as one of the built density manifestations, seems to be useful in predicting daylight access.

From the results the correlation value of Plot ratio ( $R^2= 0.349$ ), Plot coverage ( $R^2=0.252$ ) and compacity ( $R^2=0.658$ ), it show that the Compacity has more correlation with the solar potential then other two factors. As the exposure to the sun the plot ratio has higher potential in getting solar radiation. If the potential energy is compared to the volume it is not.

5.3.3 Wall surface area radiation per meter square of built up area Vs. Built up area

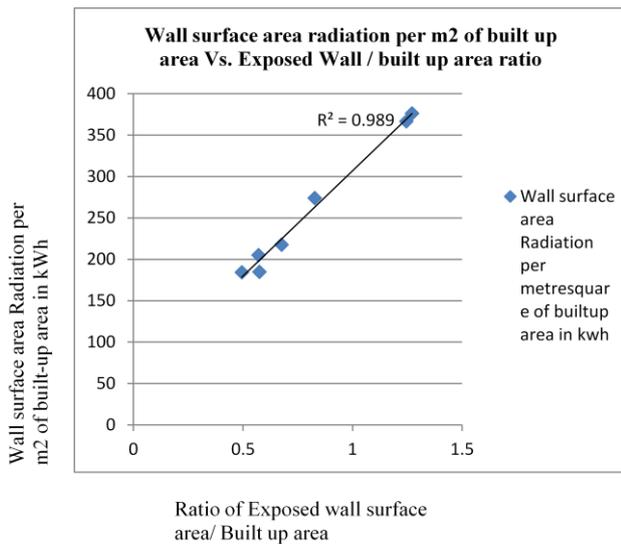


Figure28. Wall surface area radiation per meter square of built up area Vs. Ratio of Exposed wall area/ built up area

This result shows better correlation among all the indicators considered for optimum solar access. Increase in the solar access is due to increase in exposed surface. In this the least value shows the least percentage of walls exposed to the proportion of built-up area.

5.3.4 Orientation of samples Vs Wall surface area radiation per meter square of built up area

The correlation between orientation of the samples and Wall surface area radiation per meter square of built up area is not in better value. It shows (R2=0.115) all the values, but the radiation for the radiation per square meter area of orientation varies 500kWh to 110kWh from south to north, so it means that radiation per meter square built up area is not determined by orientation alone.

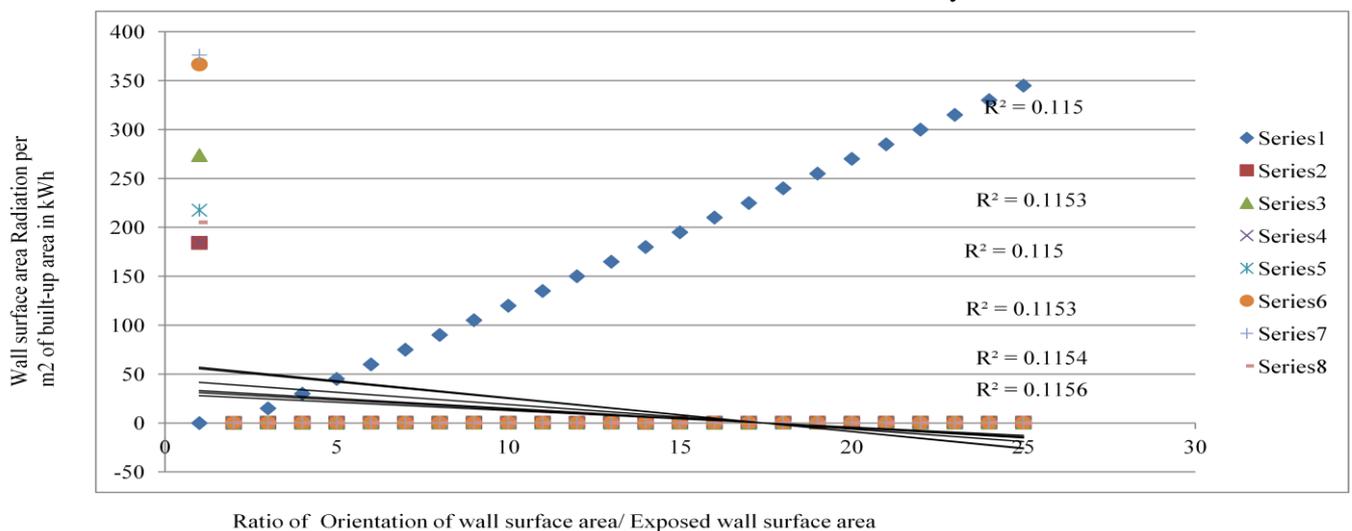


Figure29. Orientation of samples Vs Wall surface area radiation per meter square of built up area

6. Conclusions

6.1 Results and Conclusion

The daylight and solar potential of an urban development are primarily determined by the amount of solar radiation falls on the surfaces. According to the results, solar access for day lighting and space heating are better correlated to the factors of plot ratio, compactness and Ratio of wall surface area exposed by built up area than the other factors like plot coverage etc. It shows that the high the plot ratio (density) decrease in the solar access, but it is not a primary fact, because ratio of wall

surface area exposed by built up area have better correlation with solar access than the other factors. It means more the exposed surface increase the solar access. Important fact that the exposed surface is cannot obstructed by the adjacent structures, so there is no point in exposing surfaces if it gets only diffused not a direct.

For solar potential (heating and Photo voltaic) the roof areas are better than the wall surfaces, because all the sample's roof areas accessing average of 800kWh/m2, but the roof should be unobstructed, the values of varying skyline has the effect in the solar potential not in the day lighting in continuous building areas. Varying street heights has the impact

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in solar access, according to its road width and position of the structure.

The orientation of the street does not have more relation with the accessing solar radiation for day lighting, because it depends on the exposed surfaces with relation to the built up area not on orientation. Normally the street oriented towards south gets more radiation than direction, north get the least also it is diffused light not a direct. For space heating, the orientation of the street had an impact, south face gets more radiation than other, for this orientation is not only enough, because the road width subject to adjacent street height having a part.

This study reveals it complex issue, because the different terms in density (plot ratio, plot coverage) and compacity had a different relation with the solar access potential. The plot ratio, compacity and ratio of exposed wall surface area by builtup area has better correlation with the daylight, compacity has better correlation solar potential (thermal and photovoltaic).

Finally these paper intents the urban form has more role in accessing solar radiation. Generalized terms of Densification or de- densification of the urban areas are not better solution for sustainable urban energy, if the urban forms are not well analyzed.

#### **6.2 Limitation of the research**

First, the major findings of this study are fundamentally based on computer simulation.

Though the simulation programs used have been widely tested for competencies, variations in architectural features, for instance, projections from building facades could significantly affect the outcome.

Secondly, in some samples whole model of the sample was not simulated due to capacity of the computer, so its leads to taken a sample within the sample.

#### **6.2 Acknowledgements**

I would like to express my sincere gratitude to my advisor Prof. Mindjid Maizia and I would like to take the opportunity to thank the rest of the faculty professors of Department Amangement.

