GIS-BASED DETERMINATION OF SUITABLE AREAS WITH MULTI-CRITERIA APPROACH FOR SOLAR POWER PLANTS AND ASSESSMENT OF LAND DECISIONS: THE CASE STUDY OF İZMİR-TURKEY

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by
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ABSTRACT

GIS-BASED DETERMINATION OF SUITABLE AREAS WITH MULTI-CRITERIA APPROACH FOR SOLAR POWER PLANTS AND ASSESSMENT OF LAND DECISIONS: THE CASE STUDY OF İZMİR

The need to energy has become an important reality for human life with the increase in living standards and population. İzmir has important renewable energy sources especially solar energy. Rapid urbanization and environmental problems due to internal migration after the 1960s have made renewable energy sources a priority because of the wrong implementations of urban policies in İzmir. In order to talk about energy potential, it is first necessary to talk about and analyze the land potential. It is necessary to determine the true criteria and methods for true analyzes of the suitable areas for efficiency and sustainability.

The study presents a GIS-based approach to identify the most suitable area for Solar Power Plants (SPP) development in İzmir. The first suitability map includes 9 criteria. The last suitability map includes the first suitable map results and criteria of land capability class (10^{th} criteria) using the same method. It can be said that the SPP installation is more suitable, especially the northern part of İzmir and districts of border. When the evaluation is compared, it can be said that İzmir has fertile lands and it should definitely be taken into account in energy projects. It also draws attention importance of land use decisions and legislation while choosing the suitable area from perspectives of planning. In addition, the current and potential solar energy area choices were evaluated together with the results which are produced for the study area in terms of land decisions and planning.

Keywords: Renewable Energy Sources (RES), Solar Energy, Suitability, Solar Power Plant (SPP), Analytical Hierarchy Process (AHP), Geographical Information Systems (GIS)

ÖZET

GÜNEŞ ENERJİSİ SANTRALLERİ İÇİN ÇOK KRİTERLİ YAKLAŞIM İLE UYGUN ALANLARIN COĞRAFİ BİLGİ SİSTEMİ TABANLI BELİRLENMESİ VE ARAZİ KARARLARININ DEĞERLENDİRİLMESİ: İZMİR ÖRNEĞİ

Enerji ihtiyacı, yaşam standartlarının yükselmesi ve nüfusun artması ile birlikte insan yaşamı için önemli bir gerçeklik haline gelmiştir. İzmir, özellikle güneş enerjisi olmak üzere önemli yenilenebilir enerji kaynaklarına sahiptir. 1960'lardan sonra yaşanan hızlı kentleşme ve iç göçe bağlı çevre sorunları, İzmir'de yanlış uygulanan kent politikaları nedeniyle yenilenebilir enerji kaynaklarının kullanımını öncelik haline getirmiştir. Enerji potansiyelinden bahsetmek için öncelikle arazi potansiyelinden bahsetmek ve bunu analiz etmek gerekir. Verimlilik ve sürdürülebilirlik için uygun alanların; doğru analizler için doğru parametrelerin ve yöntemlerin belirlenmesi gerekmektedir.

Bu çalışma, İzmir'de Güneş Enerjisi Santralleri (GES) gelişimi için en uygun alanı belirlemek amacıyla CBS tabanlı bir yaklaşım sunmaktadır. İlk uygunluk haritası 9 parametreyi içermektedir. Son uygunluk haritası, ilk uygun harita sonuçları ile arazi kabiliyeti (10. kriter) verisinin aynı method kullanılarak değerlendirilmesiyle oluşturulmuştur. Sonuçlara göre GES kurulumunun özellikle İzmir'in kuzeyi ve çevre ilçelerinde daha uygun olduğu söylenebilir. Değerlendirilmeler kıyaslandığında İzmir'in verimli topraklara sahip olduğu ve enerji projelerinde kesinlikle dikkate alınması gerektiği söylenebilir. Bu çalışma, uygun alan seçilirken arazi kullanım kararlarının ve mevzuatın önemine planlama açısından dikkat çekmektedir. Son olarak mevcut ve potansiyel güneş enerjisi alan seçimleri, arazi kararları ve planlama açısından çalışma alanı için üretilen sonuçlarla birlikte değerlendirilmiştir.

Anahtar Kelimeler: Yenilenebilir Enerji Kaynakları (YES), Güneş Enerjisi, Uygunluk, Güneş Enerji Santrali (GES), Analitik Hiyerarşi Süreci (AHS), Coğrafi Bilgi Sistemleri (CBS).

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LIST OF ABBREVIATIONS

SPP: Solar Power Plant
AHP: Analytical Hierarchy Process
GIS: Geographic Information System
MCDA: Multi-Criteria Decision Analysis
RES: Renewable Energy Sources
YES: Yenilenebilir Enerji Kaynakları
GES: Güneş Enerji Santrali
ÇÖKA: Çok Kriterli Karar Analizi
AHS: Analitik Hiyerarşi Süreci
CBS: Coğrafi Bilgi Sistemi
LUCC: Land Use Capability Class
TEIAŞ: Turkish Electricity Transmission Company
MENR: Ministry Of Energy And Natural Resources
TURKSTAT: Turkish Statistical Institute
TSKB: Industrial Development Bank Of Turkey
IRENA: International Renewable Energy Agency
BP: British Petroleum
YEGM: Yenilenebilir Enerji Genel Müdürlüğü
BNEF: Bloomberg New Energy Finance
İZKA: İzmir Kalkınma Ajansı
IEA: International Energy Agency
MS: Meteorological Service
GEPA: Güneş Enerjisi Potansiyeli Atlası
DEM: Digital Elevation Model
CORINE: Coordination of Information on the Environment

CHAPTER 1

INTRODUCTION

Energy is the main element of human society. The increasing need for energy with the industrial revolution and the environmental impacts of fossil fuels has made it necessary to find alternative sources. The need for energy has increased in direct proportion to the increasing population and advancing technological developments. Increasing energy needs and the increasing population; the depletion of fossil fuel reserves leads to the continuous use of fossil fuel-based energy sources, which become problematic by creating various challenges such as greenhouse gas emissions and other environmental problems. This situation will affect the countries of the world economically, politically, and environmentally soon. The most basic solution to this problem is to use renewable energy sources and increase energy efficiency (Özgöçmen, 2007).

The world has been going through a hard process since the 2000s. Regarding energy, increasing sensitivity to environmental problems since the 1970s has brought renewable energy resources to an extremely important position today (Koç and Kaya, 2015). The constant increase in energy needs and the limited availability of resources have increased the emphasis on alternative energy sources. Energy use is of great importance in the development of countries. Energy is a strategic resource for countries. Countries need sufficient, continuous, and clean energy to grow the economy and raise their living standards to increase their competitiveness (Şen, 2002).

Solar energy started to develop in the 1970s. Solar energy is renewable and green energy will play an important role in sustainable energy development, meeting future energy demand, and reducing environmental pollution. The development of solar energy projects can be provided by various planning and environmental and economic constraints (Marull et al., 2007). Multiple factors may be affected in the development of solar energy. The multiplicity of factors and the complexity of energy projects require multi-criteria analysis (Mateo and Cristobal, 2012).

Turkey, is located in a very advantageous geographical location in terms of solar potential compared to many countries, and has shown less progress in utilizing this potential compared to countries with low potential. İzmir has high solar potential and correct decisions can give to contribute this energy development.

This study aims to determine the appropriate area for the development of solar power plants within the study area (İzmir, Turkey). The suitability analysis of solar power plants is the first step of the planning process for energy planning. To minimize the negative effects of solar energy panels and reduce the opposition of the stakeholders, it is necessary to determine the appropriate and limited areas by evaluating many criteria. In addition to this; the economic, social, and environmental consequences of the land selection which are made without considering the land use capability classes should be especially taken into consideration.

In this direction, 1) solar radiation, 2) aspect, 3) slope, 4) settlement area, 5) main road, 6) forest, 7) water source, 8) drainage, 9) fault line and last criteria 10) land use capability class were evaluated as multi-criteria. After evaluating 9 criteria, the land use capability class which remains on the agenda of political, environmental, and social problems was emphasized. Weights that are determined using the pairwise comparison method were assigned according to their importance for a suitable area for solar power plants. AHP is to estimate the weights or relative importance of the criteria is applied using pairwise comparison methods.

Consequently, suitable areas for solar power plants were determined with 5 suitable classes from particularly suitable to not suitable by weighted overlay analysis as a multi-criteria decision-making method in ArcGIS. The first suitable map, including 9 criteria, is determined and the last criteria (land capability class) is added on the first map. Thus, following this last map, the plan decisions of the city for the energy planning decisions were evaluated.

The problems and the structure of thesis have described in the following sections.

1.1. Problem Definition

Although solar panels are a sustainable, abundant, and permanent energy source, solar panels are not paying enough attention to energy plans and legislation. Making planning decisions without conducting suitability analyzes for location selection, not evaluating the natural capabilities of the land, and not applying clear policies are the issues that need to be emphasized. Therefore, the purpose of this study is to determine suitable areas for solar power plants and evaluating the existing installation decisions, it reveals to what extent the existing potential is evaluated in terms of land decisions. Regarding the above-mentioned subjects, this study tries to consider on and evaluate the bellow problems:

1. What kind of criteria should be taken into consideration for the suitability analysis for the solar power plant of the study area?

2. Which method can be appropriate to analyze land-use suitability by using GIS?

3. Where should solar power plants be installed according to districts if suitable areas are determined in İzmir?

4. How much are the land properties are evaluated in the planning practices for solar power plants' suitability?

5. What is the feasibility of a solar power plant in terms of planning and legal regulations in İzmir and what kind of suggestions can be made?

1.2. Thesis Structure

The thesis consists of seventh chapters. The chapters are briefly explained in the following:

The first chapter briefly introduces the energy, renewable energy and solar energy. After that it explains the complexity of energy planning and the necessity for a plan with analyzed of different criteria using of method by using GIS. It explains complexity energy projects and comprehensive analysis. It includes general information about thesis and the importance of such a topic. It contains research questions about the study.

The second chapter explains general information of the renewable energy sources and their situation. Also, gives information about solar energy and its locational examples in World and Turkey. It includes comparison between energy sources and environmental concerns. This chapter shortly explains the planning regulations of solar power plants, problems and society reaction on projects.

