Determining Renewable Energy Efficiency in Eskisehir, Turkey: A GIS Based Solution

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Abstract—The energy demand of the world is increasing in relation to the world's population growth and industrialization. Thus efficient solutions for the shortage of natural energy are becoming compulsory. Natural energy resources are still being used commonly all over the world. Due to the shortage of such energy resources and their negative impacts on the environment, solutions for these alarming issues have been considered by scientists, especially environmentalists. Owing to their environmentally friendly attributes and availability, renewable energy resources are considered as alternatives to natural energy resources. Several countries are attracted by the prospect of renewable energy, and prepare their energy strategies with consideration to renewable energy resources. Turkey is a coal-dependent country comprising approximately 2% of world’s coal consumption. Coal is a fossil fuel facing great shortages. As such, Turkey tended to renewable energy in recent years. In this research, the renewable energy efficiency prospects in Turkey were studied. An outlook of the energy situation in the country within the frame of solar and wind energy was provided, and a case study to determine wind energy efficiency in Eskisehir was examined. The objective of the study is finding solutions for energy shortages. Geographic Information System (GIS), which is a computer system to solve spatial related problems, was used in this study and multi-criteria site selection was utilized for the methodology. It is understood that GIS may be an efficient solution to energy-related problems.

Keywords—Energy Shortage, Energy Efficiency, Renewable Energy, GIS, Multi-criteria site selection.

I. INTRODUCTION

Preferred energy resources on the earth for millions of years have been fossil fuels which are oil, natural gas, and coal. Humanity utilizes fossil fuel resources in various fields ranging from construction and machinery industry to electricity, heating, transportation, agriculture and so on. The other energy resources on the earth are nuclear energy and renewables. Fossil fuels and nuclear energy sources are limited [1]. Due to population growth, industrialization and technological developments, the energy demand of the world is increasing dramatically. Since the energy demand of the world is greater than existing fossil fuel resources, the world is face-to-face with energy shortages. Turkey is a coal-dependent country. 1.8% of world's coal consumption can be attributed to Turkey [2]. In addition, energy demand is rising in the country mostly due to the rising population. According to the Turkish Statistical Institute, the population of Turkey is 73,722,988 as of December 31, 2010, increasing 1.161.676 from the previous year [3]. This statistic reveals that the energy shortage can reach an alarming level in the near future.

Fossil fuels are not clean energy resources. It is well known that greenhouse gas emission is at a highly critical level and this leads to a pressing international concern: Global warming. Many governments try to cope with global warming and its probable effects. It is understood that more scientific analysis is required to draw conclusions and develop possible solutions. As such, many scientific studies are conducted on this issue and many of them are continuing research. Recently renewables have attracted everyone’s attention as clean and sustainable energy resources. Unlike fossil and nuclear energy resources, renewables are unlimited and environmentally friendly. Economy is another aspect of renewable energy resources. The price of fossil fuel based energy is increasing rapidly, while renewable energy resources are all free. Turkey is considered as an energy-efficient country. However, it has to import energy because of the limited resources. So it is logical to head toward renewable energy, determining their efficiency in the country, and extend usage of them.

In this study, renewable energy efficiency in Turkey was analyzed. Solar and wind energy resources were assumed as renewables in this paper. Suggesting renewable energy based approaches and determining the capability of GIS regarding energy based issues are objectives of the study.

II. A BRIEF OUTLOOK OF THE ENERGY SITUATION IN TURKEY

Turkey, with a mainly young population has a huge energy demand per person. Growing economy and industrialization also affect energy consumption. Turkey also utilizes massive industrial electricity consumption as it can be seen from Fig.1. According to statistics from 2005, Turkey produced 26.81 Mtoe of energy from fossil resources [5]. However the annual energy consumption of the country is much greater than produced energy. Turkey is an energy-importing country. Though Turkey has a strong and growing economy, imported expensive energy affects progress of the economy of the country negatively. It seems that, Turkey will not be able to respond to the energy demand with domestic energy resources.
in the near future and have to allocate even further funding for imported energy.

Primary energy resources for energy production in Turkey are fossil fuels. The following section provides an analysis of fossil fuels regarding their negative impact on the environment, and is followed by a section on renewable energy resources focusing on the sustainability and environmental advantages provided by them.

A. Fossil-fuel based energy sources

Coal which is the major fossil energy resource in Turkey accounts for just 24% of the total energy consumption [6]. Oil, lignite and natural gas also have wide usage areas for energy production. Electricity generation of the country mostly depends on natural gas and lignite. However, fossil energy resources of Turkey are quite limited in view of the increasing energy demand (Table 1). In addition, fossil fuels contain pollutant gases such as SO$_2$, NOx and CO$_2$. Especially carbon emission of coal and lignite causes environmental problems such as global warming and climate change in the long term. These environmental facts force countries to sign an agreement called the Kyoto protocol. It is clear that countries have to take more precautions and head towards clear and sustainable energy resources.