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Source 1: IUCN/UNEP/WWF (1991). "Caring for the Earth: A Strategy for Sustainable Living." Gland, Switzerland. Retrieved on: 2009-03-29.

Source 2: Markus J., Milne M.K., Kearins, K., & Walton, S. (2006). *Creating Adventures in*

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Sources4:

<[www.healthyplaces.org.au/site/glossary.php](http://www.healthyplaces.org.au/site/glossary.php)

Source5:

<<http://www.bricoleurbanism.org/category/urban-design/page/2/>

Source6: M. GROSSO-urban form and renewable energy potential-Renewable Energy I5 (1998) 331-336

Source7: Energy loads, CO2 emissions and building stocks: morphologies, typologies, energy systems and behaviour- Serge Salat

Source 8: Energy requirements of characteristic urban blocks- Mindjid Maïzia, Claire Sèze, Sébastien Berge, Jacques Teller, Sigrid Reiter, Raphael Ménard

Source 9: Urban Form, Density and Solar Potential - Vicky Cheng, Koen Steemers, Marylene Montavon and Raphael Compagnon (2006)

Source 10: Compact cities in a sustainable manner Vicky Cheng, Koen Steemers, Marylene Montavon and Raphael Compagnon (*2nd International Solar Cities Congress - Oxford 3-6 April 2006*)

Source 11: Energy and the city: density, buildings and transport- Koen Steemers

Source 12: Settlement Planning & Dladla Development cc. (T) 011 467 0040 (F) 011 467 0090 e-mail: [setplan@icon.co.za](mailto:setplan@icon.co.za)  
EMM DENSIFICATION FRAMEWORK: Status Quo Analysis & Findings Document.

#### **Abbreviations**

1. FSI , Floor space index, Ratio of built area by site area.
2. SVF, Sky view factor, the extent of sky observed from a point as a proportion of the total possible sky hemisphere.
3. DLF, Daylight factor, ratio of internal light level to external light level.

## 5.2.2 Sample 2:

**Appendix1:** This sample gets the solar radiation in all the direction, because it is dispersed type. But the radiation per meter square area of built-up area is very less compared to other samples due to more floor depth to floor height ratio.

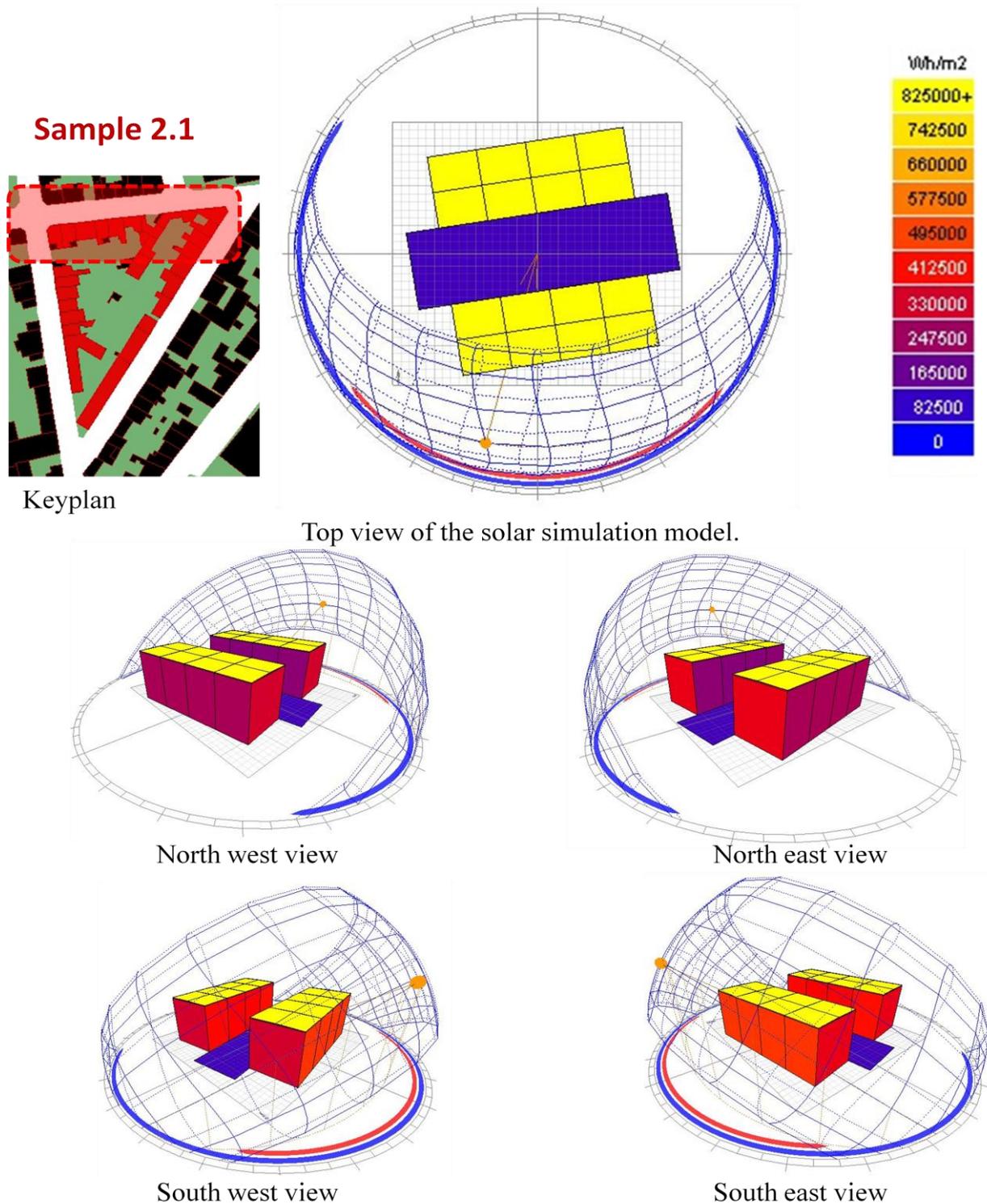


Figure30. Sample 2.1 simulation models (North south orientation -9degree tilted)

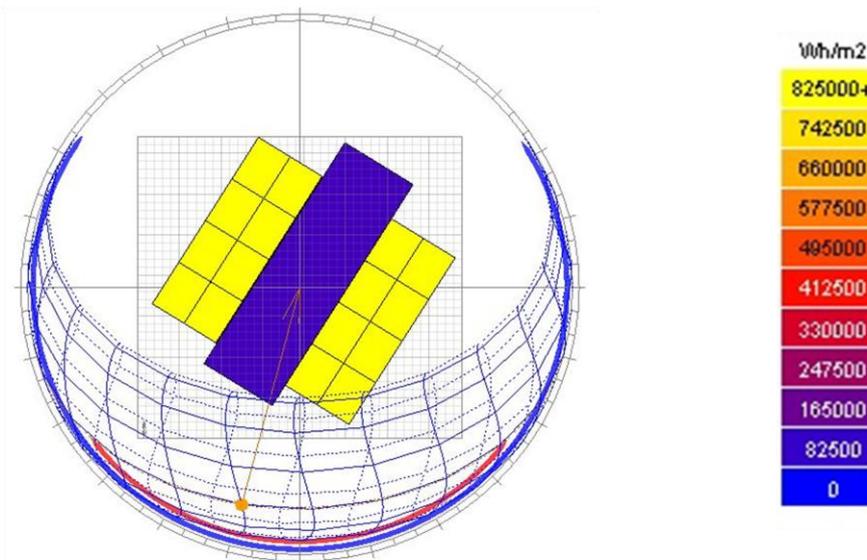
This sample2.1 gets more radiation in the south facing part of the buildings than north; sample has 33.7% of surface area of the sample2 surface area. All the part of the street was not simulation due to limitation of the modeling.

