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A feasibility study of solar energy in South Korea

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ABSTRACT

Through the years using renewable energies become one of the interesting issues in each country. Among the renewable energies, solar energy is more attractive. Governments planned to install more solar power plants. Feasibility study is an important step of every solar energy project. This paper investigates the feasibility of using solar energy in different regions of South Korea. For this purpose, the maximum, minimum, and average values of yearly horizontal radiation were calculated for 24 stations for a five-year period. Monthly and annual clearness indices for these stations were then calculated. The annual average horizontal radiation map and Geographic Information Systems (GIS) maps of global horizontal radiation were prepared for each month of the year. Maps were then prepared for the annual average of monthly mean clearness index for the 24 stations. Furthermore, the sunshine hours were presented for 78 stations for a three-year period. The results show that the central and southern regions of South Korea receive higher quantities of horizontal radiation, but not the northern areas.

1. Introduction

In the 1970s, there were significant petroleum shortages and higher prices. There were two big crises, one in 1973 (an oil crisis) and one in 1979 (an energy crisis). Countries have since planned many programs to use renewable energy like solar, wind, geothermal energy. Demand is also growing, and it is expected that the world electricity usage will reach 32,922 terawatt hours by the year 2035 (approximately two times the amount used in 2008) [1].

The total energy consumption in 2014 is shown in Fig. 1. Oil consumption represents about 39.9%, while other sources such as geothermal, solar, wind, and heat represent 3.3%. Therefore, there is a long way to go in changing energy consumption resources from non-renewable (oil, coal, natural gas) to renewable sources (solar, wind, geothermal, etc.) [2].

The top five countries for investment in renewable power and fuels in 2015 were China, the United States, Japan, the United Kingdom, and India (not including hydro > 50 MW) [3]. Solar energy includes solar photovoltaics (PV), concentrating solar thermal power (CSP), and solar thermal heating and cooling. At the end of 2015, a total of 227 GW of Solar PV was installed [3]. Fig. 2 shows the top 15 countries for solar PV [3].

South Korea represents 2% of global PV use (in the next 5 countries), adding 1 GW during 2015 with a total of 3.4 GW by the end of the year. Global operational capacity of CSP increased by 420 MW to nearly 4.8 GW at the end of 2015. The main application of solar thermal technology has been water heating in single-family houses during the last 50 years. Global operating capacity of water heating systems was nearly 435 GW (thermal) by the end of 2015 [3].

Using renewable energy helps eliminate pollution and environmental issues like CO_2 emissions. The technology related to these resources is growing fast. Sustainable development goals and enhanced energy security are included among the main factors that have attracted global attention to renewable energy [4]. Activities and investments by governments and private sectors related to R & D and supply of new technologies is strongly increasing in this area. As a result, the unit cost of power generation from renewable resources has significantly decreased, making it more competitive with traditional power generation systems.

With 10% efficiency, just 0.1% of the incident solar energy on the Earth's surface can produce 3000 GW of power. The annual solar radiation reaching the earth's surface is approximately 3,400,000 EJ [5]. Other benefits include:

1. Recovery of degraded areas.
2. Reducing dependence on the national power grid network.
3. Improved water quality.
4. Accelerated electrification of rural areas [6].

The amount of incident radiation on a point of the Earth's surface depends on several factors: the altitude, latitude, fraction of sunshine hours, relative humidity, precipitation, and air temperature. Several

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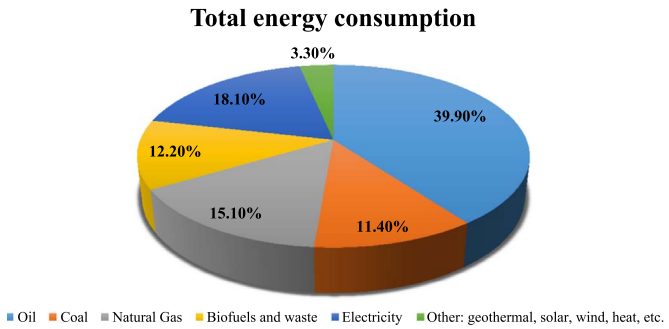

Fig. 1. Total energy consumption in 2014.

