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Feasibility Assessment of Solar Panel Installation in Chiswick and Tower Bridge – London, To Enhance Renewable Energy and Sustainable Urban Development

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Abstract: *Photovoltaic is one source of renewable energy that converts sun irradiation into electricity which is economically viable and environment friendly. Growing population and technology alike, there has been degradation of environmental health due to social activities such as the greenhouse gasses effect. The awareness of these activities has exposed the negative impact by traditional power generating methods such as coal and oil fired power stations. Hence, the need for environment friendly source of generating power. High rate of development in the United Kingdom, demand for solar energy, since sources of pollution kept growing at an increasing rate. This as a result, facilitated the need for analysing a suitable site and design, for the installation of solar panel to achieve optimum power generation. The advantages in flexibility of handling different spatial data and ability to support interrelations between data sets, Geographical Information Systems (GIS) has become an important support for decision making, in the management of renewable energy. Arc Map became useful tool to produce a digital map in the evaluation using Chiswick and Tower Bridge remotely sensed spatial data. These areas were determined by specific values of slope and aspect defined by the criteria restriction, aimed at directing the panel surface to maximum exposure to the sun, as a determinant of energy received from the sun. The evaluation assumptions that all suitable roofs were subjected to equal atmospheric absorption and scattering on the sun irradiation. The final map data processed is the areas of suitable roofs for PV cells, with the amount of energy each building will produce. The GIS flexibility in aiding interaction between spatial data has provided the means for identifying and quantifying the effect of terrain topography and to visualise building orientation effect on solar panel energy production.*

Keywords: *GIS, DEM, photovoltaic, sun irradiation, analysis, spatial data, environmental health*

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I. Introduction

Development has increasingly been changing both in structure, technology, population and social activities. The rapid development in technology mandated dependency on electrical energy by administrative departments and private investors. As population keeps growing higher and technology alike, there has been degradation of environmental health due to social activities such as the green house gasses effect. The awareness of these activities has exposed the negative impact by traditional power generating methods such as coal and oil fired power stations. Hence, the need for better environment friendly source of generating power finds its location to play a significant role that was internationally accepted.

The report of the investigation by the international collaborative effort, first conducted in 1992, according to Baban et al. (2001), has reviled the consequences, of the impact of anthropogenic activities on the environment. This, however, lead to promoting the use of renewable energy in 1997. Thus, in the European Union (EU), several of such programmes were introduced with the aim of increasing sources of renewable energy. Development of renewable energy technologies have been enhanced today, due to those factors. Photovoltaic is one of such sources of renewable energy used to convert sun irradiation into electricity with the advantage of being economically viable and has no negative impact on the environment. Hofierka and Suri (2002) defined irradiation as the amount of solar energy falling on a surface unit area, at a specific time interval.

Voegtle et al (2005) further suggested that to achieve success in the use of this technique, some criteria have to be met. The criteria accountable include- installation should be at minimum size possible, azimuthally orientation for maximum exposition to sun, slope angle for the production of efficient energy also avoiding shadowing effect caused by surrounding objects to determine the duration and intensity of the sun irradiation. This suggests that the suitable locations for the installation of solar panels (also called photovoltaic) are building roofs. Therefore, for the purpose of adequate planning and estimation, it is necessary to obtain detail information about the suitability of area on which solar panel would yield maximum output of energy.

Due to the high rate of development in the United Kingdom (UK), the demand for solar energy has surface, since sources of pollution kept on growing at an increasing rate. This as a result, facilitated the need for analysing a suitable site and design, for the installation of the solar panel to achieve optimum power generation. Renewable energy source is becoming economically feasible, due to the development of relevant technologies. Voivontas et al. (1998) believes that, as renewable energy reduces loss of energy and improves stability and reliability, the systems may become a key element of the developing energy rule. They further suggested that due to the advantages in flexibility of handling different spatial data and ability to support interrelations between data sets, Geographical Information Systems (GIS) will become an important support for decision making, in the management of renewable energy.

Aim and Objectives:

The aim of the study is to identify suitable building roofs for the installation of solar panel. Objectives should account for:

- Identification of building roofs where high solar energy is produced
- Calculation of energy produced by each building in the data
- Validation of the viability of the result obtained from map processed

1.2 How Solar panels Converts Sun Energy into Electricity

Solar panels are made from semiconductors, mostly composed of silicon atoms. The panels are constructed with two layers of silicon. One of the layers called the N-layer is constructed of silicon atoms with extra free moving electrons. The layer called the P-layer has ‘‘missing’’ electrons as it is called, that attracts any free electron.