Appendix2:

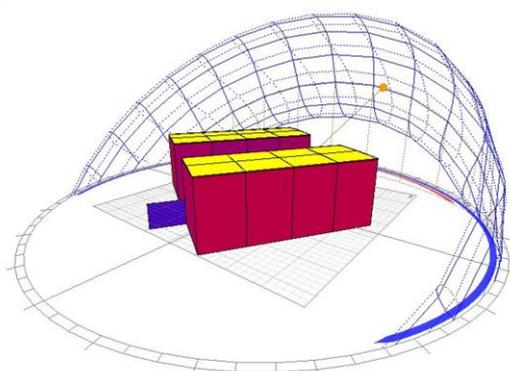
Sample 2.2



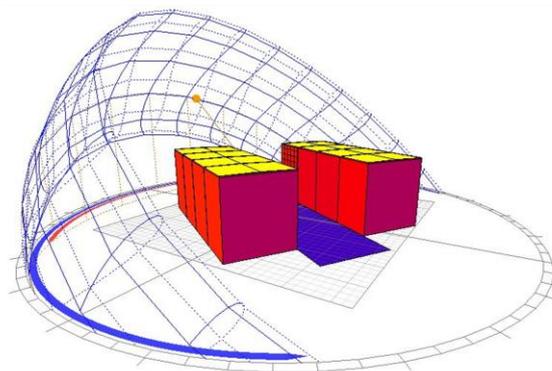
Keyplan



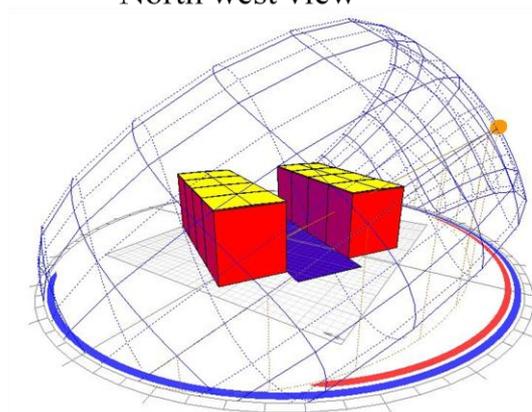
Top view of the solar simulation model.



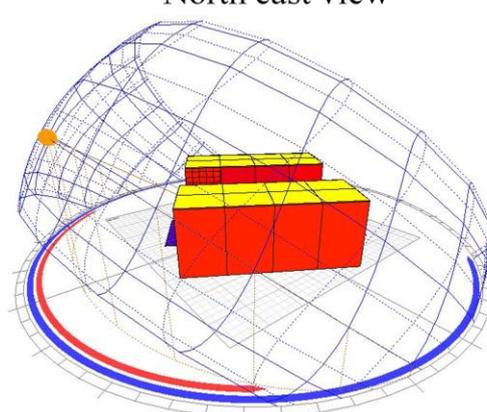
North west view



North east view



South west view



South east view

Figure31. Sample 2.2 simulation models (South east orientation -122degree)

This sample 2.2 occupies 49.4% of the surface area of the total sample2, which gets more radiation in the south east direction.

## Appendix3:

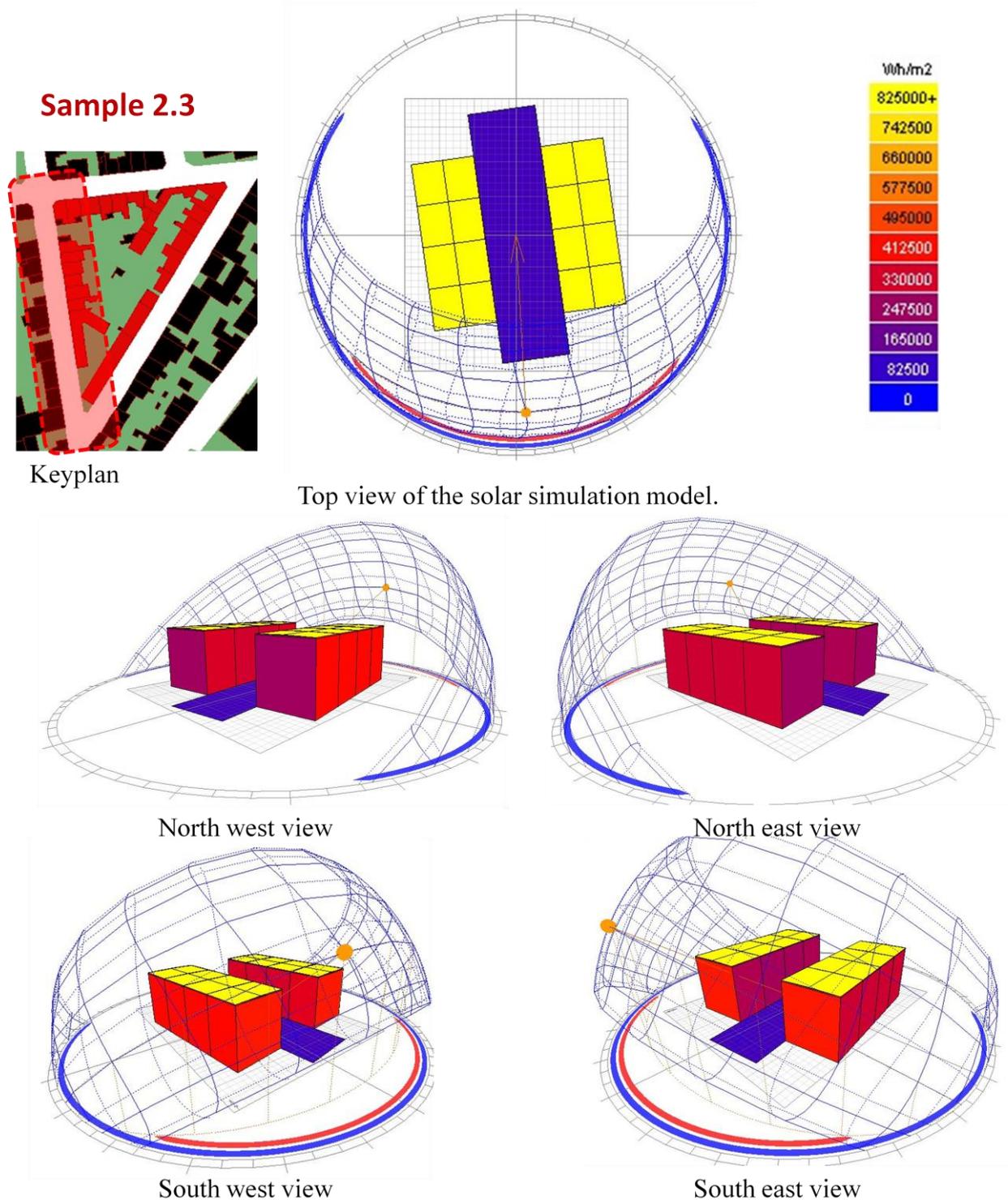


Figure32. Sample 2.3 simulation models (East west orientation -82degree tilted)

This sample 2.3 occupies 16.9% of the surface area of the total sample2, which gets merely equal radiation in the both the directions east and west.

