Solar Electricity Potential Based on ArcGIS Maps and Consumption of Energy for Engineering Faculty Buildings in Anadolu University

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Abstract

It is very significant to predict the solar energy potential correctly while solar panel applications are being carried out. This study describes a model for prediction of solar energy potential and compares the prediction and energy consumption values in Engineering Faculty building roofs of İki Eylül Campus in Anadolu University. In order to evaluate this potential, a digital surface model (DSM) and high-resolution orthoimage are modeled and annual solar radiation maps included direct and diffuse solar radiations are generated at Solar Analyst platform of ArcGIS. Then, optimal tilt angle, aspect and site latitude factors are considered in selection of panel location. When total consumption and prediction values are compared the results show that estimated energy are compensated a substantial amount of energy consumption of the selected area.

Keywords—Energy consumption; Solar potential; ARCGIS

1. Introduction

In order to reduce hydrocarbon dependence in oil and electricity generation, alternative energy resources are great importance in the world. As it is known, solar is one of the most important sources today due to its important advantages [1]. Solar energy is important in production of electricity applications. It is also an alternative to fossil fuels because it is clean and has a low production cost. At the same time, solar energy has the highest potential when we compare other energy sources.

The solar radiation on the earth consists of direct radiation, diffuse radiation and ground-reflected radiation [2]. In addition, there are various factors effects the incoming solar radiation. Incoming solar radiation belongs to location and seasonal effects of the atmosphere. Rotation of Earth around in its own orbit and around the Sun affects the incoming solar radiation [3].

The solar radiation can be determined using the altitude data and the coordinates of the selected region by using some specific software. ArcGIS is one of the significant program to analyze locations for assessment energy potentials for specific region [4,5]. Nevertheless, PV potential of a selected area can be calculated by using LIDAR data [6]. Grass-r.sun, SagaGIS are ESRI's programs can be also used to analyze solar radiation in Wh/m^2 as well as ArcGIS [7, 8].

Suitable roof areas are identified using the property analysis tool and analyzed by using GIS to find energy-potential and its solar maps[9].

Bergamasco and Asinari are determined the PV potential for all area in Italy, and demonstrated a study find to get suitable rooftop installations analyzed in GIS [10].

To handle the analysis with insufficient reliable solar radiation data, some application models have been improved[11]. Three basic fields are reference points in the indicating of this study:

- modelling solar irradiation,
- calculating suitable rooftop size,
- determining solar energy potential from annual solar radiation.

Solar panel installation is an available method not only decreasing energy costs, but also generating electricity in a profitable and environmentally friendly way [12].

The system brings up a question how much the PV potential of building roofs that are to be intended to install solar panels? Therefore, it is very significant to estimate the daily, monthly or yearly irradiation accurately. Determining whether the area to be installed is suitable for a photovoltaic panel significantly affects energy production. For these reasons, solar energy potential estimation in the region where the solar panel installation is constructed is an important issue for solar energy investment.

In this study, the solar energy potential are predicted by using solar radiation model based on ArcGIS and the predication and energy consumption values are compared for Engineering Faculty of İki Eylül Campus in Anadolu University.

2. Application methodology

Description of applied area, estimation of roof top area, tilt angle with aspect factors and solar radiation model are presented in this section.

2.1. Description of Applied Area

The selected area is located at North Hemisphere, 39°48' latitude and 30°32' longitude. The high resolution orthoimage of the Engineering Faculty is given in Fig. 1. Digital Surface Model (DSM) of the Faculty is shown in Fig.2. The 0.5m resolution raster data has selected a clear view to parcel region in this study.

Fig.1. Orthoimage of Engineering Faculty İki Eylül Campus.

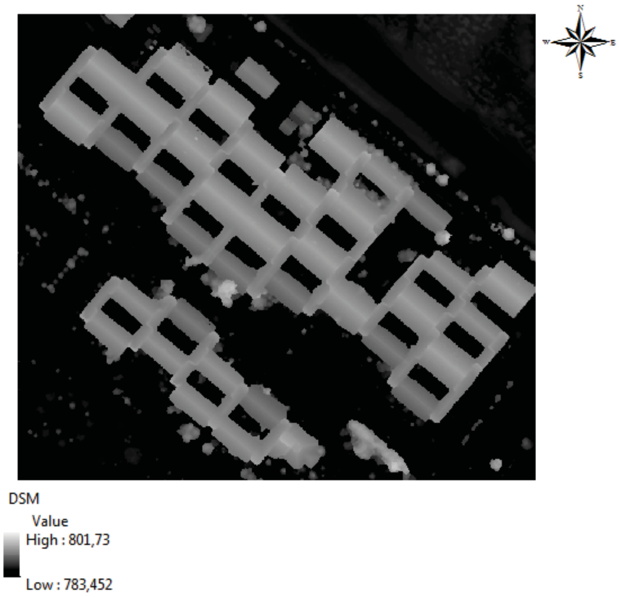

Fig. 2. DSM of Engineering Faculty at İki Eylül Campus.

