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The Utilization of Solar Radiation in Generating Electricity for Developing The Tourist Areas in the Southern and Southeastern Mountains Slopes of Duhok Province

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A B S T R A C T

The study aims to determine the potentiality of investing the solar radiation in Duhokprovince's southern and southeastern mountains, and its use in developing tourismprojects. It also aims to set an investment plan for the solar radiation received by the solar panels to produce the electrical energy that meets the needs of the tourism areas. The selected study area contained samples of solar cells, which were installed to identify the amount of radiation recorded as (19.06) kW/h/day/panel, and in turn generates (3.0) kW/h/day of electrical energy. By utilizing some technologies and simulation methods, anarea of approximately (29) km length and 1 km width within the same mountain series wassuggested to be used to establish (1,000,000) panels with special specifications. This will provide approximately (87,000) Mega W/h/day of electrical power that will satisfy the area needs of electricity. Such a procedure will work to enhance the development of tourism areas and provide the electricity required for hotels, resorts, restaurants, health spas and other facilities in the area. As a result, this will reduce the load on the governmental electricity network, and will make this project leading one in the field of national development and sustainability.

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استخدام الاشعاع الشمسي في توليد الكهرباء لتطوير المناطق السياحية في سفوح الجبال الجنوبية والجنوبية الشرقية لمحافظة دهوك

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خلاصة:

يهدف البحث إلى تحديد إمكانية استثمار الإشعاع الشمسي في الجبال الجنوبية والجنوبية الشرقية لمحافظة دهوك، والاستفادة منه في تطوير المشاريع السياحية. كما يهدف أيضا إلى وضع خطة استثمارية للإشعاع الشمسي الذي تستقبله الألواح الشمسية لإنتاج الطاقة الكهربائية التي تلبي احتياجات المناطق السياحية. تحتوي منطقة الدراسة المختارة عينات من الخلايا الشمسية التي تم تركيبها للتعرف على كمية الإشعاع المسجلة بـــ(19.06) كيلوواط/ساعة/يوم/لوحة، والتي بدورها تولد(3.0) كيلوواط/ساعة/يوم من الطاقة الكهربائية. ومن خلال الاستفادة من بعض التقنيات وأساليب المحاكاة، تم اقتراح إنشاء مساحة تبلغ حوالي(29)كيلومتراً طولاً و1 كيلومتر عرضاً ضمن السلسلة الجبلية نفسها، لإنشاء ()1,000,000 لوح بمواصفات خاصة، إذ سيوفر هذا النظام حوالي (87,000) ميجاوات/ساعة/يوم من الطاقة الكهربائية التي ستلبي احتياجات المنطقة من الكهرباء، وسيعمل مثل هذا الإجراء على تعزيز تنمية المناطق السياحية وتوفير الكهرباء اللازمة للفنادق والمطاعم والمنتجعات الصحية والسياحية وغيرها من المرافق في المنطقة، الأمر الذي سيؤدي إلى تخفيف الحمل على شبكة الكهرباء الحكومية، ويجعل هذا المشروع رائداً في مجال التنمية الوطنية والاستدامة.

الكلمات المفتاحية: الإشعاع الشمسي؛ طاقة شمسية؛ التنمية السياحية؛ استثمار ؛ الاستدامة

- **Introduction:**

Solar radiation as an investment climatic element is at the forefront in the fields of environmental investments, which involve the tourism development in developing and developed countries by using solar panels to generate electricity.

The study problem determined by the decline in electricity services and the frequent cuts of the power supplied to tourism areas. Additionally, there has been reluctance on the part of some tourists to visit the tourism areas with polluted atmospheres, due to dependence on fuel (oil and gas) that pollute the atmospheres of these areas with carbon, sulfur and other greenhouse gases that are used for heating or cooling purposes (such as chlorine fluorocarbon gas), especially during the hot summer season.

Furthermore, there are problems of the stops of water pumping facilities to the tourist hotels due to frequent power outages and the lack of leisure services. These reasons have created the need to go ahead with a plan to develop these areas through the investment of solar radiation that reaches the mountains slopes, and duly use it in producing electricity and utilize it in developing the infrastructure of all tourism projects in the study area.