Appendix4:

7.2.3 Sample3

In this sample major part is oriented towards north south with continuous buildings

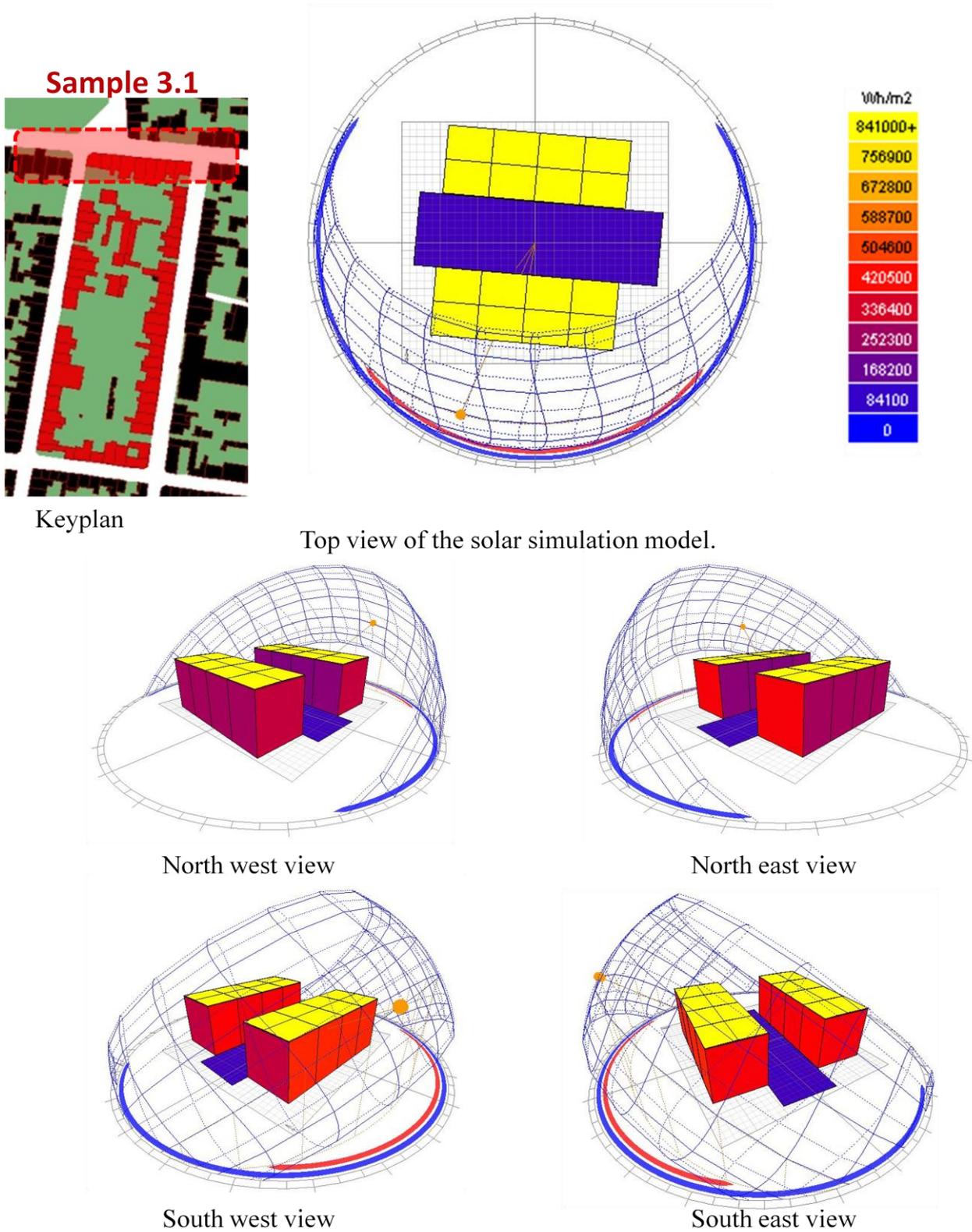
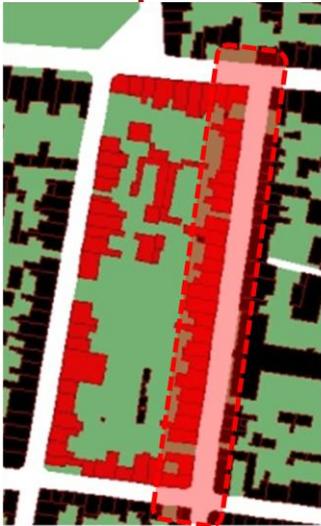


Figure33. Sample 3.1 simulation models (North south orientation 5degree tilted)

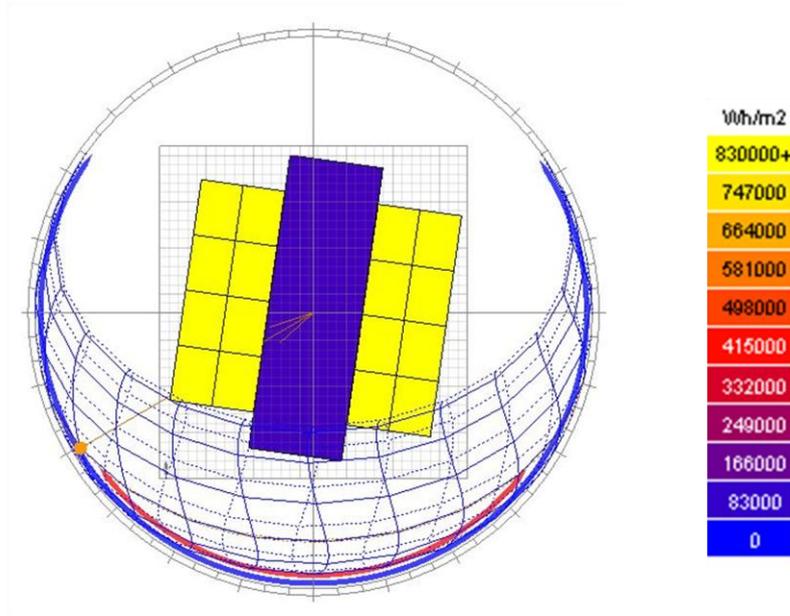
This sample 3.1 occupies 16.4% of the surface area of the total sample3, which gets more radiation in south facing face of the sample.