B. Renewable energy resources

Turkey is a developing country with huge industrialization and economic growth among continental Europe and Asia. The country has implemented renewable energy resources such as hydropower, biomass, geothermal, solar and wind. However, the energy policy of the government still depends on fossil energy resources instead of renewables. Coal has the biggest market share of about 55%. According to the Ministry of Energy and Natural Resources (MENR), the energy demand of the country will be 314,353 ktoe in 2020, and the majority of the energy demand will not be addressed by domestic resources [8]. If Turkey does not want to be foreign-dependent for energy, it has to realize renewables as domestic and free resources.

In the beginning of the year 2000, consumption and production of renewable energy was almost equal. Biomass had a big market share between years of 1995-2000 with its usage for residential heating. But it is not a favored energy source now due to its negative effects on the environment. The rate of total biomass consumption is slowing down: it is projected to be 1.2% per annum between 1995 and 2000, 1.1% between 2000 and 2010 and 1% between 2010 and 2020 [9]. Recently, the market share of wind energy has been increasing. Owing to its geographic position, Turkey has wide highlands which are convenient to produce energy from wind. The solar radiation of the country is also sufficient to produce energy. Table 2 represents the former, current and projected renewable energy supply in Turkey. As can be seen from the table, energy production from biomass decreases while geothermal, solar and wind energy production increase.

Table 2: Renewable energy supply in Turkey [8]

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<th></th>
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<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Hydropower (ktoe)</td>
<td>2656</td>
<td>4067</td>
<td>4903</td>
<td>7060</td>
<td>9419</td>
</tr>
<tr>
<td>Geothermal, solar and wind (ktoe)</td>
<td>978</td>
<td>1683</td>
<td>2896</td>
<td>4242</td>
<td>6397</td>
</tr>
<tr>
<td>Biomass and waste (ktoe)</td>
<td>6457</td>
<td>5325</td>
<td>4416</td>
<td>4001</td>
<td>3925</td>
</tr>
</tbody>
</table>

C. Solar energy

Turkey is in an advantageous geographic location for solar energy production. As can be seen from Table 3, the southeastern Anatolia and Mediterranean regions are the most appropriate areas for solar energy. Total sunshine duration for the country is 2640 hours per year [10]. The amount of solar radiation is also high enough to utilize solar energy. It is calculated that the total solar energy potential of Turkey is 88 Mtoe/year, and 40% of the potential can be used economically [11].

A common solar energy practice is domestic water heating in Turkey. Additionally, the use of photovoltaic cells (PVs) to produce electricity for industrial purposes is increasing rapidly. There are two basic technological methods to convert sunlight into energy: PVs and solar thermal power systems. PVs convert direct sunlight to electricity. Solar thermal systems need turbines to convert steam to energy. There are also two conversion methods: active and passive. While active conversion needs a collector, no such component is needed in passive solar energy conversion. The total area of installed solar collectors in Turkey is approximately 17 million square meters. It is expected that this number will increase and the solar energy sector will boom with new enterprises and employments in the near future.
D. Wind energy
Owing to its geographical location, Turkey has about 781 thousand km² of mountainous area. It is known that wind forms as a consequence of displacement of air masses which have different temperatures. Surrounded by mountains, Turkey has regular air inflow and thus significant wind energy potential (Fig.2). According to Wind Atlas which is published by the Turkish Energy Market Regulatory Agency (EMRA) in May 2002, it can be stated that the Marmara, Aegean and East-Mediterranean regions have high wind energy potential in Turkey. The highest wind speed values calculated have been 6.4 m/s in Karabiga (Canakkale), 7.1 m/s in Nurdağı (Gaziantep) and 7.3 m/s in Senkoy (Mugla) [13].

Wind energy enables clean and sufficient energy production instead of traditional energy production methods which cause carbon emission and air pollution, with negligible impact on the environment in the form of visual and noise intrusion, and electromagnetic interference. Wind energy, which causes no physical pollution, is a safe, sustainable and environmentally friendly form of renewable energy.

III. ESKİŞEHİR CASE STUDY

A. Methodology
Multi-criteria analysis was determined as the methodology of the study and a case study for Eskişehir was performed. The goal is to explore the most suitable areas for probable wind farms in the city. In accordance with this purpose, site selection was implemented using ArcGIS 10 software. The wind farm location criteria have some constraints regarding topography, land use, wind speed and direction, hydrology, population, access, ecology and resources [15]. Criteria were determined by taking into consideration environmental constraints as shown in Table 4.

B. Study area
Eskişehir is a developing city of Turkey. Although wind speed is moderate according to the Turkish Wind Atlas, the city has a large flat terrain, which is preferable considering the slope constraints of wind farm location criteria. Additionally, Eskişehir also has adequate highlands for air inflow. Thus it can be stated that the city may have sufficient wind energy potential.