The study assumes that there is a great potential for the investment of solar radiation in the southern sides of the mountain slopes in the targeted area; a procedure that will develop tourism areas and minimize the pressure on national electricity. Moreover, the annual rate of solar radiation reaching the study area is about (19.60 $kw/h/m^2$); an amount that qualifies this area to set up development projects, not only in the field of tourism but also in all other fields.

Solar radiation is considered one of the most flexible and cheapest elements required for providing electricity, especially after the great development and widespread applications of solar radiation in electricity generation fields. The living conditions improvements, diversification of expenditure areas, steady population growth and the development of the transportation network between urban and rural areas, have all contributed to the encouragement of the tourism investment and the achievement of some profits that can promote the tourism development and make greater scope for tourism investment by using solar radiation to generate electricity.

The significance of this study comes from its being as a pioneering step in conjunction with the widespread interest in the transition from fossil energy sources that pollute the atmosphere and the environment to a clean, renewable, non-depleted and cheap energy source, especially if we know that the study area enjoys a location within the second range of the solar belt in the northern hemisphere of the Earth with an encouraging annual rate of solar radiation that can be invested and developed for the purpose of bringing about the required ecological climate balance in Kurdistan Region of Iraq.

- **Methodology and Materials:**

The descriptive analytical methodology used in this research monitors and analyzes solar radiation spatially follows up its observations during a specific period of time, and identifies its characteristics for investment and development purposes.

Furthermore, since the research targets the climatic applications used for the purpose of developing the natural tourism environment, field surveys have been conducted to assess the sites for installing the solar cell panels and define the best angles to receive the solar radiation, with the use of GPS application to locate the coordinates and directions of the cell panels. Also, the used spatial analysis method is based on the study area natural data analysis, and explores the spatial relationships of the phenomenon elements with the possibility of investing and evolving them.

The data collected at two stations, located near the study area, were utilized to observe the solar radiation and some other climatic elements.

Moreover, the quantitative approach, mathematical formulas and software programs such as ARCGIS10.3 for 3D location mapping and digital models (DEM) for the study area were used side by side with some other applications, such as METEOBLUE and GLOBAL WEATHER CFSR DATA FOR SWAT to obtain some solar radiation values and cloud ratios to compensate for some missing data that are required for radiological assessment purposes. Also, the Day Time Declination Angle application wasused to measure the brightness angles during each month of the year and the day lengths by hours and minutes on the basis of the coordinates of the study area.

The study area comprises the Southern and Southeastern slopes within Akre district, with a length of approximately (29.639) km and 1 km wide, **in two areas which are SariSada and Bakirman** within a longitude of (E43º 40' 33'')to (E 44º 02' 26'') and a latitude of (N36º 49'19'') to (N36º 44'04''), in Dohuk province, see figures (1) and (2). Solar radiation is concentrated in these locations with their highland plateau (661m), as they are considered the best locations conducive to obtaining radiation angles near to the vertical angles as compared to the plain areas

.

Fig. (1): Geographical location of the Study Area

Fig. (2): The study area location

- **Collected Data:**

Solar radiation in addition to other climatic elements, that affect the generation of electrical energy by using solar panels were observed and studied. Each element was observed, recorded then analyzed within this research to identify the possibilities of generating electrical energy that would be used for sustaining and developing the tourism areas in the study sites.

1. Solar Radiation angle:

It is the angle formed between the solar radiation beam and the horizon line. Itis called the declination angle [1]. With the use of the Day Time Declination software, these angles are recorded as presented in table (1).

Table (1): The monthly average solar radiation angles (in degrees) in the study area

Months	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Average SR angles (°)	32.38 °	40.1 °	51.6 °	62.59 °	72.18 °	76.34 °	74.35 °	66.47 °	55.29 °	34.38 °	34.26 °	30.23

Also, samples of solar panels were installed, and solar radiation angles were installed in places on the south and south-eastern slopes of the study area as shown in figure (3).

Fig. (3): A sample of the solar panel installed on the study area.