Appendix5:

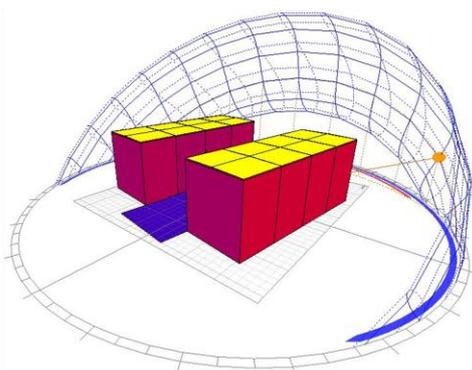
Sample 3.2



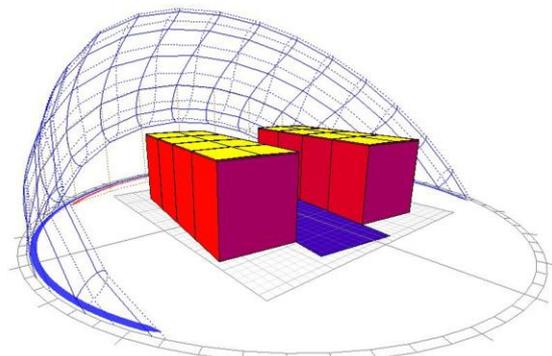
Keyplan



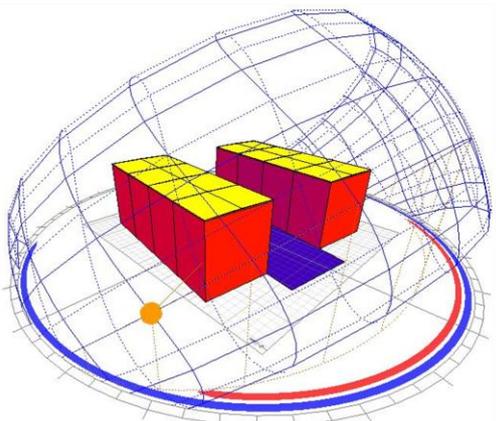
Top view of the solar simulation model.



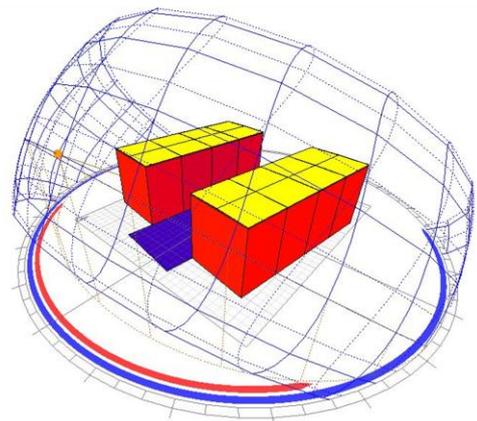
North west view



North east view



South west view



South east view

Figure34. Sample 3.2 simulation models (East west orientation 98degree tilted)

This sample 3.2 occupies 35.6% of the surface area of the total sample3, which gets merely equal radiation in both the direction east& west that is 0.21mWh/m<sup>2</sup> of the surface area.

## Appendix6:

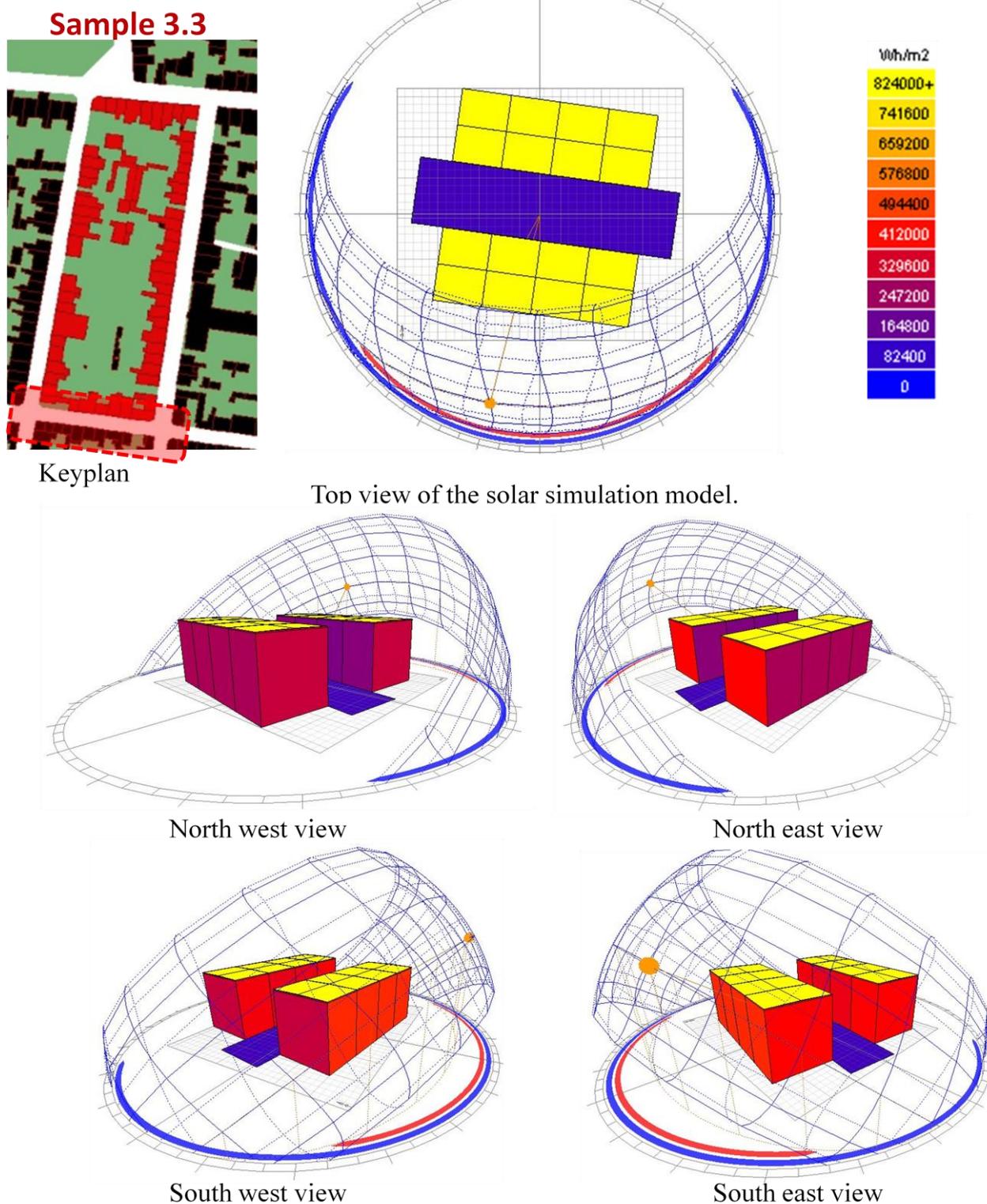


Figure35. Sample 3.3 simulation models (North south orientation 5degree tilted)

This sample 3.5 occupies 13.1% of the surface area of the total sample3, which gets more radiation in south facing face of the sample.