2.2. Rooftop Area Estimation

DSM and high-resolution orthoimage are utilized to calculate the rooftop area in m^2. Roof dimension is digitized for each parcels in the ArcMap. To produce high quality segmentation result, the selected area is divided into the different five regions by area in order. However, some roof constructions are excluded this analysis because of the inapplicability of roofs. The suitable roof area is determined as 13,320 m^2 by using ArcCatolog platform for this selected region.

2.3. Tilt Angle and Aspect Factors

As is known, geographical features such as elevation and aspect basically affect the total amount of incoming radiation for an area [12].Initially five areas are selected to analysis by observing aerial imagery in this study. Aspect and slope maps are generated with same resolution, and then these maps are reclassified. In the slope map all pixels representing a slope lower than 35^0 are taken suitable tilt angle for solar energy potential [13]. The slope map of the Faculty and suitable roofs are indicated by using this data as well as aspect map is given in Fig. 3 and Fig. 4., respectively.

Fig. 3. Slope map of Engineering Faculty at İki Eylül Campus.

Fig. 4. Aspect map of Engineering Faculty at İki Eylül Campus.

After aspect analysis is handled, the classification is realized according to Fig. 5. Aspect (azimuth) value is taken at 67.5^0-292.5^0 that is available for generating energy since the south facing parts of the rooftops receive best amount of solar radiation [14]. The structure of buildings is one of the most important factors for determining PV potential. These systems can be installed on the exterior facades of buildings; however, the roofs are only considered for PV installation in the selected area.

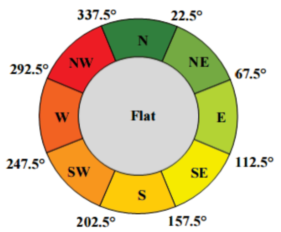

Fig. 5. Nine azimuth classifications and rooftop azimuths [14].

Aspect is a significant factor to evaluate the amount of incoming radiation on the Earth. Fig.6. shows the Sun path that shows aspect of incoming radiation changing in winter and summer and suitable tilt angle varies as a results of this condition. However, solar radiation reaches its maximum value at right angle. In the summer months, the incoming radiation is close to right angle but it is opposite of winter. For this reason, optimum tilt angle is not the constant value.

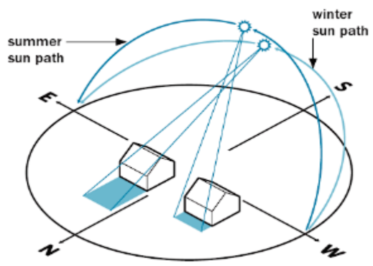

Fig. 6. Sun path in summer and winter [15].

It is observed that tilted south-oriented roofs take more radiation than other parts of the roof construction. To obtain the most suitable roof area, aspect and slope maps are reclassified and correlated. According to overlay process, one map is derived from the inclination (slope) and orientation (aspect) maps consequently by using ArcGIS. This process is essential for this analysis due to representing the most suitable building roof area. After the overlay analysis, the distribution of the suitable and unsuitable roofs of the Campus is given in Fig. 7.

Fig. 7. Overlay map of Engineering Faculty

According to Fig.7. marked roofs in yellow are suitable for PV panel installation. The total area of the campus is calculated firstly, then the most suitable roof areas are specified using the polygons in the ArcMap platform, lastly solar radiation model is developed.

2.4. Solar Radiation Model

As the solar radiation and overlay map of the Faculty are analyzed, it is observed that building roof edges and lower elevation roofs may have low annual solar radiation while comparing the other parts of the rooftop. The solar radiation calculations of Solar Analyst tool are as follows:

$$Global_{tot} = Dir_{tot} + Dif_{tot} \quad (1)$$

Global radiation (Globaltot) is the sum of the direct and diffuse radiation. It is the intensity of solar power in Watt per square meter [W/m^2]. Total direct irradiation (Dirtot) for a selected region is the sum of the direct insolation (Dirθ,α) from all sun maps[16]:

$$Dir_{tot} = \Sigma\, Dir_{\theta,\alpha} \quad (2)$$

The direct irradiation (Dirθ,α) with a centroid at zenith angle (θ) and aspect angle (α) equals the below equivalent:

$$Dir_{\theta,\alpha} = S_{Const} \text{ x } \beta^{m(\theta)} \text{ x } SunDur_{\theta,\alpha} \text{ x } SunGap_{\theta,\alpha} \text{ x } \cos(AngIn_{\theta,\alpha}) \quad (3)$$