2. Day length:

Day length means the duration within which the Earth receives solar radiation. On this basis, the amount of radiation and the number of brightness hours received by the study area stations are determined. There are two types of solar brightness, namely the theoretical brightness and the actual brightness.

Theoretical brightness is the time between sunrise and sunset [2], while actual brightness refers to the duration when the sun is clearly visible during the actual brightness period. There are several effects by factors that reduce the actual brightness rather than the theoretical brightness. Examples are the clouds and dust that block or reduce the arrival of solar radiation to the study area. These are added to the atmospheric components such as clouds and pollutants that play a role in increasing the percentage of the diffused radiation. For instance, on a very cloudy day, most of the solar radiation is diffused. The ratio of direct-to-diffuse radiation varies with latitudes and climate, and the percentage of diffused radiation is much greater in high latitudes and cloudy areas than low latitudes and sunny areas [3].

Moreover, the percentage of diffused radiation beam is much higher during the winter months than summer months in high latitudes and cloudy areas, as compared to sunny areas that tend to form less seasonal changes between the diffused and direct radiation beams [2].

The location of the study area is characterized by a sunny atmosphere almost during most of the seasons, except winter months. The study area indicates a long day from the end of spring months till the end of summer months, while the length of day hours decreases from the end of autumn and lasts to the end of winter season. The hours that represent the day length in the study area were also determined by means of the Day Time Declination software, as shown in table (2).

Table (2): The average of the actual day length in (h.min.sec.) within the study area

Months	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Average actual day length	10.05.10	10.46.45	11.47.44	12.49.22	13.42.09	14.09.17	13.56.26	13.10.08	12.10.13	11.08.42	10.16.22	09.50.34

3. Amount of solar radiation:

The process of calculating the solar radiation requires identifying some of the main factors affecting the amount of solar radiation [4], that reaches the study area, and the type of surfaces whether low or high, horizontal or oblique.

Monthly rates of the total solar radiation reaching the study area were collected and measured in (kW/m^2) for the period from 2010 until 2018 as presented in table (3).

Table (3): Monthly rates of the total solar radiation in (kW/m^2)[5] []

Months	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Average rates of Solar radiation (kW/m^2)	7.4	12.1	16.6	22.6	26.3	30.5	32.0	28.4	24.1	16.9	10.5	7.9

4. Sky Serenity:

The clarity of the sky is one of the factors that affect the arrival of solar radiation to the study area. Hence, the amount of clouds in the sky was measured using the eighth system of clouds counting. The records for the study area present an annual rate of (2.4) of the amount of clouds in the sky. Also, the lowest monthly rate during the summer and autumn months with an average of (1.3) of the amount of clouds was recorded as presented in table (4).

Table (4): Monthly rate of clouds amount in the study area [5]

Months	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Clouds amount	4.75	4	3.75	3.5	2.5	1	1	1	1	2	2.25	3

5. Climatic Elements:

The study area is affected by several natural factors, where the climatic elements have an active role in the development of tourism activity in the study area, which does not experience a significant extreme in the climatic elements and for many months during the spring, summer and autumn.

- *The suitable temperature degrees:*

The temperature degrees fluctuate seasonally between summer and winter months and annually as well. Hence, They affect the climate of the tourism environment [7]. The temperature that is not more than (25C^o)and the humidity that does not exceed (60%) are determined within the ideal climatic characteristics for tourism during a season or a specific period. The climatic elements, such as moderate temperature degrees, fresh air, mild humidity and solar radiation affect the determination of tourism area and act as factors that attract tourists. The thermal rates refer to the tourist thermal characteristics in the study are as shown in table (5) below:

Table (5): The rates of monthly temperature degrees for the duration (2010-2018) in the study area.[5] []

Months	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Temp. degree rates C^o	6.1	8.1	11.2	16.9	23.2	29.8	33.7	34.0	28.8	21.7	13.7	8.2

- *Relative humidity:*

Humidity as an attractive characteristic of the tourism areas, as mentioned earlier, should approximately reach (60%). Moderate non-extreme proportions of relative humidity ranging from (20-64%) characterize the study area. They did not exceed (65%) as indicated in table (6).