The two layers are separated by an electric field, generated by the interaction of atoms from both sides. The electrons are caused to move by the solar energy, when the sun hits the atoms in the layers. This causes the free electrons in the P-layer to cross the electric field into the N-layer, moving in only one direction; But the electrons in N-layer is not able to cross to the electric field into P-layer, thus, excess free electrons are build up in the N-layer. When an electric conductor comes in contact with the N-layer, it gives space to the build up electrons to move. This circuit will connect back the P-layer, depositing free electrons to continue the process. As the electrons returns to the P-layer, they give energy to operate electrical appliances connected within the system. This movement of electrons is called current, and the current generated by the PV cells is the Direct Current (DC). To be used on electric appliances, a converter is used to convert the DC into Alternating Current (AC) (Solar Panel Information and Reviews, 2011).

II. Methodology

To achieve maximum power from PV system, the design and location have to be appropriately calculated and planned. Hofierka and Suri (2002) proposed that in the design of solar energy system implemented in some part of Europe, a building integrated South facing horizontal panels, inclined at an angel of 15, 25, and 40 degrees are suitable. In the same vein, Segen (2008), supported that the most productive aspect for solar panel installation in the UK which is located on 51° latitude, Northern Hemisphere, is between 90 and 270 degrees, East-West facing south. These criteria were strictly adhered to in the process of this analysis. This is aimed at directing the panel surface to maximum exposure to the sun, which determines the amount of energy received from the sun.

2.1 GIS Implementation

Arc Map was used to produce a digital map in the evaluation using Chiswick and Tower Bridge remotely sensed spatial data provided separately for each of them. Each suitable roof of buildings of the site is presented in an extracted map represented by a polygon. These areas were determined by specific values of slope and aspect defined by the criteria restriction.

The evaluation was based on assumptions that all suitable roofs were subjected to equal atmospheric absorption and scattering on the sun irradiation, and met the necessary conditions. The model in Figure 1.7 explains the process of feasible evaluation of suitable roofs in Chiswick and Tower Bridge using Arc Map.

2.2 Processes

The lay down step by step process using model builder was followed to create a three coloured complete process model. Blue coloured part of the model represent input data, yellow represent function and green represent output. Chiswick and Tower-Bridge Digital Elevation (DEM) map was used as input raster data in two different model builder for each city. For Chiswick DEM raster data, slope function was applied to select only the slopes within the DEM of Chiswick. Similarly, aspect function was applied to the DEM to select the aspect in the DEM. Since the interest is in the slope and aspect related to buildings, extract by mask function was applied to extract only the slopes and aspect related to buildings, providing the suitable range of aspect and slope, where:

- 90 to 170 degrees aspect was reassigned a new value 1
- 170 to 190 degrees aspect was reassigned a new value 2
- 190 to 270 degrees aspect was reassigned a new value 1

and 30 to 70 degrees slope was reassigned to a new value 1. Aspect slope were rectified to select aspect that slope within the angle of 30 deg to 70 deg and are East-West facing south. Research proves that in the Northern hemisphere, London with 51 deg latitude is situated, the optimum slope for roof for solar energy production, is equal to approximate Latitude minus 15 degrees in the summer and plus 15 degrees in the winter. Ideally, the optimum slope angle of the roof will be between 30 deg and 70 deg (Segen, 2008). To intersect the raster data set of the slope and aspect with the building dataset which is a vector, the raster datasets were converted to vector polygon using the raster to polygon function, then the polygon of slope and aspect were intersected to select the common suitable areas between both of them. Then using the identity function, the generated multiple polygons were associated with the building dataset, choosing only FID in the joint attribute parameter to specify that only the building IDs will be associated with the roof and no other information is transferred. To enable a meaningful calculation of areas of buildings, multiple polygons generated within a building were dissolved to be represented by the building as a single unit, and then the cumulative areas of suitable polygons for each building clumped by dissolve function were calculated. Field was added, where the calculated energy will be kept (stored) defining its parameter as LONG to allow it to hold real values with high precision. Finally, the energy produced was calculated from the field using the equation:

Energy = Insolation X area 0.16

where insolation = 1836

area = suitable roof area and 0.16 is efficiency of the PV cell.