The third chapter explains background of related to GIS with planning and land suitability analysis in general. It includes the criteria assessment, multi-criteria decision modeling, analytic hierarchy process.

The fourth chapter gives general information about the study area. It tries to explain beneficial information for the topic such as demographical features, climate, solar potential, land use capability class etc. Also, it includes previous studies and planning regulations.

The fifth chapter explains the raw data collection and processing and identification of 10 criteria with the analysis method. This chapter includes the comprehensive evaluation of selected criteria, Analytical Hierarchy Process as a Multi-criteria approach to determine the criteria weights and weighted overlay method application. It includes the examination of six criteria with the analysis method, thematic maps, and quantitative data.

The sixth chapter contains the first suitability map and final map. The numerical area data is explained in this chapter. There is a comparison the 2 suitability map and explainings, the land capability class criteria. Finally, it includes the comparison existing solar power plants and potential areas.

The final chapter concludes and discusses the overall result of the study. This chapter includes the evaluation and recommendations perspectives of legal and planning for solar power plants.

CHAPTER 2

SOLAR ENERGY SITUATION IN RENEWABLE ENERGY IN THE WORLD AND TURKEY

2.1. Energy Sources

Energy is one of the important needs for life. The fact that energy is consumed after it is used and the renewal period long indicates whether it is renewable. Energy sources are sources that enable energy to be produced in any way. Energy is used in four basic transformations as chemical energy, heat energy, mechanical energy, and electrical energy. Its resources are classified in 2 ways, based on being conventional and renewable (Koç and Şenel, 2013). The traditional use class is based on mostly fossil-based energies that have been used for a long time and whose reserves cannot be replicated in a short time. New and repeatable energies have been in use for a long time, but they are resources that are used with systematic and planned techniques and whose reserves can be repeated in a short time.

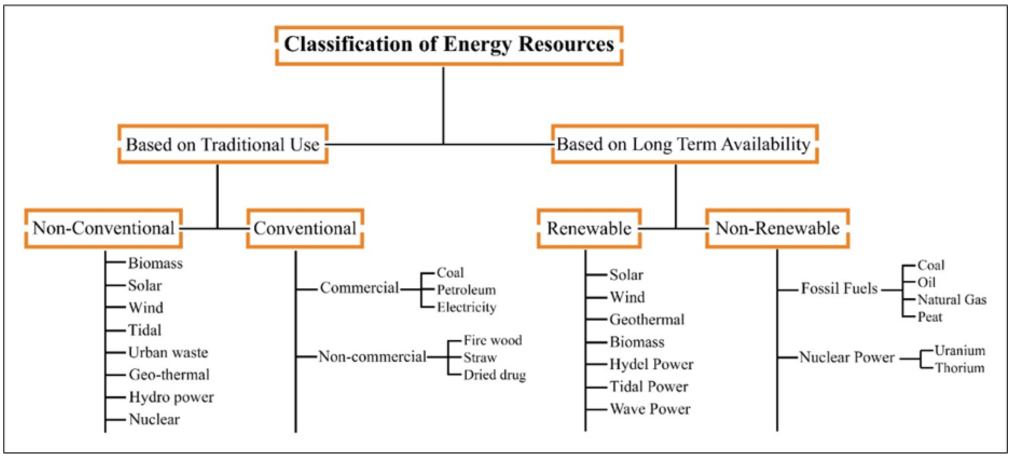


Figure 2. 1. Classification of Energy Sources

(Source: Koç and Şenel, 2013)

Non-renewable energy sources are divided into two groups as nuclear power and fossil fuels. It is assumed that these resources will be depleted in the near future. The most striking feature of this group of energy resources is that they are non-renewable, that is, they can be used once and are exhausted. In the 18th century, nitrogen is released into the atmosphere during the combustion of fuels containing carbon, such as oil, coal and natural gas, whose use has increased with the industrial revolution, especially when used in industry. The increase of NOx in the air causes the greenhouse effect to cause warming of the atmosphere and climate changes. At the same time, as acid rain disrupts the natural structure of the soil, all plants and people are directly affected (Oral, 2017). In addition, the increase in nitrogen oxide ratio in the air has direct negative effects on human health. As a result, these negativities have made it necessary for people all over the world to turn to renewable energy sources, that is, alternative, clean energy sources.

Instead of fossil fuel-based energy production which causes a great deal of damage to the environment, the interest in energy resources with low environmental impact, continuous and renewable energy is increasing. Renewable energy sources can be naturally renewed without being exhausted. Renewable energy sources significantly reduce greenhouse gas emissions if they are replaced with fossil fuels. Renewable energy sources are the most exclusive alternative and the only solution. Advantage of renewable energy sources; reduces foreign dependency and other areas of influence such as environmental pollution (Tiwari and Mishra, 2011). Renewable energy sources can be used directly or by converting to another type of energy. Renewable energy sources; It is an energy type that stands out with its non-polluting, sustainable, domestic, and environmentally friendly features with the use of appropriate technology. Turkey is a country with a very high renewable energy resource potential. Due to the increasing need for energy, the status of existing energy resources should be determined to ensure the planned use of non-renewable energy resources and to benefit more from renewable energy resources.

2.2. General Situation of Renewable Energy Sources in World and Turkey

2.2.1. Renewable Energy Sources in World

The widespread use of renewable energy sources is an important step in protecting the future. The negativities arising from the use of renewable energy sources are almost negligible compared to other energy sources. However, due to insufficient renewable energy resources and economic reasons, the necessary importance has not been given to renewable energy in the energy policies of countries around the world.

Table 2. 1. Fuel Consumption of Some Countries by Resources-MTEP

(Source: BP, 2018)

Country	Natural Gas	Petroleum	Coal	Nuclear Power	Hydrolic	Renewable	Total
USA	702,6	919,7	317	192,2	65,33	103,8	2300,6
Russian	390,8	152,3	88	46,3	43	0,3	720,7
China	243,3	641,2	1926,7	66,6	272,1	143,5	3293,4
Canada	99,5	110	14,4	22,6	87,6	10,3	344,4
Germany	75,9	113,2	66,4	17,2	3,8	47,3	323,8
India	49,9	239,2	452,2	8,8	31,6	27,5	809,2
French	36,7	78,9	8,4	93,5	14,5	10,6	242,6

The countries of the world need to switch to low-carbon energy sources such as renewable energy. In terms of renewable energy, China ranks 1st and the USA is 2nd, and consumption values are quite high compared to other countries (Table 2.1).

The energy sector in the world is on radical structural change due to the frightening consequences of climate change. In particular, industrialized countries that do not have sufficient fossil resources and whose external dependence on energy is increasing, are trying to turn the crisis into an opportunity by strengthening their economies by turning to safe energy resources and selling renewable energy and clean technologies. In the next periods, the powerful countries of the world will compete to increase their shares in the new technology market, while trying to maintain their influence on fossil resources.

The countries consume 30% more energy than 30 years ago. According to estimates, this requirement will be more than 65% in 2020 and 250% in 2050. By 2050, renewable energy is expected to take 62% share of total electricity production (IEA, 2019). The circle represents the total electrical energy demand and the shares between different energy sources. The situation that solar energy will come with its great potential until 2025, 2050, 2075, and 2100 is remarkable (Figure 2.2).

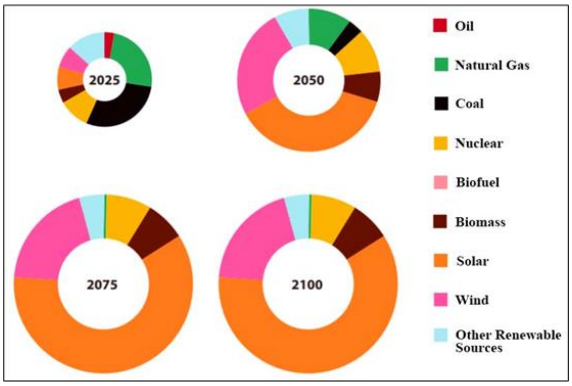


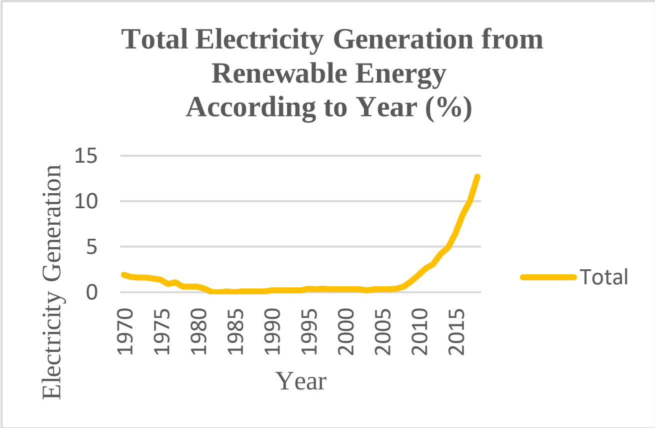
Figure 2. 2. Energy Demand by Different Resources
(Source: Shell Scenarios Sky, 2020)

2.2.2. Renewable Energy Sources in Turkey

Turkey supplies its energy demand mostly from fossil energy sources. Since it is highly dependent on foreign sources in terms of primary energy sources, it imports energy by spending billions of dollars every year. With the increase of foreign dependency on energy upto 70%, it is necessary to increase the use of renewable energy resources in order to reduce Turkey's dependence on foreign energy (Yılmaz and Kösem, 2011). It is very important for the future of Turkey to use clean and renewable energy resources that can be solved within itself. Turkey's renewable energy installed power follows an increasing trend over the years. Turkey's installed power has been determined as 93.022.7 MW as of August 2020. Turkey's installed power based on renewable energy resources which were 25.6 GW in 2013, increased by an annual average of 10% and reached the level of approximately 47 GW as of September 2020, and its share in the total installed power which was 40% in 2013 was 50.4% as of September 2020 (TEIAS, 2020) (Table 2.2).