Table (6): The monthly humidity rates (RH%) for the duration (2010-2018) in the study area.[5] []

Months	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
RH% rates	64	60	58	49	34	21	20	20	22	33	49	59

In order to determine the study area's need for electrical energy generated from solar radiation cell systems for air conditioning (cooling and heating) during the tourist seasons. Additionally, to provide comfort and all other requirements of the tourist environment, Tom's equation was applied using relative humidity to determine the comfort months in the study area. The formula of the equation used to calculate the temperature and humidity index follows [8]:

THI=Td - (0.55 - 0.55*RH) (Td-58) (1)

Where:

THI = Comfort index,

Td = Dry Air Temperature in Fahrenheit,

RH = Relative Humidity.

The comfort months in the study area were classified according to Tom's classification as shown in table (7).

Table (7) Comfort index according to Tom's classification in the study area for the period of (2010-2018)

Months	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Temp. (F)	45	49	53	61	68	73	77	77	72	66	57	49
Comfort index	C-	C-	C*	P	P	P-	H*	H*	P-	P	C	C-

- *Wind speeds and directions:*

The increase in wind speed is considered a non-desired factor that affects the tourism areas since it irritates the dust storms [8]. The wind speeds and directions in the study area are clearly demonstrated in table (8), where the presented data indicate a suitable speed for the establishment of tourism projects.

Table (8): The monthly wind speed rates in the study area for the duration (2010-2018).[6]

Months	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Wind speed rates	1.3	1.6	1.8	1.9	2.1	2.4	1.9	1.9	1.7	1.7	1.3	1.3

- *Solar radiation:*

A field survey and duly data collection were carried out to calculate the amount of solar radiation during the installation of solar systems at the mountains slopes in the study sites, and to convert it to electric energy

for investment in the areas of the tourism environment. Furthermore, the inclination angle equation was applied to determine the best inclination angle to install the solar radiation panels in the study area[9]. This equation is exclusive for the areas located at latitude of (25^o to 50^o), and it is applied as follows:

Inclination angle = (latitude *0.76) +3   (2)

For the study area on latitude of (36^o), the output of the equation will be:

The inclination of = (36^o * 0.76) +3 = 30.36

At this angle of inclining, the solar panels have achieved the best harvest for the solar radiation to generate as much electricity as possible. The amount of radiation reaching the study area was recorded (19.60) $KW/h/m^2$. Experimental models of solar radiation cells used with the specifications described in the model and the received solar radiation to produce electric energy are shown in figure (4).

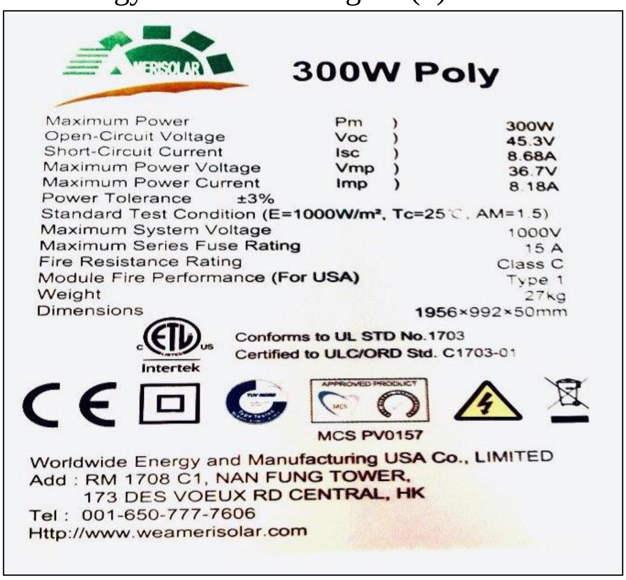

Fig. (4): Solar radiation panel cell specifications (adopted example) [10]

The efficiency of the panel and its electrical capacity to receive solar radiation are shown in the following listed steps [11],[12]:

<u>Step 1:</u> The efficiency of the panel:

$\eta = P_{max}/(1000W/m^2 \times Area)$ (3)

Where:

Area: it is the area of the cell to measure its efficiency, m^2 .