Appendix7:

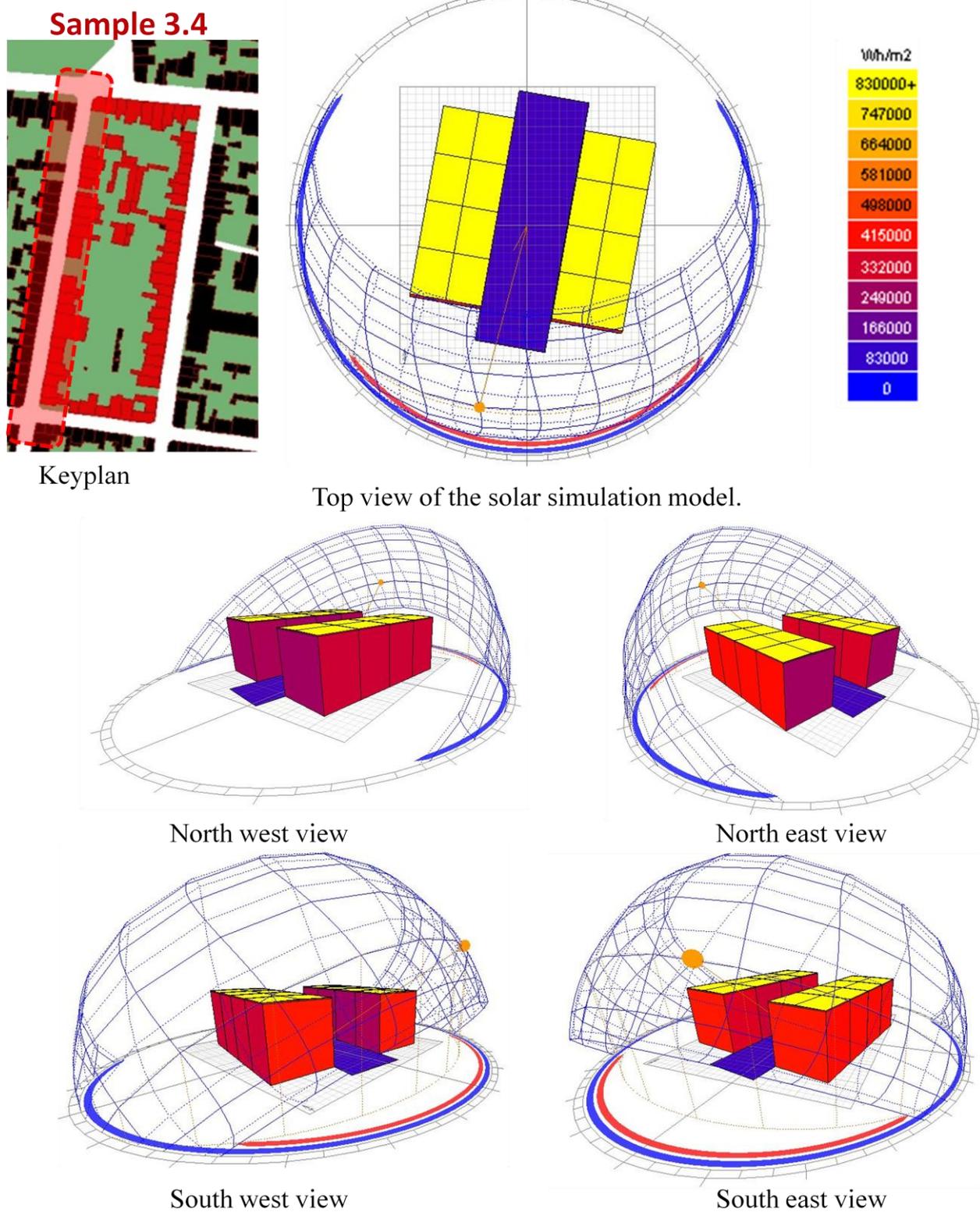


Figure36. Sample 3.4 simulation models (East west orientation 100degree tilted)

This sample 3.4 occupies 34.9% of the surface area of the total sample3, which gets merely equal radiation in both the direction east& west that is 0.171mWh/m2 of the surface area.

## Appendix8:

## 7.2.4 Sample4

This sample has equal length and width of the street with the continuous buildings.

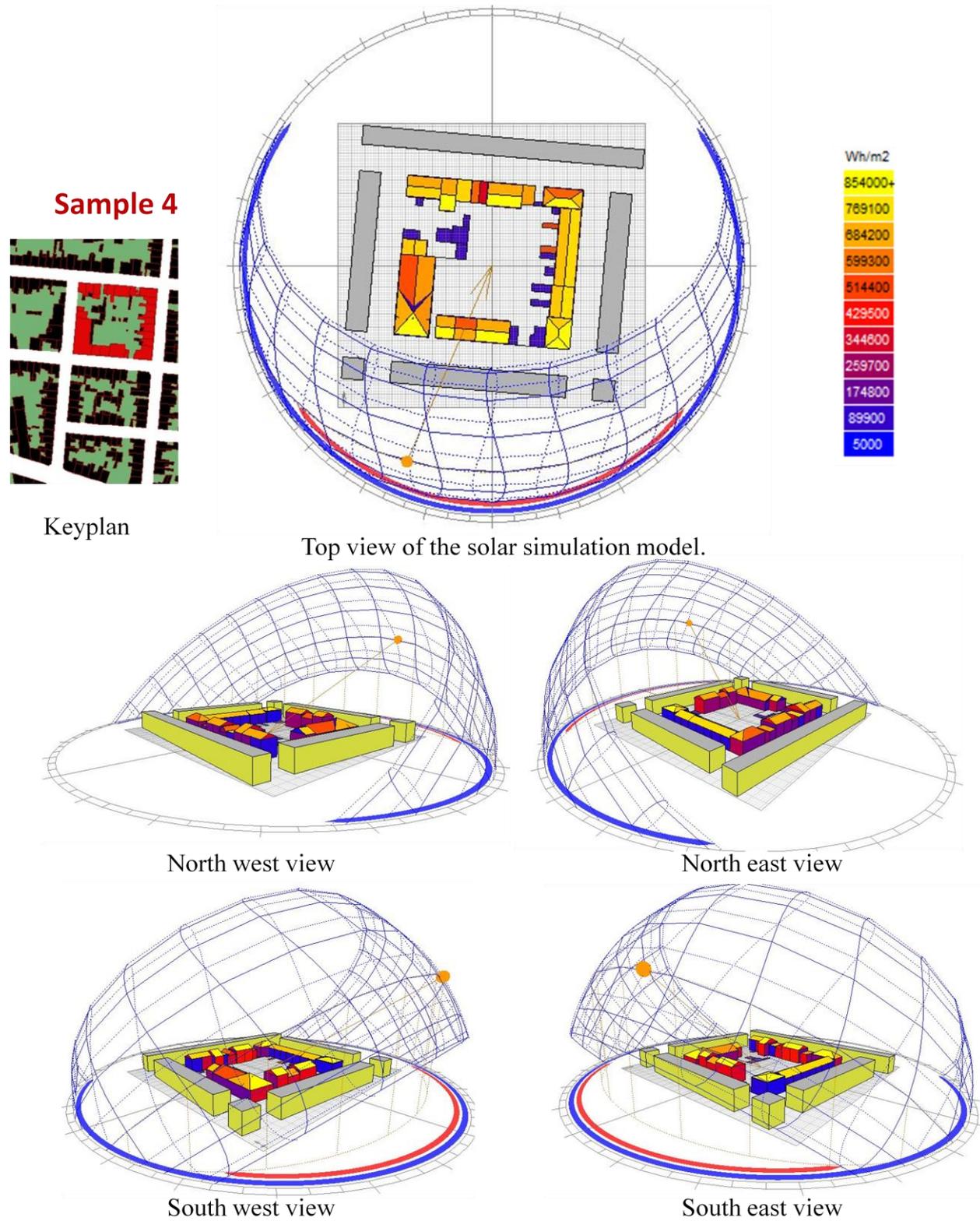


Figure37. Sample 4 simulation models (the sample itself tilted 5degree)