Porsuk River, the largest water body of Eskişehir, divides the city into Tepebasi and Odunpazari Municipalities. Tepebasi, which is the most rapidly developing region of the city was selected as the study area of the study. The Tepebasi district has a military airport, natural parks and large settlement potential. Highlands and large lowlands are also within the border of the district. Fig.3 represents the pilot area of the study.
C. Site Selection

1) Dataset

A Map of the Tepebasi district, a digital elevation model (DEM) map of the pilot region and the road network are the main data of the study and they were provided by the Tepebasi Municipality. Slope and aspect maps were obtained from the DEM map (Fig.4-5). Assuming that large settlements will be near the main street, buffer analysis was implemented for the roads that have prime importance (Fig.6). The same process was implemented for the airport, railways and woodlands. Due to the fact that the Porsuk River, a unique water body of the city is beyond the pilot area, criteria regarding the water body were omitted. Historical sites and natural reserves are also omitted for the same reason.

2) Weighted overlay analysis

Combining the layers considering all criteria and producing a meaningful finding are the major concerns of this study. Weighted overlay is the utilized method for the multi-criteria analysis. It is based on weighting data layers based on their importance. In this study, all data layers were considered equally significant and weighted with equal percentage. Another problem is classifying data layers relative to desirable and undesirable criteria. The reclassifying process is given in Table 5. Fig. 6 shows the reclassified road buffer map. As can be seen from the map, a score of 10 represents suitable areas while a score of 0 represents unsuitable ones.

Table 5: Reclassifying for the maps used in the wind farm site selection

<table>
<thead>
<tr>
<th>Class</th>
<th>Score</th>
<th>Class</th>
<th>Score</th>
</tr>
</thead>
<tbody>
<tr>
<td>Large settlements</td>
<td>0-2000 m</td>
<td>0-1000 m</td>
<td>0</td>
</tr>
<tr>
<td>&gt; 2000 m</td>
<td>10</td>
<td>&gt; 1000 m</td>
<td>10</td>
</tr>
<tr>
<td>Airport</td>
<td>0-2500 m</td>
<td>0-10%</td>
<td>10</td>
</tr>
<tr>
<td>&gt; 2500 m</td>
<td>10</td>
<td>&gt; 10%</td>
<td>0</td>
</tr>
<tr>
<td>Railway</td>
<td>0-100 m</td>
<td>West</td>
<td>10</td>
</tr>
<tr>
<td>&gt; 100 m</td>
<td>10</td>
<td>Southwest</td>
<td>5</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Other</td>
<td>0</td>
</tr>
</tbody>
</table>

3) Results and limitations

As a result of the weighted overlay analysis, a final map which represents the most suitable areas for wind farm locations was obtained (Fig. 4). As can be seen, there is a broad field of suitable prospective wind farm sites. A great majority of the areas are in the region/district called Yukari Sogutonu. This part of the city has rural settlement, no historical sites, no nature reserves and no undevelopable national property. It has wide lowlands and it lies westward. Thus it can be inferred that the result of the multi-criteria site selection supports the determined criteria and constraints.

Although it provides coherent results, the study has limitations which cannot be ignored. Wind speed of Eskisehir was taken from the Turkish Wind Atlas instead of using real wind speed and wind direction data. The reason for this limitation is a complete lack of financial support for this
study. The other limitation is bird habitats. It has been established that wind turbines have adverse effects on the vision and migration habits of birds. Wind farms must not be installed on bird migration routes. Aviary migration routes were not accounted for within the scope of this study.

IV. CONCLUSION

This study provides a general overview of renewable energy and its possible implementation in Turkey. The case study conducted is a basic example in how renewable energy research is capable through the utilization of various methods and technologies. Renewable energy resources are in great demand throughout the world. After understanding that fossil energy resources are limited and pollutant, interest toward renewables has increased greatly. Countries began to prepare their energy policies based on these realizations. Of course, Turkey is not oblivious to renewable energy. There is great renewable energy potential in Turkey. Especially solar and wind energy industries are developing rapidly with new projects. Renewable energy resources are clean, sustainable and environmentally friendly. Unlike fossil energy resources, renewables do not cause carbon emission and global warming. It is necessary to prefer renewable energy resources as much as possible for a sustainable future. This study suggested extending the use of renewables and examined the capability of using GIS for energy-related challenges considering environmental criteria. For this purpose, an outlook regarding energy in Turkey was provided. Then a GIS based multi-criteria site selection was implemented to determine suitable wind farm locations. Despite some limitations, environment-oriented criteria are considered and large areas were obtained for wind farm installation. The study has portrayed both the effectiveness of GIS as a research tool and on a standalone basis established that the city of Eskisehir is capable of implementing wind power as a sustainable and renewable energy source. As a conclusion, it can be stated that renewable energy is an indispensible need for future of human beings and GIS is a useful tool to solve energy-related problems.

REFERENCES