P_{max}:The maximum capacity of the solar cell, can be obtained from equation (4)

$P_{max} = V_{OC} I_{SC} FF$ (4)

Where:
V_{oc}: is the open circuit voltage, measured byvolts,
I_{SC}: Short circuit current, measured by amps.
FF: The fullness factor, calculated from the equation :
$FF=I_{mp} \times V_{mp}/I_{sc} \times V_{oc}$
$FF= (8.18\times36.7)/ (8.68\times45.3) = 0.7635$
$P_{max}=V_{OC}*I_{SC}*FF= 45.3\times8.68\times0.7635=300.21$
$\eta= P_{max}/ (1000W/m^2\times \text{Area}) = 300.21/ (1000\times1.94) =\%15.475$
Step 2: Based on the first step, it is indicated that the used panel could convert (15.475%) out of the solar radiation to electricity and thus the electrical capacity produced from 19.6 KWh/m^2-day will be as follow:
$19.6KWh/m^2 - day \times 15.475\% =3.03$ KWh/day
This is the power produced by this panel per day. To calculate the current that can be produced of 3.03 KWh/day, it will be as:
$I= (3033Wh/day)/220=13.79Ah/day$

- **Results and Discussion:**

Solar radiation is considered one of the renewable energy sources that have recently been widely used to generate electric energy. Yet, it affected by several factors in the study area and in such a way that makes it vary from one side to the other. These factors are:

1. ***Solar Radiation angle:***

The ***Solar Radiation angle***is considered one of the main factors affecting the distribution of solar radiation in the area. Its importance in the study area is clearly evident on the slopes facing the radiation that reached approximately perpendicular to these slopes within the southern sides mountain series, which are considered the areas that mostly received the solar radiation compared to the opposite slopes on the other side of the mountainous series which are located in the shade.
By observing the data of solar radiation angles, it becomes clear that the highest angles (76.34) were recorded during the months of June and July, as presented in table (1).
The solar radiation that reaches the study area is more intense and concentrated, as it traverses a shorter distance and falls on a smaller area, thus reducing the reflected and refracted radioactive wastes, and in turn making the slopes that are facing the radiation more economical and investing so as to generate electrical energy.

2. ***The length of the day:***

The outcome results of the Day Time Declination software also showed that the annual average number of hours of actual brightness reaching the study area is about (11:59:24), as it is evident from the results shown in table (2).As such, the potentiality of investing the reached solar radiation is concentrated in the summer time, especially during daylight hours after 12:00 pm, depending on the solar radiation angle and the length of daylight hours. Spatially speaking, it is concentrated on the slopes facing the solar radiation in the study area.

3. The amount of solar radiation:

Since the study area is located at altitudes of approximately (661) m, these slopes with plateau heights are the best areas for harvesting the largest possible amount of the vertical radiations that reach the study area. Additionally, the amount of radiation that reached the horizontal surfaces varies from the amounts that reached the sloped surfaces. Also, calculating the amount of solar radiation will make it possible to calculate the amount of electricity generated by this solar radiation and then use it in the development and sustainability of the tourist areas.

It is also observed that the areas, where the day hours are long and receive a large amount of solar radiation, will be qualified for the production of electric power. It is evident from the the data presented in table (3)that the monthly rates of the total solar radiation in the study area increase during spring, summer and autumn, while they decrease during winter. Added to that, it is noticed that the Southern and Southeastern sides of the study area, especially those facing the solar radiation receive a larger amount of radiation compared to the Western sides. This is so because the solar radiation reaches these sides with angles near to vertical, while the radiation that reaches the western sides does so with inclined angles.

On this basis, the study area that receives an appropriate amount of solar radiation that reaches (19.60) kW/h/m^2 can generate suitable electrical energy that can be used in several fields and thus reduces the pressure on national electricity. This can be achieved using systems of solar radiation cells, which are made of crystallized silicon with special specifications. Several models of solar radiation cell panels have been installed and tested. They have all the capacity to obtain an appropriate amount of electrical power that can be invested in the tourist areas and achieve the research goals.