The direct radiation (Dif) is in W/m^2 andhas these factors; Sconst is Solar flux (constant), $\beta^{m(\theta)}$is the transmissivity of the atmosphere for the shortest path in the direction of the zenith and SunDurθ,α is the time duration represented by the sky sector. SunGapθ,α is the gap fraction of the sun sector. AngInθ,α is the angle of incidence between the centroid of the sky sector and the axis normal to the surface.

$$Dif_{\theta,\alpha} = R_{glb} \text{ x } P_{dif} \text{ x } Dur \text{ x } SkyGap_{\theta,\alpha} \text{ x } Weight_{\theta,\alpha} \text{ x } \cos(AngIn_{\theta,\alpha}) \quad (4)$$

The diffuse radiation (Dif) is represented in W/m^2 and calculated by multiplying these factors; R_{glb} is the global normal radiation. P_{dif} is proportion of global normal radiation flux that is diffused and it is 0.2 for very clear sky conditions, 0.7 for cloudy sky conditions.Dur (time interval), the gap fraction is $SkyGap_{\theta,\alpha}$,$Weight_{\theta,\alpha}$ (proportion of diffuse radiation), $\cos(AngIn_{\theta,\alpha})$ angle of incidence.

ArcGIS has point solar radiation and area solar radiation parts. In this study, area Solar Radiation tool is handled. When building rooftops are identified then annual solar radiation maps are generated for that region.

It is essential to compile the results in order that energy potential on each selected roof can be calculated. General energy formula is given as [17].

$$E= A.r.H.PR \quad (5)$$

E = Solar energy (kWh),
A = Total suitable PV panel Area (m^2),
r = PV panel yield (%),
H = Annual insolation (kWh/m^2),
PR = Performance ratio coefficient

3. Application and Results

Suitable roof analysis and comparison of the prediction and consumption values are determined for the selected region. The DSM data and aerial imagery are important for determine the location of the analyzed area. Statistical analysis has been carried out to explain the relation of the factors affecting the energy potential and then to estimate the energy potential of the selected area. Following this analysis, total energy potential of the roofs is determined. Suitable roof space for PV panel installation is specified as 13,320m^2 using ArcGIS. The estimated solar energy potential value for this area is 2.06MW. Annual Radiation Engineering Faculty of İki Eylül Campus is shown in Fig. 8.

Fig.8. Annual Radiation of Engineeering Faculty

To determine the suitable number of panels, a 260 W panel of 1.62m^2 is selected which is currently used in the renewable energy lab of İki Eylül Campus in Anadolu University [18]. The number of PV panels are determined in ArcMap platform. Since the shape of some roofs and the panel size are not suitable, the number of the most suitable roof area to install is 13,320m^2 and the number of panels required is 8,818 according to the chosen PV panel. Lastly, solar radiation maps of buildings of engineering faculty is produced for five months to observe how much of the solar energy potential could meet the energy consumption. Radiation value of Engineering Faculty of İki Eylül Campus for five months is given in Fig. 9.

Fig.9. Radiation value of Engineering Faculty for five months

The faculty is composed of two buildings. Both parts of the faculty have adjoined buildings and almost same height due to this construction they have minor shadow effect on each other. Energy consumption cost and energy potential of Engineering Faculty of İki Eylül Campus is drawn in Fig.10. Since energy consumption data includes only five months, solar radiation analysis is applied for these specified months.

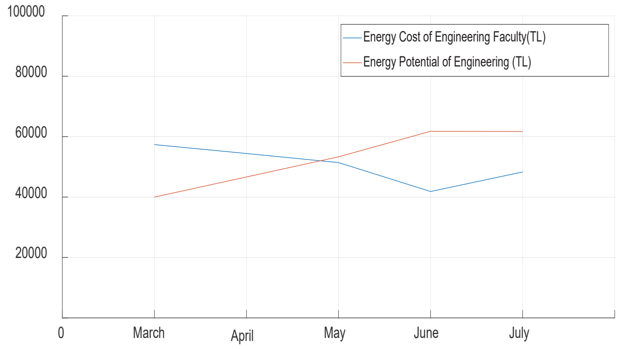

Fig. 10. Energy consumption cost and energy potential of Engineering Faculty of İki Eylül Campus.

Once the energy cost and the estimated profit are compared, the output of the solar energy can be observed and the difference reaches its maximum value on June that receives the most amount of irradiation.

4. Conclusions

In this study, the solar energy potential is find on the Solar Analyst tool at ArcGIS using DSM data Engineering Faculty of Anadolu University İki Eylül Campus by considered some geologic factors. The results show that azimuth factor has a significant effect on incoming radiation, south facing parts of buildings receive most amount of radiation and tilt angle is also identifier factor. The results verified that the annual solar potential on vertical rooftops is less than the smooth parts, also it has been seen that estimated energy are compensated a substantial amount of energy consumption.

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