The final map data processed from the model is the areas of suitable roofs for PV cells, with the amount of energy each building will produce. With the aid of Arcmap, the result was joined with the building shape file, after projecting both the energy result and the shape file, to Universal Traverse Mercator (UTM) system. The joined shape file was then projected from layer to KML so that it is uploaded into Google map. Finally, the KML projected map was successfully opened in Google map to validate the viability of the result obtained from map processed, on which some observations were made.

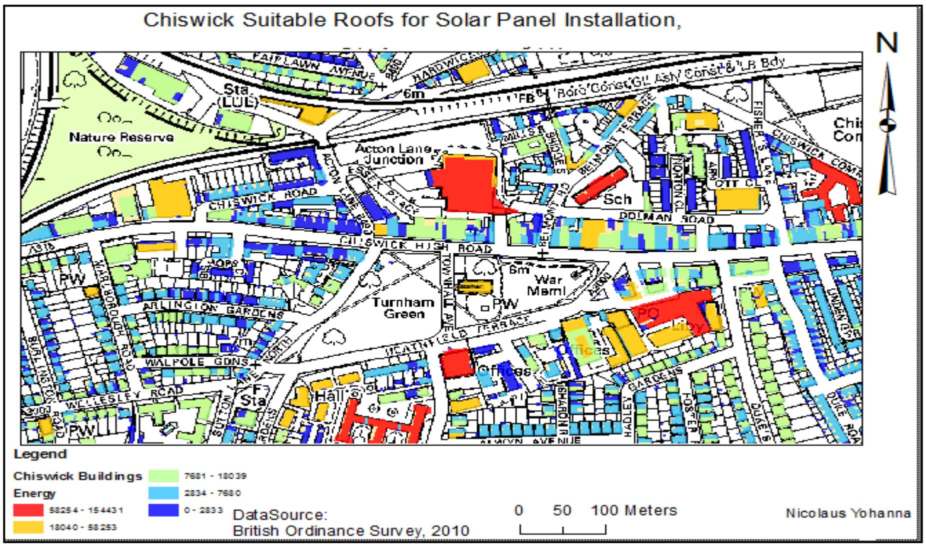

Figure 1: Energy generated by building roofs in Tower-Bridge, London

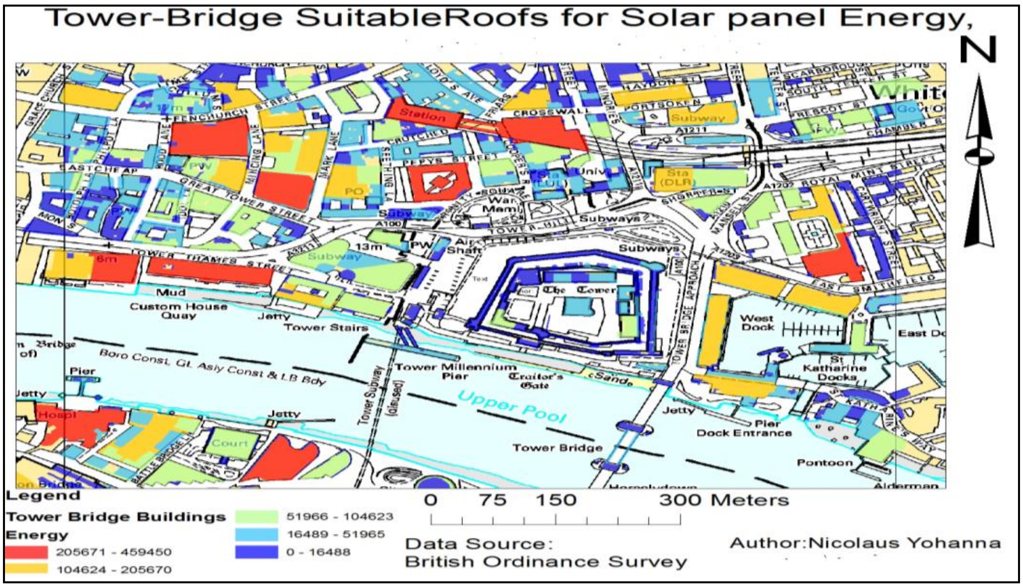

Figure 2: Energy generated by building roofs in Tower Bridge, London
Source: Author's work, 2023