4. Sky serenity:

When the solar radiation penetrates the atmosphere during the day, it is exposed to reflection and refraction processes as the atmosphere absorbs a part of it and leads to an increase the temperatures on the surface of the Earth. This will contribute in the evaporation of the existing air moisture from the surface of the soil and leads to the formation of clouds that cause a reduction in the amount of solar radiation that reaches the Earth. In turn, the formed clouds will reduce the transparency of the weather.

Thus, on a partly cloudy day, the solar radiation system produces about (80%) of its full capacity. Even on a full cloudy day the system can produce (30%) of its capacity[14]. Consequently, the thicker clouds in the sky, especially those having dark base, will lead to a decrease in the amount of radiation reaching the area. Thus during cloudy days, the temperature will decrease, while it will be higher during sunny clear days[1].

The increased clouding and rainfall are considered factors that hinder tourism and recreation, especially if the clouds are of the heavy rainy season, accompanied with other with climatic phenomena. Accordingly, on analyzing the clouding rates shown in table (4), it is found out that the percentage of cloud formation decreased starting from spring months, through summer till the end of autumn months. This gives an indication about the length of the period when the sky is clear, the potentially of solar radiation reaching the study area without any cloud obstacles, and the lowest percentages of the reflected and lost radiation.

This contributes to having an appropriate amount of solar radiation throughout the year in the study area, thus make it a tourist area that can enjoy climatic conditions and invest its solar radiation in the development of the infrastructure of tourist and health resorts.

5. *Climatic elements:*

The study area is affected by several natural factors as the climatic elements have an active role in the development of tourism activity. As such, the study area does not experience a significant extreme in the climatic elements for many months during spring, summer and autumn.

- *The suitable temperature degrees:*

The ideal tourist climate can be determined as the mild climate with no excessive heat or cold during the tourism season or the whole year. It also it does not have a big temperature fluctuation during the day and night or during a short period. In addition, the ideal tourist climate is characterized by having a high number of sunny days with moderate temperature and mild wind speed [15].

The shown temperature rates (in table 5) are suitable for the tourism activity, as it indicates moderation in temperature for long months during the year, which is not extreme between high and low temperature degrees. This is added to the length of the tourist season, which extends from the end of winter through spring, summer and autumn. Accordingly, the study area enjoys moderate temperatures that allow for tourism investment through the development of infrastructure associated with the provision of non-polluting electricity for the environment by installing solar radiation cell systems in the study area.

- *Relative humidity:*

Based on the records of humidity in the study area that are represented in table (6), relative humidity represents a favorable climate for tourist purposes with percentages that are not considered a negative factor that affects solar energy systems as they have moderate proportions throughout the tourist seasons. Additionally, by using Tom's equation to determine the comfort index in the study area, the comfort months in the study area were classified as presented in figure (5).

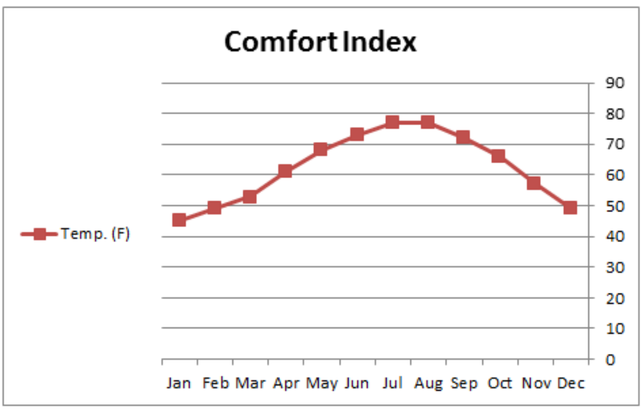

Fig. (5): Comfort index according to Tom's classification in the study area for the period of (2010-2018)

As the study area reaches these results concerning comfort index levels, as referred to in table (7), it needs to be supplied with electricity generated from solar energy to provide cooling services during the tourist seasons for the months of summer, and heating services during winter months. Although its consumption of electric energy based on fossil fuels has reached 279187 mega W/h in 2015, and (437036 mega W/h) in 2020, it is expected to be (155032 mega W/h) in 2025 and about (357100 mega W/h) in 2030 [16].