Table 2. 2. Renewable Energy Installed Power Development-MW
(Source: TEIAS, 2020)

Resources/Year	**2015**	**2016**	**2017**	**2018**	**2019**	**2020/9**
Hydroelectric	25.868	26.682	27.273	28.291	28.503	29.790
Wind	4.498	5.751	6.516	7.005	7.591	8.077
Solar	310	833	3.421	5.063	5.995	6.361
Geothermal	624	821	1.064	1.283	1.515	1.515
Biomass	345	467	575	739	1.163	1.238
Total	**31.645**	**34.554**	**38.849**	**42.381**	**44.767**	**46.981**



Graph 2. 1. Total Electricity Production from Renewable Energy

(Source: TURKSTAT, 2018)

Graph 2.1. includes that, renewable energy and waste include geothermal, solar, wind, solid biomass, biogas and waste. It can be follwedis seen that there is a rapid increase in years. As a result of the decisions taken in international agreements, Turkey carries out studies aiming to increase the existing installed power of renewable energy sources by creating strategic studies and action plans on a national basis. It is certain that Turkey can play an important role in energy independence. Turkey's important task is to decrease energy independence.

2.3. Comparison Between Solar Energy and Other Energy Sources

With the beginning of industrialization, the sun started to be seen as an energy source. The fact that the sun started to be seen as an energy source gained more importance with the realization that the energy obtained from fossil fuels polluted the world. On Earth, energy flows are possible thanks to the presence of solar energy. Many energy sources are based on solar energy. Solar energy is an abundant, uninterrupted, renewable, and free energy source. In addition to all these features, the absence of corrosive features in terms of environmental problems in solar energy makes this energy source environmentally friendly energy. (Varınca and Varank, 2006).

Table 2. 3. Comparison Between Solar Energy and Fossil Fuels
(Source: Consumer Affairs, 2021)

	Solar Energy	**Fossil Fuels**
Efficiency Rate	15%-22%	20%-40%
Co2 Emissions	-	+
Long-Term Availability	+	-

It is expected that solar power plants will indirectly benefit the economy of the country with their distinctive features from power plants that use other energy resources as fuel. Unlike fossil fuel power plants, SPP can be commissioned in a very short time, they do not need to fuel, they are easier to operate and operation-maintenance costs are realized at low levels. The most important feature that distinguishes SPPs from hydraulic power plants (HPP) is that they are supposed to be built on unused lands, and these power plants cause less damage to nature and provide income by generating electricity in idle lands. Solar energy has advantages over wind energy, which has an important potential in Turkey. The lack of moving parts (wind blades) of PV systems such as wind power plants (WPP) eliminates the possibility of mechanical wear, thus reducing operating and maintenance costs. Operation and maintenance costs are higher in biomass power plants than in SPPs (TSKB, 2020).

Solar energy is used as heat energy and electrical energy after transformations. The areas where solar energy is used can be customized for many purposes. The main purpose of using this type of energy is to reduce the use of fossil fuels in the face of economic conditions, increasing the usage areas of solar energy and taking its place. Solar energy can use in buildings and workplaces, agricultural technology, industry, transportation, communication, electrical energy etc (Varınca and Varank, 2006). The amount of power coming from the sun, which has a very large and inexhaustible energy source, is approximately 1.8x1011 MW. This value is thousands of times the current consumption amount of commercial energy resources in the world. Accordingly, solar energy has the power to meet the current and future energy needs of the world (Şen, 2002).

It is expected that the usage areas of solar energy will become widespread in Turkey. Most of the energy sources used today occur as a result of events that are influenced by the solar factor. It has become an issue on which studies have been carried out with its features such as not having a polluting effect on the environment, being able to implement it within the country, not being dependent on, not having a complex system, and having low costs. The sun is an infinite source of energy for the world due to its unlimited radiation duration. This energy source can dominate wide geography.

2.4. Solar Energy Sources in World and Turkey

Solar energy is the energy source that has been used throughout history. Solar energy has been known as the energy of the future. Today, a wide range of solar energy technologies are available such as solar thermal heating systems, solar PV systems, and solar buildings (Kapluhan, 2014). Some countries use their solar potential advantages and some countries use their technological efficiency. Turkey has started to rank in higher in the world related to using solar energy development. Turkey is very advantageous compared to European countries in terms of sunshine duration and potential.

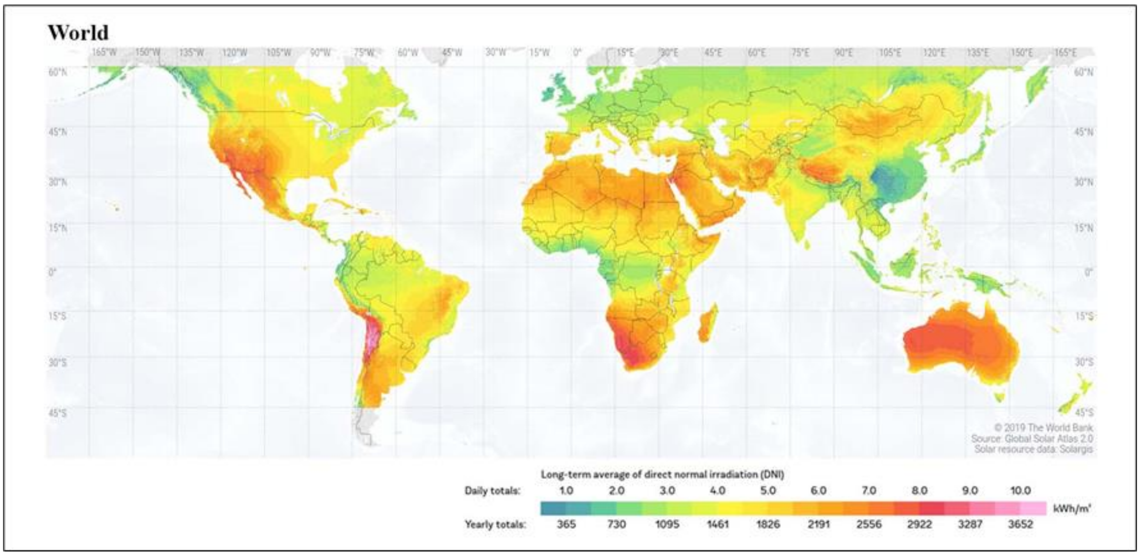


Figure 2. 3. World Solar Potential Map
(Source: Global Solar Atlas, Solargis)

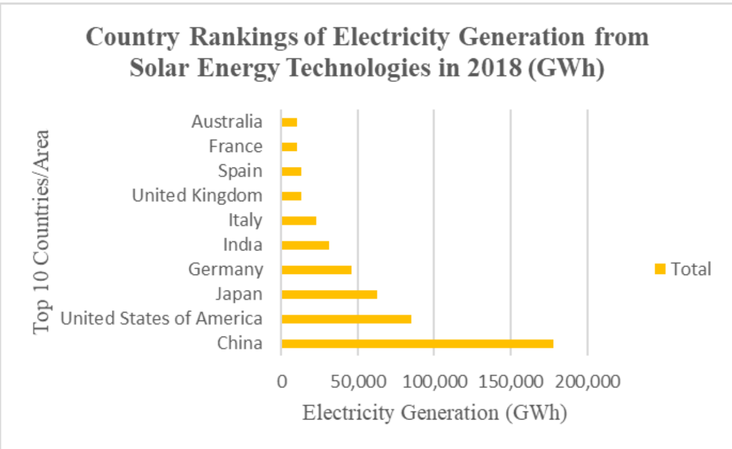
These solar radiation map created to show the current estimated solar energy with daily and annual totals (Figure 2.3). All countries produce more or less electricity with solar energy in world. China, the USA, Japan, Germany, and India in the top 5 according to a number of the solar power plants. Turkey is in the top 15 (Table 2.4).

Table 2. 4. Solar Power Plant by Country

(Source: Energy Atlas, 2019)

Rank	Country	Update	Installed power (MW)
1	China	December 2020	254,355
2	United States	December 2020	75,572
3	Japan	December 2020	67
4	Germany	December 2020	53,783
5	Indıa	December 2020	39,211
6	Italy	December 2020	21,6
7	Australia	December 2020	17,627
8	Vietnam	December 2020	16,504
9	South Korea	December 2020	14,575
10	Spain	December 2020	14,089
11	United Kingdom	December 2020	13,563
12	France	December 2020	11,733
13	Netherlands	December 2020	10,213
14	Brazil	December 2020	7,881
15	**Turkey**	May 2021	7,170
16	South Africa	December 2020	5,99
17	Taiwan	December 2020	5,817
18	Belgium	December 2020	5,646
19	Mexico	December 2020	5,644
20	Ukraine	December 2020	5,36

Some countries are proving valid answers that solar power production is the world's alternative source for fossil fuels. China has been growing to use its solar potential and technological efficiency and ranking first in the global solar market. After China, the countries in the global market are the USA and Japan. (Graph 2.2).



Graph 2. 2. Electricity Production from Solar Energy Technologies

(Source: IRENA, 2020)

Turkey has a great potential in terms of solar energy depending on its geographical location. The share of solar energy in energy production has been increasing with the investments and new installations in recent years. The production is very low when compared to the potential (Figure 2.4 and 2.5).