In this sample 4, north south oriented unobstructed face gets more radiation than the other faces of the sample.

Appendix9:

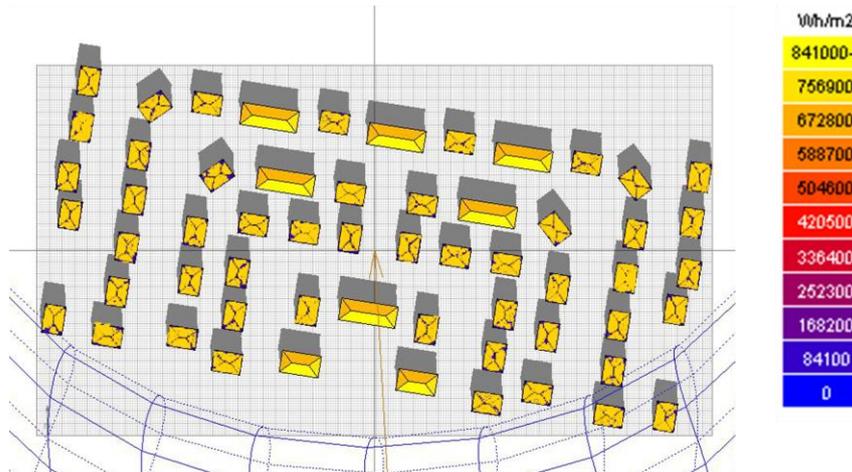
7.2.5 Sample5.

This sample predominated oriented in north south and east west direction with 10degree inclined. All the buildings in the sample are dispersed.

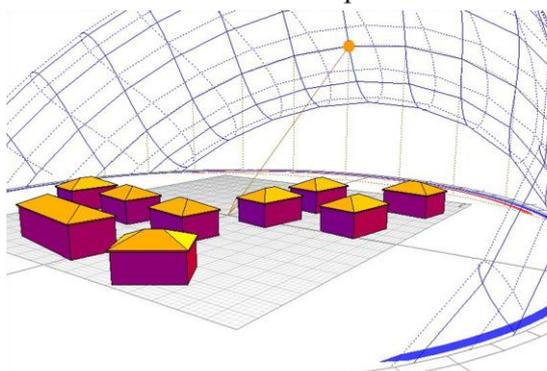
Sample 5



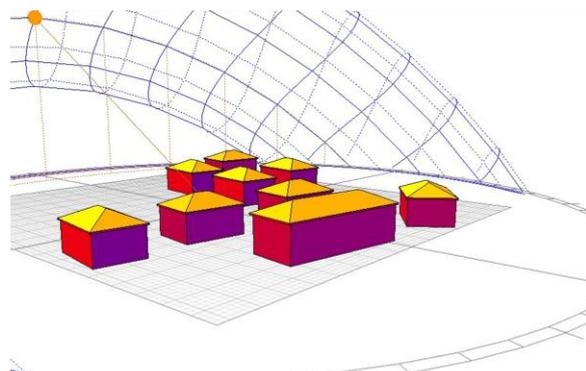
Keyplan



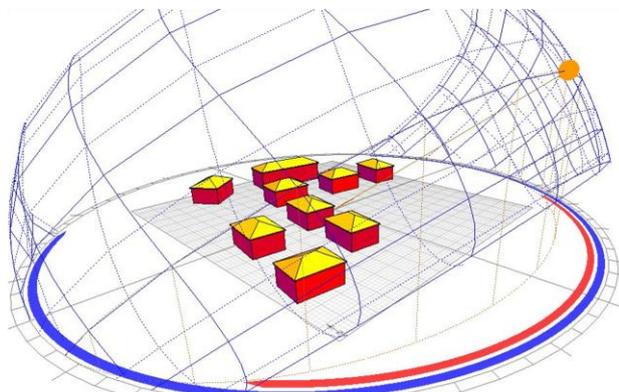
Top view of the solar simulation model.



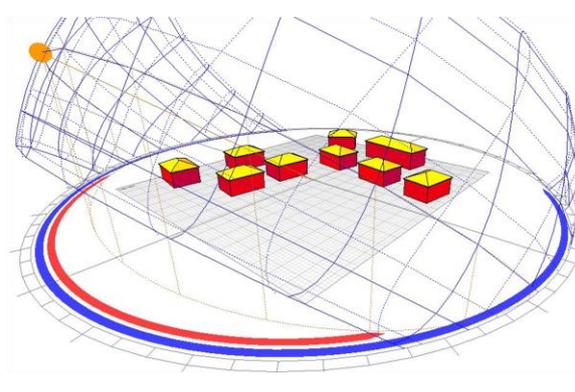
North west view



North east view



South west view



South east view

Figure38. Sample 5 simulation models.

All the exterior walls of the sample are exposed, so all the surfaces access solar radiation, some of the building models obstructed by the adjacent building it leads to access less radiation per square meter area. Surface area of the building is more than the buildup area of the sample.

## Appendix10:

## 7.2.6 Sample6

In this sample all the buildings are dispersed and different orientations.