III. Observation and Analysis

In this chapter, the results of the simulation/modelling will be explored and analysed within the context of the 2 scenarios namely Chiswick and Tower Bridge

3.1 Tower Bridge

The Tower-Bridge region shows some surfaces with red colour, which represents high values of energy, are not actually roofs. Some are concrete building forms, under the building foots that happen to be within the defined criteria for suitable slope and aspect. An example of such areas can be seen around Trinity Square building as seen in Figure 3, giving false roof energy of 248624 Watts m^{-2} as shown in Figure 4

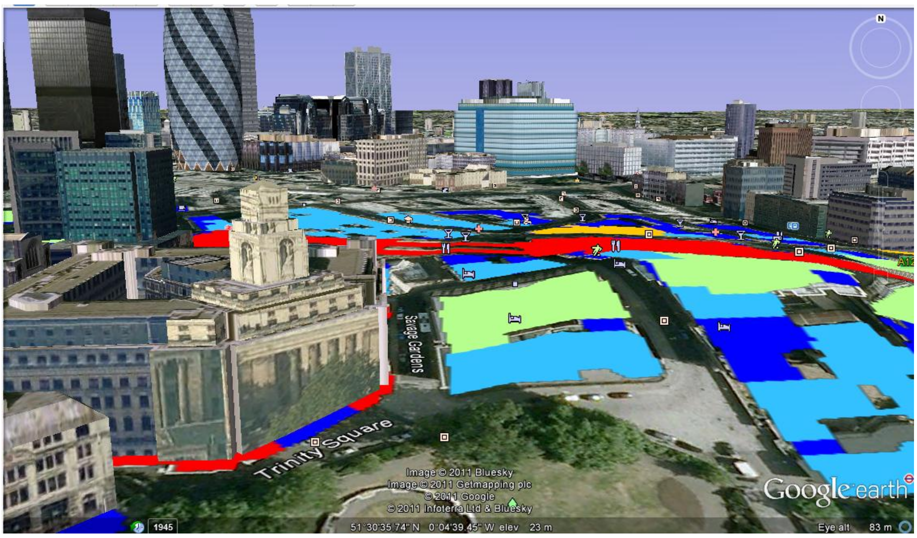

Figure 3: Tower Bridge map showing surfaces appearing as solar panel roofs
Source: Author's work, 2023

The Murray house building roofs around St. Katherine Dock (Stop C) shown in Figure 4 give very high energy of 257302 Watts m^{-2}, while Mitsui OS Bulk Shopping Ltd, located adjacent to it produces lower energy of 168,968 Watts m^{-2} which is as a result of orientation (aspect) and slope of the roofs.

Figure 4: Murray House around St. Catherine Dock (Tower Bridge), showing different energy values compared with its adjacent buildings.

Source; Author's work, 2023

Generally, these two buildings produce higher energies compared to other buildings located near them, due to their nature of design and location which is comparably in an open space where there are no tall trees or buildings casting shade on them.

3.2 Chiswick

In the Chiswick region, the result shows different areas producing different values of energy, represented in different colours of red, yellow, light-blue and dark blue as shown in Figure 5 representing the amount of energy generated by every suitable building roofs, with red having the highest energy, followed by yellow and dark blue with the least. The regions with higher energy are roofs of tall buildings in congested areas built in the south facing orientation, and at a suitable angle.

Figure 5: Chiswick region suitable building roofs for solar panel

Source: Author's work, 2023

Patches of blue colours between the red, are corners of the roofs that do not face the same orientation with the red part of the roof and some are engraved lower than the others, so that the higher parts cast shadow on the lower ones, causing them to have lesser time exposure to the sun. Buildings constructed near those that produce high energy, seem to produce lower energy because they are partially oriented away from the direction of high sun intensity and have slope angles higher than 70 degrees or lower than 30 degrees, as shown in Figure 6.

Figure 6: Patches of engraved blue colours represent lower energy.