- *Wind speeds and directions:*

The wind speed in the study area does not exceed 3 meters per second. This confirms its freeness from the fast winds that stir the dust storms; a phenomenon that is inconsistent with the establishment of tourist projects. The winds in Akre district are characterized by being pure and free from dust storms which rarely reach these areas due to the low wind speed in the area, namely less than (3) meter/second. This is due to the fact that there is a heat homogeneity with the effect of the long hours of solar brightness during the hours of the day; thus qualifying the area to establish projects represented by installing energy systems based on solar radiation so as to generate electricity and provide tourist services, such as lighting, heating and cooling in summer and winter months.

- *Solar radiation:*

Solar radiation is considered the core of the climatic elements that affect the identification and establishment of tourism projects and spas. The southern and southeastern sides of the mountain slopes in the study area enjoy having large percentages of solar radiation with angles approaching the vertical. This contributes to the increase in the hours of sunbathing during spring, summer and autumn seasons, especially if we know that the brightness of the sun and the length of the duration of sunbathing are factors of tourists' attractions. In addition to that, the blue bright sky side by side with the dryness of the air are important factors that contribute to the flow of tourists to these areas [3].
Solar radiation as an electric power generator also has a key role in the development of the infrastructure as a basis for the electric grid and the provision of all the requirements of the tourism environment and spas within a clean and pollution-free environment.
Based on the obtained results from solar radiation reaching the study area and the specifications of the panels utilized in the study, with one panel producing (3) KW/h/day per square meter, using the simulation method and virtual reality for the study area, if (1,000,000) units of solar radiation panels are used in the study area, as presented in figure (6), the produced electrical energy will be approximately (87000) Mega W/h/day.

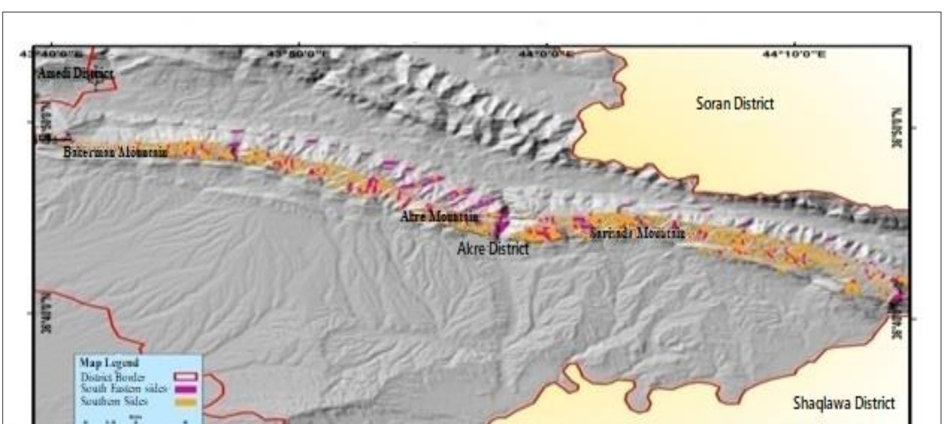

Fig. (6): The Southern and Southeastern sides of Akre mountain series

This will contribute to meeting all the needs of the study area of electric power for tourism purposes, reducing the pressure on national energy and maintaining a clean and pollution free environment.

- **Conclusions:**

The study concludes that:

- Since study area is located within the second part of the sunny belt in the north hemisphere of the earth, the annual rate of solar radiation received by the area is suitable for investment to develop the targeted area.
- The spatial characteristics represented by the site and position have a major role in the process of investing the climatic elements within the geographical potentiality to generate the electrical power of the received solar radiation.
- Also, the selected slopes with plateau heights are the best in harvesting the highest amount of perpendicular radiation reaching the study area.
- The winds in Akre district within Duhok Governorate, are clear and free of dust due to their low rate of speed, not more (3) m/sec throughout the year; hence suitable for the solar radiation projects.
- Additionally, the sun brightness and the length of sunbathing period are considered as tourism attraction factors. As such, solar radiations plays a crucial role in generating electrical energy.
- Furthermore, the quality and characteristics of solar panels form an important factor in the process of converting solar radiation into electrical energy and making the solar radiation project successful through the provision of electrical services requirements for development purposes.

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