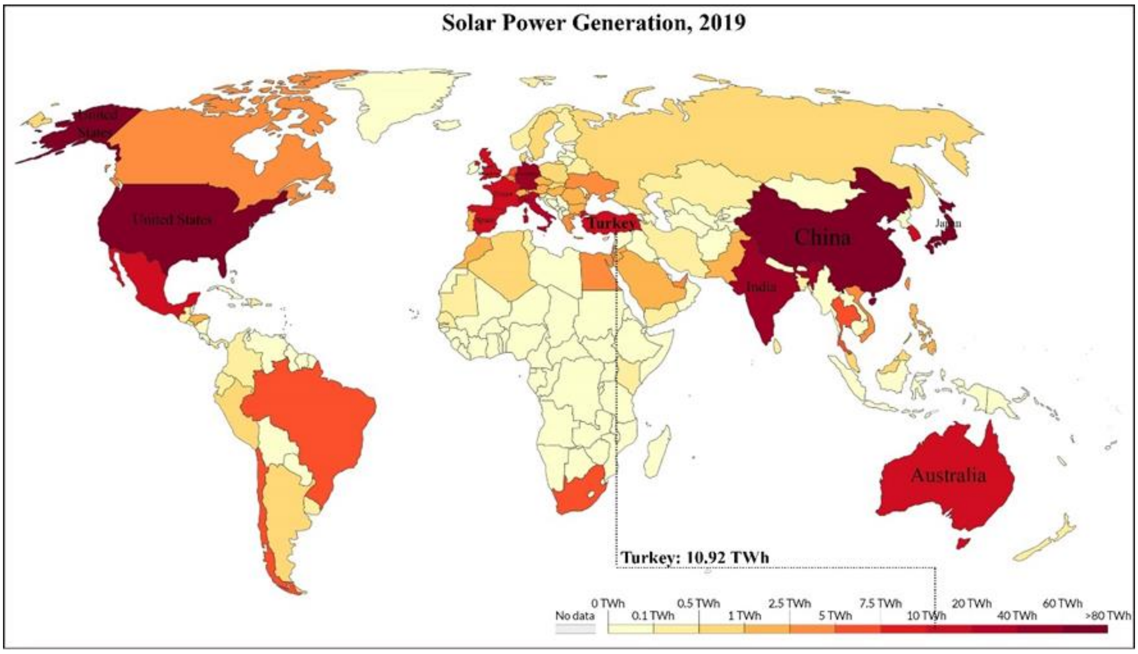


Figure 2. 4. Solar Power Production Map

(Source: BP,2019)

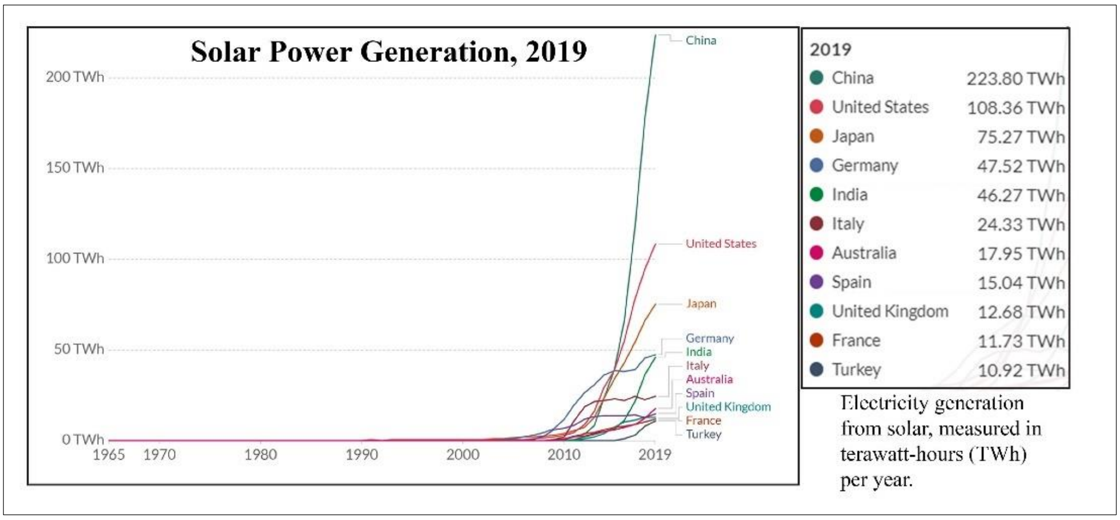


Figure 2. 5. Solar Power Production

(Source:BP, 2019)

6.2% of the solar capacity in the world is in our country with a surface area of 781.000 kilometer square. This ratio is more than 50% of the total thermal capacity of the European Union countries (Karadağ, Güçsaç, Ersöz, Çalışkan, 2009).

Solar energy offers the significant potential to its future energy needs for Turkey. A large part of our country has very suitable values in terms of solar radiation and sunshine duration. Most solar energy measurements and evaluations carried out by the Meteorological Service and Electrical Power Resources Survey and Development Administration have determined the existence of this potential.

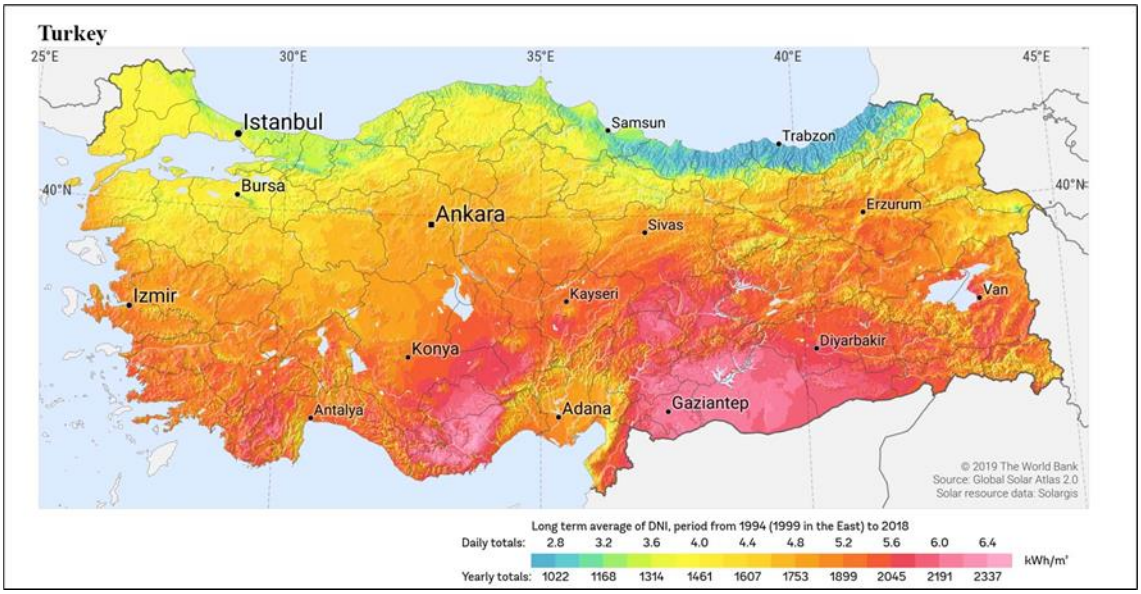


Figure 2. 6. World Solar Potential Map

(Source: Global Solar Atlas, Solargis)

These solar radiation maps created to show the current estimated solar energy with daily and annual totals (Figure 2.6).

This map was prepared by using the Solar Radiation Model and main criteria through Geographical Information Systems for Turkey. Especially the Solar Energy Potential Atlas prepared by the Electrical Power Resources Survey and Development Administration and shows the solar energy potential of all provinces and districts in detail. (Figure 2.7).

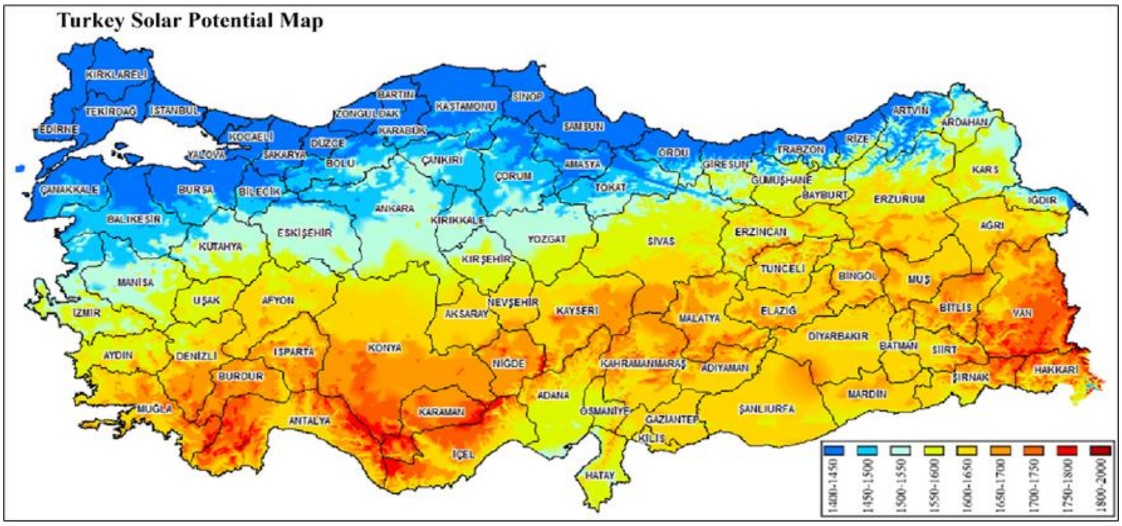


Figure 2. 7. Turkey Solar Potential Map

(Source: Energy Atlas)

According to this atlas, the total annual sunshine duration is 2727 hours. The average total incoming solar energy amount is 1527 kWh / m² year. Turkey has a high solar energy potential of 110 days per year, and if the necessary investments are made, Turkey can produce an average of 1100 kWh of solar energy per square meter per year (Kılıç, 2015).

Table 2. 5. Solar Power Installed Power and Number of Plant

(Source: TEIAS, 2019)

	Installed Power (MW)	**Number of Plant**
Solar	5.995,20	6901
Others	38.410,50	1192
Total	44.405,70	8093

The installed capacity of renewable energy in primary sources with a maximum of 28.502 MW of power plants, with 7.591 MW of wind power plants, solar power plant with 5.995 MW has the largest share. The share of biomass and geothermal power plants is low. The solar power plants have the highest number of power plants with 6901 (TEIAS, 2019) (Table 2.5).

Turkey is a ‘sunshine country’ except the Eastern Black Sea Region. While the region that receives the most solar energy in Turkey is Southeast Anatolia Region, it is followed by the Mediterranean Region. The regions with the least solar potential are the Black Sea and the Marmara Region (Table 2.6).

Table 2. 6. Solar Energy Potential According to Region
(Source: YEGM, 2019)

Region	**Total Solar Energy**	**Sunshine Duration**
	(kWh/m^2-year)	**(hour/year)**
Region of Southeast Anatolia	1.460	2.993
Region of Mediterranean	1.390	2.956
Region of Eastern Anatolia	1.365	2.664
Region of Central Anatolia	1.314	2.628
Region of Aegean	1.304	2.738
Region of Marmara	1.168	2.409
Region of Black Sea	1.120	1.971

Within the scope of 2023 targets, 34.000 MW hydroelectric, 20.000 MW wind energy, 5.000 MW solar energy, 1.000 MW geothermal energy, and 1.000 MW biomass energy are planned to be produced in Turkey. In line with these goals, at least 30 percent of Turkey's demand for energy will be provided by renewable energy sources are planned by 2023 (ETKB, 2017). Turkey has to activate all existing renewable energy investments in order to achieve and advance 2023 targets in the field of renewable energy. The analysis shows that; Turkey can generate 47% of its electricity production from renewable energy sources in 2030. By 2030, the installed power of solar energy can reach 24 GW (BNEF, 2020).