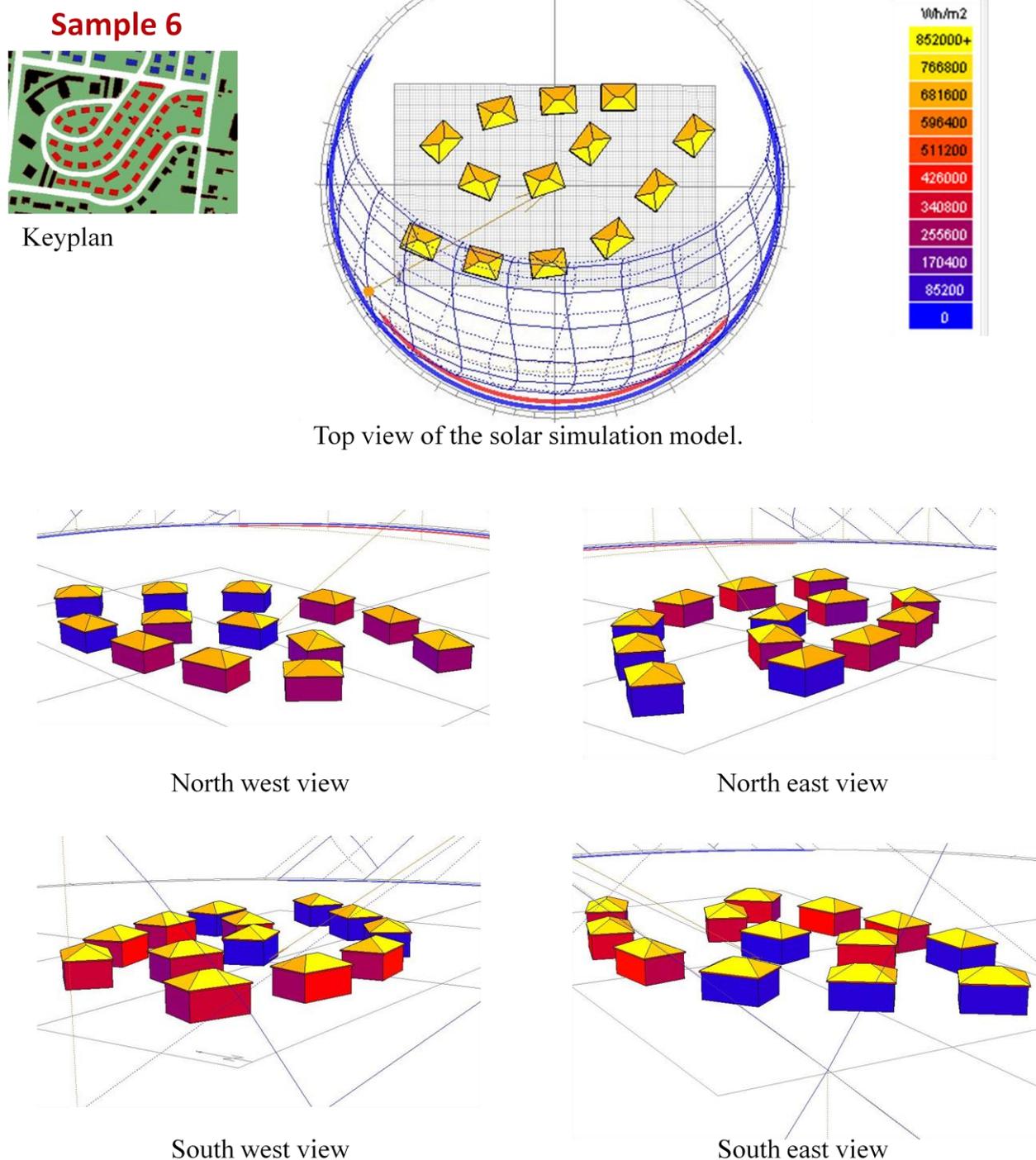


Figure39. Sample 6 simulation models.

All the exterior walls of the sample are exposed, so all the surfaces access solar radiation, some of the building models obstructed by the adjacent building it leads to access less radiation per square meter area. Surface area of the building is more than the buildup area of the sample.

## Appendix11:

## 7.2.7 Sample7

In the street is oriented towards north south orientation with continuous building and some building has varying skyline.

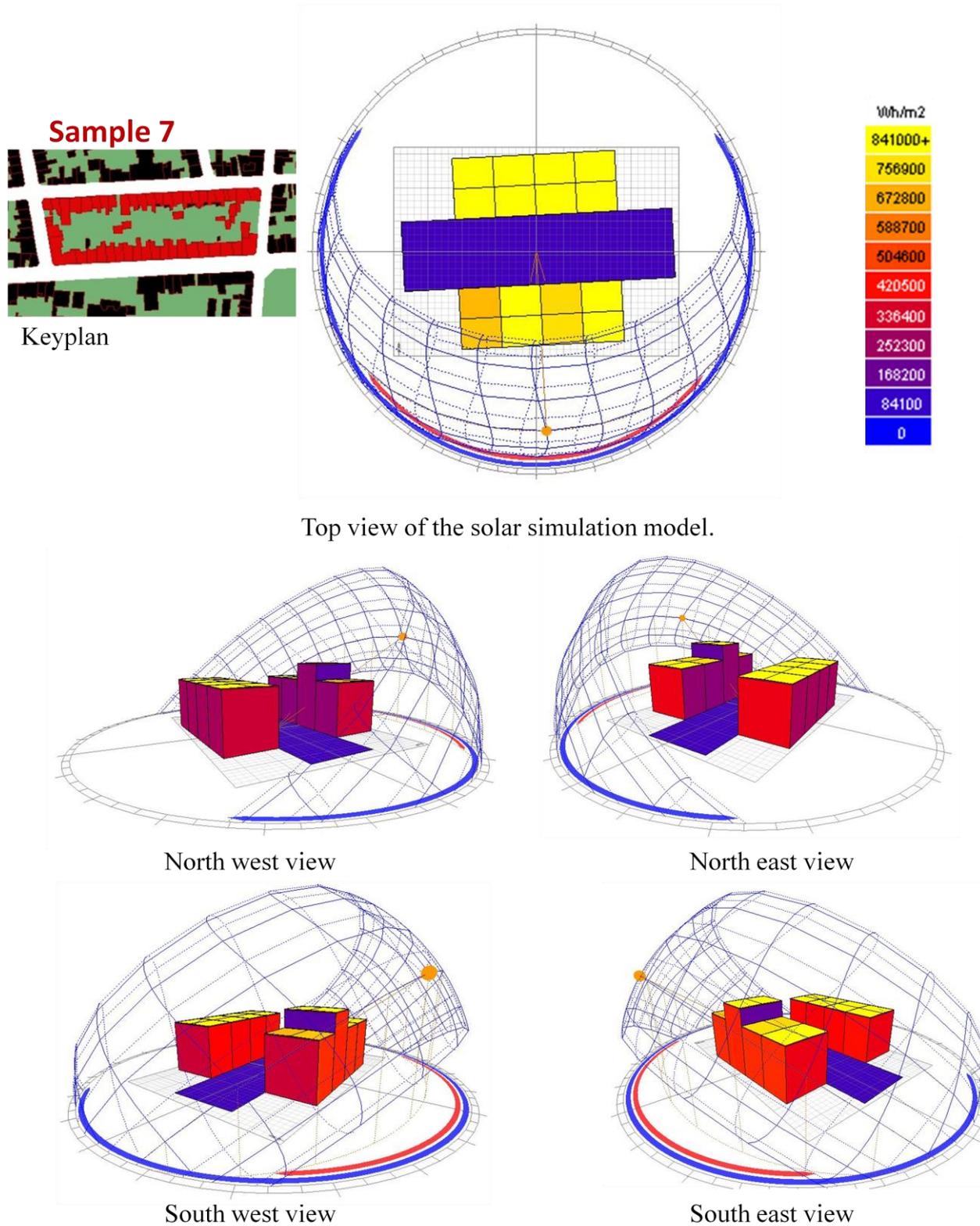


Figure40. Sample 7 simulation models (North south orientation -3degree tilted)