IV. Conclusion

The method employed in this analysis aimed at finding suitable roofs for the installation of solar panel and to provide idea to support decision making on where and how to install photovoltaic cell at an ideal cost to achieve optimum energy output. Analysis of this type will further provide local authority, private investors, and building engineers with an idea to take into consideration the suitable orientation and slope angle for roofs in future building constructions in those areas and elsewhere, as the need for using renewable energy is growing increasingly. Solar energy system distributors can also base their estimate upon the result of the analysis in order to provide appropriate services at no lost. Based on the research report available on http://j.mp/uJPnH3 (2011), in London, an average of 1460 hrs a year is sunny. This is equivalent to 46% of days in a year is sunny days. This suggests that the analysis was conducted on about average region for the use of solar panel to produce the required efficiency.

The GIS flexibility in aiding interaction between spatial data has made it become a very useful system in providing the means for identifying and quantifying the effect of terrain topography and to visualise building orientation effect on solar panel energy production, on which decision will be based.

The result of this analysis shows that Tower Bridge has higher advantage in using solar energy generating system, however, having the knowledge of the challenges which put Chiswick on the lower side of production can enhance new decision on designing a new orientation to the building structures to be erected in future and the best output result can be greatly improved.

References

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Appendix

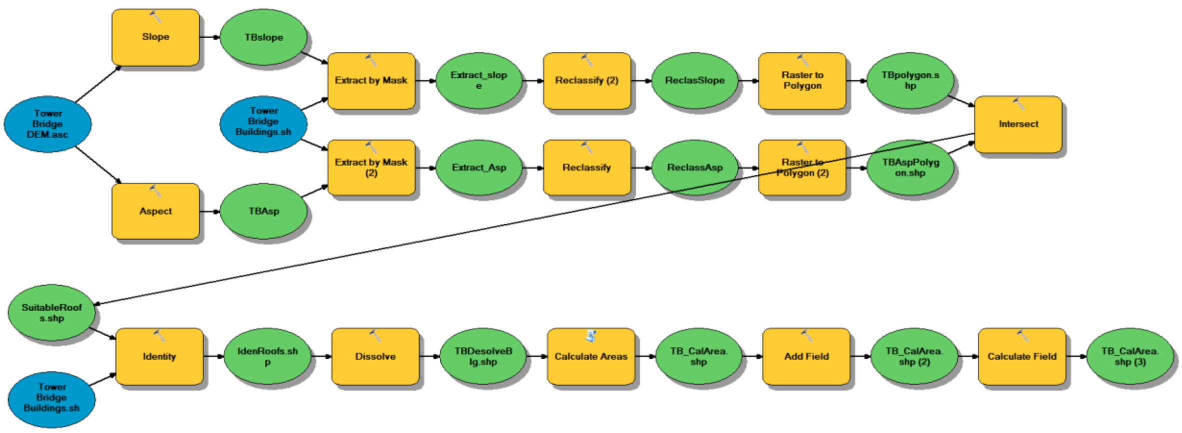

Figure 7: Detail view - Tower Bridge Model

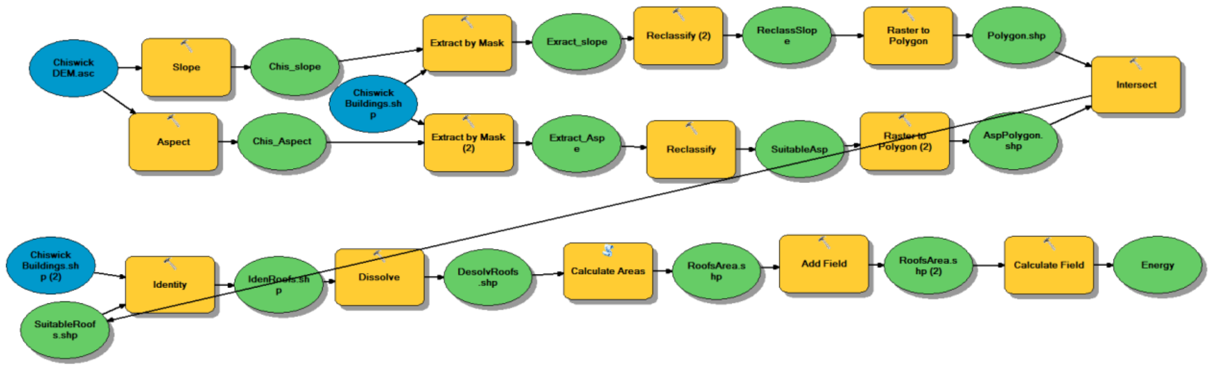

Figure 8: Detail view - Chiswick Model