Although Turkey is located in the solar belt, the acquisition and use of solar energy is much less than predicted. Solar energy, which is a part of renewable energies, should be implemented effectively and sustainably as an important alternative in meeting energy needs. Turkey will significantly reduce its dependence on foreign energy if it uses these advantages and supports it with appropriate policies.

2.5. Examples of Solar Power Plant

Solar energy is an essential source of renewable energy. Solar energy usage grows with each passing day and takes bigger shares in the energy usage graph. The countries recognize significant investment opportunities in solar energy. It aims to achieve sustainability in energy, gain independence, and solve environmental problems. Using solar energy is popular in lots of areas and sectors. There are different projects in countries that have the technology, energy potential, location, efficiency structure, etc.

First 3 country examples;

China:

China is a country that will affect energy politics worldwide with its technology, as well as having the world's largest solar panel fields. China's serious efforts on solar energy systems are derived from the country's electricity need and the air pollution crisis. The rate of using renewable energy in China which has the largest population and carbon footprint has the first place. As of 2015, China is the largest solar panel manufacturer and supplier.

Figure 2. 8. Examples of SPP in China

(Source: Webpages)

According to a draft rule released by China's National Energy Administration (NEA), the country aims to increase solar and wind power production to about 11% of total power consumption in 2021, up from 9.7% in 2020. According to the draft plan, local governments are also required to expedite the approval of new solar and wind projects in order to ensure the long-term growth of renewables in the nation.

United States:

The United States has the second largest slice, increasing its investments in solar energy by 30% since 2014. Three of the 5 largest solar power plants in the world are located in the state of California.

Figure 2. 9. Examples of SPP in California

(Source: Webpages)

The Topaz Solar Power Plant is among the most efficient solar power plants in the world. It operates with 9,000,000 solar panels and 550 MWe installed power. Solar Star is the third largest solar power plant with 2,316,000 solar panels and 579 MWe installed power. Desert Sunlight Solar Power Plant has 8,800,000 solar panels and serves with an installed power of 550 MWe.

Japan:

Japan which is the one of the most densely populated countries in the world does not have wide land and wide areas. It aims to double the use of renewable energy by 2030. The solar power is the most important between these energy sources. Despite the space constraints, there are efforts to find creative areas for solar panels.

Figure 2. 10. Examples of SPP in Japan
(Source: Webpages)

The country's most serious problem with solar energy is its geographical location. Japan is located on a tiny island, and space is limited due to the country's large population. The few unpopulated areas of the world are too hilly for solar power to be practical. Scientists have devised a novel alternative approach. On reclaimed land, solar power farms are being installed. Oita Solar Power has 82.02 MWp and Kagoshima Solar Power has 70 MWp.

Examples in Turkey:

In many cities in Turkey, solar power plant installations are rapidly increasing. There are many land-use choices for solar power plants. According to the 2023 target of the Ministry of Energy; at least 3000 MW licensed PV plant installed power will be reached. The biggest 5 solar power plant areas in Turkey;

Table 2. 7. The Biggest 5 SPP

(Source: Energy Atlas)

	Region	District	Installed Power
1	Konya	Karapınar	188,65 MWe
2	Kayseri	Melikgazi	50 MWe
3	Balıkesir	Karesi	40 MWe
4	Kahraman	Merkez	33,12 MWe
5	Niğde	Bor	26 MWe

The installed power of SPP is %94 in rural areas and %6 in urban areas. The number of SPP in rural areas have less compared with urban areas. However, in urban areas, they are mostly installed on areas such as roofs or gardens. They have smaller values in terms of installation power. In rural areas, they have bigger values in terms of installation power (Pınar, Buldur, Tuncer, 2020).

Table 2. 8 Installation Area for Solar Power Plant in Turkey

(Source:Webpages)

	Region	District	Installed Power
1	Antalya	Demre	1,2 MWp
2	Antalya	Manavgat/Çardak	2,3 MWp
3	Denizli	Çeltikçi	13.5 MWp
4	Şanlıurfa	Hilvan	37,5MWp
5	Aydın	Söke	3,3 MWp
6	Aydın	Çine	13,6 MWp
7	İzmir	Ödemiş	5,6 MWp
8	İzmir	Menemen	2 MWp
9	İzmir	Menderes	5,3 MWp

Figure 2. 11 Examples of Solar Power Plant in Different Region
(Source: Webpages)

The geographical location of the country and its year-round sunlight potential are the most significant factors for efficient solar energy. It has regions that receive intense sunlight alternately during the four seasons of the year due to its location. Solar power plants built over vast areas will meet a substantial portion of the energy demand.

2.6. Environmental Impacts of Renewable Energy and Solar Energy

During the oil crisis in the early 1970s, the main concern was about energy prices, but environmental risks have been at the forefront in the last 20 years. The importance of environmental awareness and environmental protection approaches in the 1990s can be considered as the second important development supporting the development of renewable energy resources. The search which is reliable, sustainable, and environmentally friendly resources have started instead of traditional energy resources. The appearance of energy has changed since the 2000s and the use of renewable energy sources has shown rapid development. These renewable energy sources can be an alternative and important solution for the damage caused by non-renewable energy to the environment. There is a strong link between environmental problems and energy sources. There are many factors for environmental problems. All these reasons affect each other. The environmental problems are important for sustainable development.

There are important initiatives for the transition to sustainable energy sources. Important initiatives in this regard are the United Nations Framework Convention on Climate Change and the Kyoto Protocol. Since 2015, the Paris Agreement has been the most important binding legal arrangement, replacing these two regulations. With this agreement, the provisions in the Kyoto Protocol have been made more binding and the US has been joined. The Kyoto Protocol ensures that the use of renewable energy and environmentally friendly technologies is increased and research in this direction are encouraged (Durak, 2009).

Since it will be useful in the prevention of resource consumption and harmful wastes, it is required to use renewable energy technologies and to be evaluated within technical, environmental, and economic features. The environmental effects of the options used in energy production are given in the figure. In determining the Environmental effects as color in the chart; 2 separate color boxes are used. The color on the top box; "environmental impact" of energy source and the color in the lower box "effect of this energy source after the precaution" (Özek, 2009) (Figure 2.11).

Solar energy which is one of the alternative energy sources also offers a clean, renewable energy source to reduce these destructive effects. All energy sources have some negative effects on the environment during production, installation, and operation. Looking at the environmental effects of energy production from solar sources, it can be seen how harmless it is compared to others. Nevertheless, there are some damages caused by solar energy panels with some wrong practices for site selection. Changes in the area where the activities to be implemented will directly or indirectly trigger other effects and damage the dynamics around the land. If the necessary rules do not make provision for some damages, this list will be unavoidable (Saner, 2006) (Figure 18).

ENERJİ ÜRETİMİNDE KULLANILAN SEÇENEKLERİN ÇEVRESEL ETKİLERİ							
Çevresel Etki Türleri	Fosil Yakıtlı Santraller (termik santraller)	Nükleer Santraller	Hidrolik Santraller	Temiz ve Yenilenebilir Enerji Kaynakları			
				Güneş	Rüzgar	Jeotermal	Biyokütle
Katı atıklar-Toprak kirliliği	Kömür depolama ve kül-cüruf atıkları	Radyoaktivite içeren her türlü atık	Baraj çevresinde düzelemeler gereklidir.	Katı atığı yok	Katı atığı yok	Katı atığı yok	Yakılan çöp ve benzeri atıklar
Gaz atıklar-Hava kirliliği	Baca gazlarının toksin etkisi ve yüksek SO_2 emisyonları	Ksenon, kripton ve iyot gibi maddeler	Baraj gölü yüzeyindeki buharlaşmada artış	Gaz atığı yok	Gaz atığı yok	Zararsız su buharı	Yakılan malzemeden çıkan gazlar
Sıvı atıklar-Su kirliliği	Termik santral soğutma sularının canlılara etkisi	Soğutma suyuna karışan radyoaktif maddeler	Ağaçlandırma ve balıkçılığa olumlu katkı	Sıvı atığı yok	Sıvı atığı yok	Sıcak suyun olumsuz etkileri gideriliyor	Depolanan kalıntıların yeraltısuyuna etkileri
Arazi-doğa görünümü bozulması	Yanlış arazi kullanımı ve depolama	Bitki örtüsü ve ekolojik dengenin zarara uğraması	Rezervuar alanındaki olumsuz değişimler ve deprem çekincesi	Geniş arazi kullanımı	Arazi kullanımı yok	Sıcak su civarında olumlu çevre gelişmesi	Plansız ağaç kesimi-Çöp depolama alanlarının olumsuz etkileri
Görsel kirlilik-Tarımsal üretim	Ocak üretim çalışmaları nedeniyle doğal görünüm bozulması	Radyoaktif uçucuların canlılara önemli zararı	Çoraklaşma, tuzlanma,para zitlerde artış. Tarıma olumlu katkısı	Etkisi yok	Gürültü görsel-estetik etkiler	Tarımsal sulamaya olumsuz etkiler çok düşük	Çöp ve kütle depolama/yakılma dumanları

Renk	Açıklama
(kırmızı)	Zararlı
(sarı)	Kısmen zararlı
(yeşil)	Zararsız

Figure 2. 12. Environmental Effects of Sources in Energy Production

(Source: Özek, 2009)

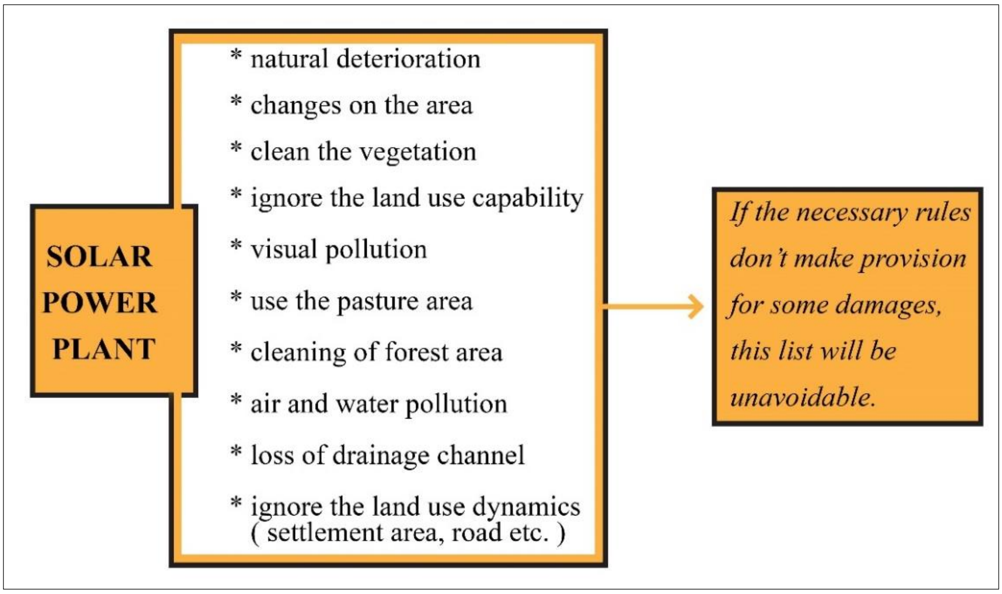


Figure 2. 13. Negative Effects of Solar Power Plant

(Source: Saner, 2015)

The level of renewable energy production in Turkey is quite low compared to its potential. Using the existing potential more effectively is of great importance in terms of both ensuring energy supply security and reducing the negative effects of the energy sector on the environment.