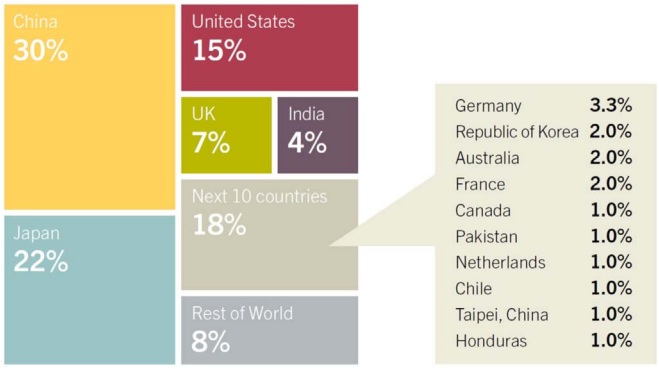

Fig. 2. Top 15 countries for solar photovoltaics.

Fig. 3. Regions of South Korea.

models have been developed to estimate the total amount of solar radiation on horizontal surfaces using various climatic parameters, such as sunshine hours, cloudiness, relative humidity, minimum and maximum temperatures, wind speed, etc. [7–9].

One of the important parts of any project or any idea before starting is feasibility studies. A feasibility study investigates the viability of a proposal, business venture, or idea. The principal function is to determine if a project will continue or not. In renewable energy projects, it is also helpful for recognizing the potential of an energy source. From the point of view of solar energy, it involves evaluating how much irradiance there is on the earth's surface in a specific region.

A number of studies have been conducted on the potential of solar energy. Osmani et al. [10] investigated renewable energy sources in the United States for electricity generation. They studied the resource potential, current usage, and the overall situation of renewable energy. The also identified the different challenges, which include economic, operational, sustainability, and technical challenges. Lastly, they discussed a sustainability evaluation outline for renewable resource deployment for electricity generation in the U.S.

Tucho et al. [11] assessed the potential of renewable energy sources for large-scale and standalone applications in Ethiopia. They presented an energy system and examined the available energy, and they mentioned that the three main sources include solar, wind, and hydroelectric sources, which could supply enough energy to fulfill the demand. In the case of solar energy, they estimated an annual geographic potential of 192 PWh from land and 0.1 PWh from rooftop areas. Since household energy use for cooking in Ethiopia is 10 times that in Western countries, they concluded that there is a strong need to satisfy this demand.

Izadyar et al. [12] reviewed previous studies on various potential parameters for renewable energy systems (theoretical, geographical, and technical parameters), as well as various methodologies for estimating these parameters in different conditions. The focus was on hybrid renewable energy systems. Okoye et al. [13] discussed the current energy situation in Nigeria and assessed the potential of solar-based technologies for electricity generation in three strategically located cities: Onitsha, Kano, and Lagos. Solar resources were modeled using synthetic hourly meteorological data for a whole year. Kano had the largest average daily global horizontal resources (6.08 kWh m^2), while the values for Onitsha and Lagos were 4.43 kWh m^2 and 4.42 kWh m^2, respectively. Furthermore, a standalone PV system on a sloping surface was sized to generate power for household usage based on an intuitive numerical simulation. They concluded that standalone PV electricity is technically and economically viable for urban residential applications in Nigeria while considering the current infrastructure and energy policies.

Alamdari et al. [14] studied many sites to evaluate solar energy in Iran using data from 63 stations. The values for the maximum, minimum, and average annual horizontal radiation were obtained for each station, and the annual average horizontal radiation was higher than 500 W/m^2 at some stations. Moreno-Tejera et al. [15] analyzed 13 years of global horizontal insolation and direct normal insolation in Seville, Spain, at different time resolutions ranging from annual to nearly instantaneous (5 s). They also proposed a new methodology for gap filling. The instantaneous values of global horizontal insolation and direct normal insolation had bimodal distributions, and they suggested that a 10-min distribution was a good time resolution for the simulation of concentrated solar power. The mean daily value for one year of insolation was 4.98 kWh/m^2 for global horizontal insolation and 5.68 kWh/m^2 for direct normal insolation.

Aliaga et al. [16] analyzed solar resources for agricultural pumping purposes and used the Geographic Information System (GIS) to investigate solar resource variability. A wide assessment was proposed in terms of energy, economics, and viability, and they compared two Mediterranean countries: Spain and Morocco. Their proposed methodology was able to solve multi-dimensional problems corresponding to agriculture division and energy requirements applied to irrigation processes based on aquifers, water resource control, and solar resource integration.

Ruiz-Arias et al. [17] proposed a method combining grid-modeled and ground-observed solar radiation data. The method is based on an optimal interpolation technique to adjust the gridded solar radiation.