2.7. Planning Rules and Regulations of Solar Power Plants

Rapid urbanization and environmental problems due to increased internal migration after the 1960s have made the use of renewable energy sources in cities an important and priority with wrong urban policies. Renewable energy has started to develop rapidly in Turkey since the beginning of the 2000s. After this rapid development, efforts have been started to put all existing energy resources into operation with the increase in energy needs. The first step was taken with the establishment of the Energy Market Regulatory Authority. After examining the investments made around the world, the Ministry of Energy and Natural Resources and the State Planning Organization supported the issue of working on renewable energy sources for Turkey. Turkey has taken more serious work on the issue of renewable energy, taking investments under more control. The priority has been given to solar, wind and geothermal energy. In the continuation, the Environmental Law No. 2872, which was renewed in 2006, made additions to issues such as carbon trace and Environmental Protection. Along with the energy efficiency Law No. 5627, which became law in 2007, economic sanctions were provided in case of increasing efficiency in energy consumption (Saner,2015).

There are lots of legislation for solar energy projects but these are most relevant for to this study.

- Law on the Use of Renewable Energy Resources for the Purpose of Generating Electrical Energy (Law No. 5346)

Law on the Use of Renewable Energy Resources for the Purpose of Generating Electrical Energy is the most important legal regulation. The purpose of this regulation is to encourage and expand the use of renewable energy sources for energy production. Lands of forest nature, private ownership of the treasury, or state property can be registered in the name of the treasury by changing the purpose of allocation under the Pasture Law. Development plans that affect the use and efficiency of renewable energy resource areas in treasury lands cannot be arranged. The establishment of electricity production facilities based on renewable energy resources is permitted, provided that a positive opinion is obtained. It encourages as much as possible the facilities to be established and operated for electricity production from other renewable sources, including solar power plants, in immovables owned by the public and the treasury, if the opinions of various institutions are appropriate.

- Law on the Environmental (Law No. 2872)

Environmental Law is an important regulation in the location of solar power plants. There is some provision related to renewable energy sources and clean technologies for the protection of the environment, prevention and elimination of environmental pollution. One of the most important regulations affecting the location selection of solar power plants within the scope of the Environmental Law is the Environmental Impact Assessment Regulation. Environmental impact assessment defined in the regulation; Environmental impact assessment defined in the regulation: it is to determine the positive and negative effects of the planned projects on the environment. Another regulation affecting the location of solar power plants is the Water Pollution Control Regulation. Solar power plants are not permitted in the absolute protection area, short-range protection area, and medium-range protection area covered by special provision studies. It is possible to choose the location of solar power plants in long-distance protection areas. It is possible to choose the location of solar power plants in long-distance protection areas.

- Law on the Forest (Law No. 6831)

The Forest Law includes both restrictive and encouraging provisions as legislation that affects the location of solar power plants. Although investments related to solar power plants in forest areas are limited, forest areas can be used for these investments for a period of time when there is a public interest.

- Law on the Pasture (Law No. 4342)

Since no alternative area has been found in recent years. According to the law, there are provisions stating that the pasturelands under the jurisdiction and possession of the state cannot be transferred to private ownership, cannot be used for other purposes and their borders cannot be narrowed. It is mentioned in the law that the right to use pastureland areas can be rented. Like the Forest Law, there are wide-ranging exceptions regarding the establishment of solar power plants on pasture lands.

- Law on the Soil Preservation and Land Utilization (Law No. 5403)

This law is the first of the legal regulations affecting the location selection of solar power plants for agricultural areas. There is a provision that absolute agricultural lands, special crop lands, planted agricultural lands and irrigated agricultural lands cannot be used for purposes other than agricultural production. This provision excludes marginal agricultural lands. However, absolute agricultural lands, special crop lands, planted agricultural lands and irrigated agricultural lands, which cannot be used for other purposes, can be used for different purposes if there is no alternative area.

There are lots of regulation and law, but these are not sufficient. Other legal regulations that may indirectly affect the location of solar power plants are the Development Law No. 3194 and the Decree Law No. 644 on the Organization and Duties of the Ministry of Environment and Urbanization.

One of the most important official documents shaping the energy policy is the Environmental Regulation Plan in Turkey. Environmental Regulation Plan is important in terms of energy investments. Development and environmental planning are shaped by political and economic developments occurring on a national, regional, and global scale. It is possible to talk about three main actors of the relationship between energy and planning. These actors are the central government, investors, and citizens. The capital investing in the energy sector focuses on the functioning of an energy market that will make energy supply continuous, it is based on producing more energy cheaper and selling it with higher profits, facilitating legal processes for this, stretching control mechanisms, and developing incentive systems for energy production. (Kurşuncu and Özlüer, 2016).

2.7.1. The Solar Power Plant Problems From Planning Perspectives

To determine the most suitable areas and plan decisions in terms of different sectors of the spaces depends on analysis for solar power plants. The unplanned and intensive SPP site selection is not associated with the environment in spatial planning. The plan strategies seem to be irrelevant in site selection process for SPP's. It is made only for economic investment and energy efficiency reasons. It causes privately owned agricultural and pasture lands to be leased to investors for this purpose (Saner, 2015 and Turney, 2011).

There are problems related to Solar Power Plants (SPP);

• While land decisions related to the energy sector should be included in the Environmental Plan, these plans generally do not include any analyzes and predictions regarding energy use, energy needs, energy demands, and energy potential related to renewable energy.

• The general approach of spatial planning is shaped in a fragmentary and investment-oriented developmental paradigm. There are not balanced environmental protection, sustainability, and scale decisions.

• The plans include the accepted to existing and decisions of new energy facilities examined in the lower scale plans. In spatial planning, no relationship can be established between the urban dynamics and energy investments. There is no sufficient interaction between the development of urban planning and energy investments. Renewable energy is reflected in the plan decisions as a strategic proposal.

• There are no sufficient analyzes for suitability. Scientific and technical site selection criteria are not taken into account for production. The analyzes are not made for the most ideal location.

It is important to evaluate the environmental dimensions of the SPP. The location selection decisions should implement with determining the true method and criteria. Most decisions of solar power plant locations will be made to minimize the environmental effects.

2.7.2. Examples of News for Land-Use Reaction of Society

Since land decisions are not made correctly for SPP, there are practices that receive a public reaction in some regions. The site selection and analyzes cause inefficiency and environmental damages.

Figure 2. 14. SPP Project in Karaburun-İzmir

(Source: https://www.birgun.net/haber/karaburun-da-ges-projesi-icin-binlerce-cam-agaci-kesilecek-311453, Last Access Date: 28.04.2021)

‘Pine trees will be cut for SPP project’

Thousands of pine trees will be cut down for the Solar Power Plant, which is planned to be established in an area of 300 thousand square meters, although there is a Special Environmental Protection Zone in Karaburun Küçükbahçe Neighborhood. While the area selected as the project site was a dense forest area, it is seen that some of this forest has been shaved and the ecosystem of the region has been severely damaged by the stripping of the soil.

Figure 2. 15. SPP Project in Seferihisar-İzmir

(Source: https://www.birgun.net/haber/seferihisar-direnmekte-sirket-jes-yapmakta-kararli-338950, Last Access Date: 28.04.2021)

'SPP in forest and agricultural areas'

It is preparing to establish 37.5 MWe geothermal power plant and auxiliary resource (SPP and WPP) facilities in forest and agricultural areas in the Orhanlı and Yeniköy neighborhoods. There is organic agriculture in these neighborhoods so the lands can be protected. Both GPP, WPP and SPP planned for Orhanlı village threaten the ecology.

Figure 2. 16. Renewable Energy Projects in İzmir
(Source: https://www.evrensel.net/haber/431529/ İzmirin-belli-basli-cevre-sorunlari, Last Access Date: 28.04.2021)

'Threat of Renewable Energy'

One of the most important problems is WPP, GPP, and SPP projects presented renewable energy which has increased in recent years. The WPP projects are concentrated in Karaburun Peninsula and these projects affect environmental features in the region. GPP projects are wanted to be established in regions where agriculture and olive cultivation are concentrated, bird paradise. SPP projects are also likely to be an effective role in the environment negatively with these types of decisions.

Figure 2. 17. SPP Project in Elmalı-Antalya
(Source: https://www.enerjigunlugu.net/antalya-eymir-merasina-ges-projesi-tepki-cekti-37320h.htm, Last Access Date: 28.04.2021)

'Destruction of Pasture and Agricultural Land Affect to Our Future'

There is a reaction to the project of establishing a solar power plant in the Eymir pasture, which is considered one of the most productive pastures of Turkey in the Elmalı district of Antalya. It is a 23.4 MWe solar power plant project planned to be built in the Eymir plain with an area of approximately 5 thousand decares. Elmalı has potential areas because it is surrounded by mountains and suitable slopes on all side. "GES is wanted to be built on the pasture. Waste of mind "

Figure 2. 18. SPP Project in Bolvadin-Afyonkarahisar
(Source: https://www.haberler.com/belediye-ges-icin-yaslari-10-50-arasinda-degisen-13976155-haberi/, Last Access Date: 28.04.2021)

'Even the green trees in the garden of the mosque have been cut'

Most of which are pine trees and whose ages are between 10-50, have been cut down in the area where the power plant will be built. After the cutting the trees, the green area turned into a barren land.

CHAPTER 3

OVERVIEW ON THE RELATIONSHIP BETWEEN PLANNING SYSTEMS AND LAND SUITABILITY ASSESSMENT OF SOLAR ENERGY DEVELOPMENT IN GIS

3.1. Geographic Information Systems and Planning

Geographical Information System (GIS) is a tool for analysis related to geographical data and other related data. The system can be seen as a decision mechanism in the environment. The first steps in the field of GIS were taken in 1963 with the geographic information systems project, which consists of inventory studies conducted to determine the size and usage types of the country lands in Canada. Many sectors use GIS, including urban and regional planning, agriculture, forestry, landscape planning, geology, protection, security, tourism, archeology, local governments, population, education, the environment, and medicine. GIS technology is most used for comprehensive planning, development plan, land use inventories, site suitability assessments, and socio-demographic analysis and mapping purposes (Warnecke et al. 1998).

In the planning discipline, it is important to make future-oriented decisions and develop strategies. The role of large-scale, accurate geographic information should be the most important decision-making element for the planning process. Spatial development and management of resources that will occur in the physical environment depend significantly on the availability of up-to-date and reliable information for the land. While data represent the characteristics of land, people, and organization in any planning process; information is about organizing, reconstructing, and improving data in a more understandable way. In GIS, with the successful use of information, decision-makers or planners are supported with more understandable information. Thanks to the many techniques of GIS, most of the problems that may arise new or previously found can be solved (Klosterman, 1995). Although some scientists claim that GIS really distracts planners from the essence of new methodology, the information provided by GIS is important (Harris, 1989).

GIS can analyze in spatial developments and use the process of collecting and storing basic data. With the development of technology, gathering information about the built environment is supported by many software and hardware. With this progress, the biggest contribution to the planning discipline is geographic information systems. In addition to new GIS methods in data production, through participatory applications, GIS promotes an inclusive society and increases the use of collaborative spatial information in planning. (Göçmen and Ventura, 2010).

3.2. Geographic Information Systems and Land Suitability Analysis

Ease of use in the layer structure provided by GIS applications in geographic studies; it also brings quality data production in a short time and questioning, analyzing, and evaluating these data with reliable methods. The process that determines the suitability of the use area by defining and evaluating the characteristics of more than one use in each land can be defined as a land suitability assessment (Steiner, McSherry and Cohen, 2000). A land suitability assessment is made to determine the potential capacity of the land to be provided for the location in an ideal way.

The techniques which are used in GIS offered some approaches to assess environmental problems in 1950-1970 and were used to analyze land suitability. Land Suitability Analysis checks how certain factors can be into the design process in search for a suitable location in any spatial decision mechanism. Land suitability is not limited to a decision in the physical environment but is a collective set of criteria such as socio-economic, ecological, environmental, political performance. Land suitability assessment becomes standard practice in planning. With powerful techniques, GIS applications as a tool to make important decisions are widely used in the conformity assessment of spatial analysis (Marull et al., 2007 and Liu et al., 2014).

Functions of GIS; it includes four main components: data entry, data storage and management, data processing and analysis, and data output. In terms of land suitability, GIS systems have developed during its history. The development of GIS can be examined in 3-time frames. Invitation phase, integration phase, and development of user-oriented GIS technology (last 10 years). Development and changes in GIS affect the method and approach to planning and land-use suitability analysis (Malczewski, 1991 and Malczewski, 2004).

Table 3. 1. GIS Development
(Source: Malczewski, 2004)

GIS development	**Perspectives of planning**	**Land-use suitability analysis**
Invitation (1950s - 1970s)	Scientific	Computer-assisted overlay mapping
Integration (1980s)	Political	Cartographic modeling/MCDA
Proliferation (1990s)	Participatory / collective design	MCDA AI/Geocomputation
		Internet/Multimedia/Visualization

Considering the historical development of GIS, it is seen that the primary perspective has shifted from the scientific system approach to other perspectives in time. It evolved into public participants and collective design approaches in line with political perspectives (Brail and Klosterman, 2001) (Table 3.1). GIS development and changes in planning practices affect methods and approaches together. Land suitability analysis; the most important goal for city planners and the disciplines involved in the process is to create a suitable model for determining future land use.

The main purpose of this study is to determine the GIS tools as the main target of the land suitability analysis. The study offers an approach to the development of solar power plants in İzmir province by determining the suitable sites with a multi-criteria approach based on GIS. The criteria defined and selected include environmental, technical, economic, and social factors. After the determined criteria and weighting study was carried out, a decision mechanism was created in the GIS environment in order to determine the most suitable site for the development of solar power plants. GIS is important as a tool for multi-criteria decision-making and land use suitability.

3.2.1. Multi-Criteria Decision Modeling

The Multi-Criteria Decision Making (MCDA) method is a decision-making method. It creates a model and technique for solution development that can be created for complex problems dealing with different data types. MCDA is one of the GIS-based approaches that contribute to decision-making in location selection, land suitability analysis, and resource evaluation (Malczewski, 1999). It is a model of identifying and selecting alternatives to find the best solution depending on different factors. The most important point in decision-making is the excess of criteria determined to choose the alternative. MCDA is considered on energy planning to using different and the best tools for decision. The multi-criteria decision-making method can be used as an efficient method to facilitate analysis in studies involving multiple criteria (Triantaphyllou, 2000 and Mateo et al, 2012).

The process of the decision-making model generally includes five main stages: defining the problem, creating alternatives and criteria, criteria selection, criteria weighting, evaluating, selecting the appropriate multi-criteria method, and finally ranking the alternatives. The main steps in multi-criteria decision making are: (Thomas L. Saaty et al, 1987 and Mateo et al, 2012)

Step 1: Defining the problem, creating alternatives, and establishing criteria

Step 2: Assign criterion weights

Step 3: Creating the evaluation matrix

$$
\begin{array}{ll}
\text{Criteria} & C_1, C_2, \ldots, C_n \\
\text{Weights} & W_1, W_2, \ldots, W_n \\
\text{Alternatives} &
\end{array}
$$

$$
\begin{bmatrix} A_1 \\ A_2 \\ \vdots \\ A_m \end{bmatrix}
\quad
\begin{bmatrix} x_{11} & x_{12} & \cdots & x_{1n} \\ x_{21} & x_{22} & \cdots & x_{2n} \\ \vdots & \vdots & \vdots & \vdots \\ x_{m1} & x_{m2} & \cdots & x_{mn} \end{bmatrix}
$$

Figure 3. 1. Evaluation Matrix

(Source: Saaty, 1987)

Step 4: Choosing the appropriate method

Step 5: Presenting alternatives

This study tries to apply the GIS based Multi Criteria Decision approach to analyze the solar power plant location and land use suitability analysis.

3.2.2. Analytic Hierarchy Process Method

The analytic hierarchy process (AHP) is a general measurement theory proposed by Thomas L. Saaty in 1980. AHP is an effective tool for solving complex problems in the decision-making process. It assists decision-makers with priorities and makes the best decision before reaching a final decision. AHP helps to make a decision by reducing complex decisions to the bottom and synthesizing the results. Among other MCDA methods, AHP is flexible and can be easily applied in the GIS environment. It is also widely applied in land suitability analysis and regional planning (Yang, Liu, and Wang, 2007). Land suitability mainly deals with large amounts of data and includes multiple factors. AHP is a classic land suitability analysis procedure and a systematic approach to making the right decisions for site selection. It also proposes the integration of a GIS-based land suitability model for site selection (Mendoza, 1997).

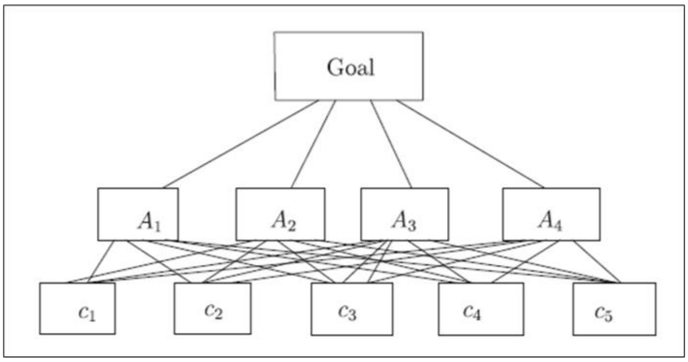


Figure 3. 2. Hierarchical AHP Model

(Source: Thomas L. Saaty and Vargas, 2012)

AHP is a formulation and analysis system that uses four steps in solving a problem. The main steps of the method are as follows:

Step 1: Structuring a problem to be decided on a hierarchical model

Step 2: Weight assignment for each criterion

Step 3: Finding the score of each alternative for each criterion

Step 4: Obtaining an overall score for each alternative

AHP is based on comparisons in terms of factors on a decision hierarchy using a predefined comparison scale. As a result, differences in significance turn into percentage distribution over decision points.

3.3. GIS Techniques of Solar Power Plant Site Selection

Energy planning particularly affects the interests and resources of multiple actors, it is socially unacceptable to propose and implement a policy alternative without taking into account the interests and preferences of the various affected factors. In order to see the success of the use of renewable energy, more than one criteria should be analyzed and taken into account in applications. The traditional single-criteria decision-making approach, which aims to determine the most efficient option by reducing the cost, may be powerless in solving these problems. While renewable energy is very important and expected to benefit from these resources, different GIS techniques should be used for site analysis (Tsoutsos et al, 2009).

Solar energy systems play an important role in the economic and social development of the country. Choosing between different alternative sources requires the use of meaningful decision-making techniques to expand renewable energy sources, where environmental regulations have an impact on the economy. These analyzes together with the multi-criteria decision-making method present an alternative formulation to renewable energy sources (Figure 3.3).

Applied techniques in research studies for solar power plant site selection	AHP	FAHP	TOPSIS	Boolean	SAW
Mensour et al. (2019) - 1	■				
Eroğlu (2018) - 2		■			
Lozano et al. (2013) - 3	■		■		
Uyan (2016) - 4	■				
Noorollahi et al. (2016) - 5		■			
Yousefi et al. (2018) - 6		■		■	
Mierzwiak et al. (2017) - 7	■				
Suh et al. (2016) - 8		■		■	
Garni et al. (2017) - 9	■				
Georgiou et al. (2016) - 10	■				■
Solid box, indicates a particular techniques for solar power plant					

Figure 3. 3. Applied Techniques in SPP Site Selection

After many literature reviews, 10 different literature studies are examined in more detail in the method section. It has been observed that there are different GIS techniques for SPP site selection. Analytical hierarchy process has been seen as the most preferred among these studies. It has been concluded that AHP is the most popular technique in the solar power plant site selection analyzes (Mardani et al., 2015).

3.4. Criteria for Solar Power Plant Site Selection

Suitability analysis for solar power plants; there should be multi-criteria and comprehensive assessment of technical, economic, environmental and social factors.

There are many criteria and sub-criteria for this analysis. In terms of planning, the criteria determined for solar power plants should be considered in terms of environmental risk while supporting economic growth. The response of energy systems to the surrounding area choices should be minimized by minimizing the negative impact of these systems' location selection.

Criteria used in previous solar power plant site selection studies	1	2	3	4	5	6	7	8	9	10
Slope		■	■	■	■	■		■	■	■
Aspect							■		■	
Solar Conditions		■	■		■	■	■	■	■	■
Transportation	■	■	■	■	■	■	■	■	■	■
Water Sources	■	■				■				
Land Use and Land Cover	■	■		■	■	■				■
Settlement Area	■	■	■	■	■	■	■		■	
Faulty Lines						■				
Elevation					■	■				■
Protected Area	■	■								
Weather Condition					■					
Vegetation		■								
Power Lines and Center		■	■	■	■		■	■	■	■
Geology		■								
Disaster		■								
Recreation		■								
Solid box, indicates a particular parameter for solar power plant										

Figure 3. 4. Criteria in SPP Site Selection

The numbering includes the literature order in Figure 3.4.

There are many studies in the literature that examine the criteria required for the installation of SPP. After the literature review, it has been included to show the criteria used in 10 different literature types of research. A part from these criteria, many criteria are used for the location of solar energy panels. It is almost impossible to calculate the importance values or weight values that express how important the determining criteria are relative to each other. Multiple criteria decision-making methods have been developed to make this assessment. These methods are used to evaluate multiple alternatives according to multiple criteria (Sánchez-Lozano et al., 2013).

A comprehensive literature search has been conducted to recognize the most important environmental, economic and social criteria of solar power plant suitable area. When the literature is reviewed, the main criteria were taken into consideration. The criteria to be used for suitability analysis in the study were selected according to the literature and expert opinions. A model was created with the AHP model integration.

CHAPTER 4

CASE STUDY AREA: İZMİR

İzmir is a metropolitan city within the western of Anatolia. It is surrounded by Aydın, Balıkesir, Manisa provinces and the Aegean Sea and Aegean Islands. It is the twenty-third largest province of the country as an area. The city is covering an area of approximately 12.085 km^2 with total of districts between 37"45' and 39"15' north latitude and 26"15' and 28"20' east longitude. It has a coastline of 629 kilometers. İzmir has very wide perspective in terms of its historical structure, culture and tourism. It is an important exhibition center and port city. The common natural vegetation includes strength trees and shrubs that are large, strong and coniferous, evergreen. The mountains extend perpendicular to the sea. The plains enter the border of Inner West Anatolia in İzmir. This feature allows the sea effects to spread to the inner parts. İzmir is one of the richest agricultural regions of Turkey. Differences in physical geography such as elevation, distance from the west and the coast in the province lead to climate differences in terms of precipitation and temperature. In İzmir which is in the Mediterranean climate zone, the summers are hot and dry, the winters are mild and rainy. According to the General Directorate of Renewable Energy and “Solar Potential Atlas of Turkey” İzmir is located in the sunny region of Turkey. İzmir has important soil and land values.

İzmir has been chosen as a study area because it has high values of energy consumption, solar potential and suitable geographical conditions. It is important to make a suitability analysis for energy investments for a metropolitan city.

Figure shows which part of Turkey and the İzmir is the study area

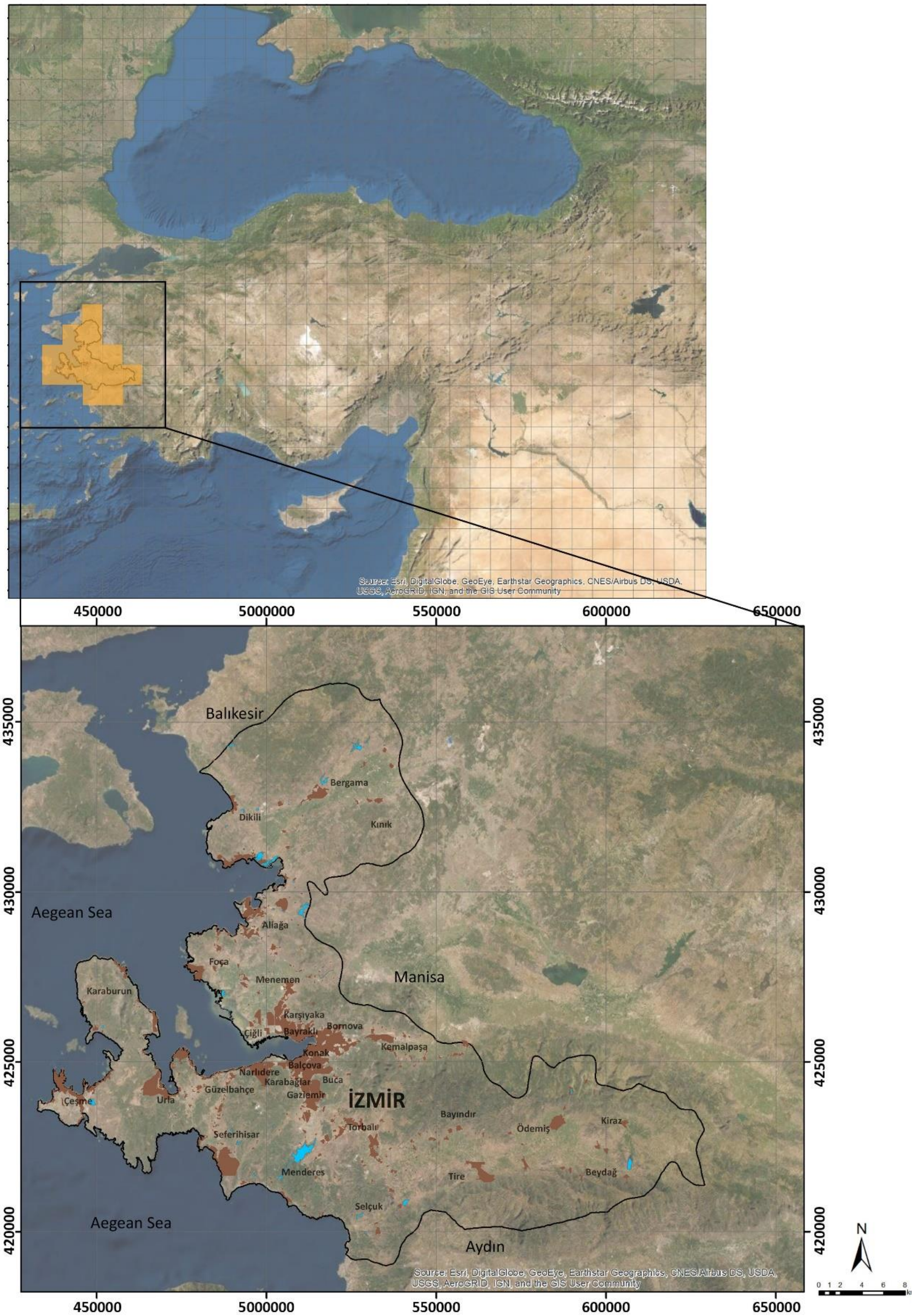


Figure 4. 1. The Study Area Location

(Source: ESRI)

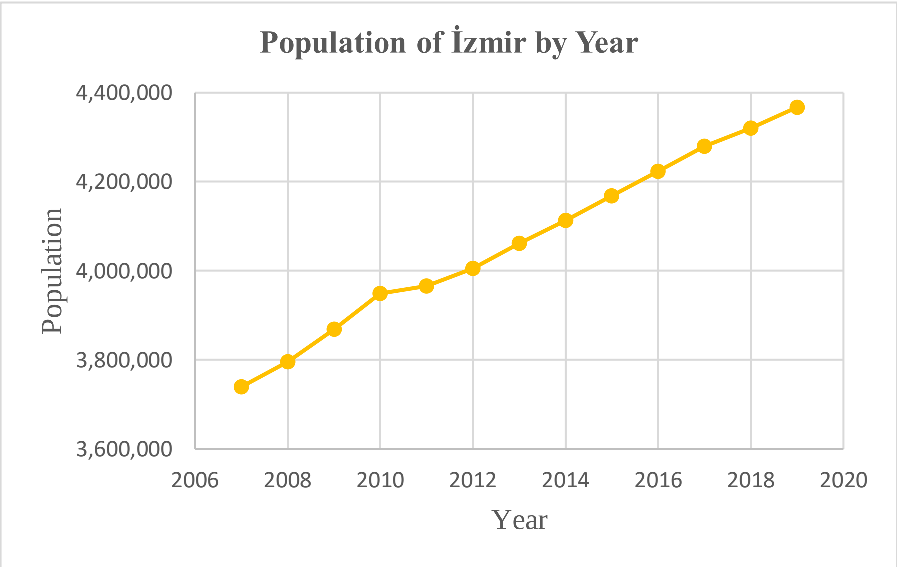
4.1. Demography of the Study Area

İzmir is the Turkey's third most populated city in Turkey with about 4.367,251 millions of population according to 2019 census. The population lives in 30 districts and 1,297 neighborhoods of these districts.

Table 4. 1. Compare the Population of Turkey and İzmir

(Source: TURKSTAT)

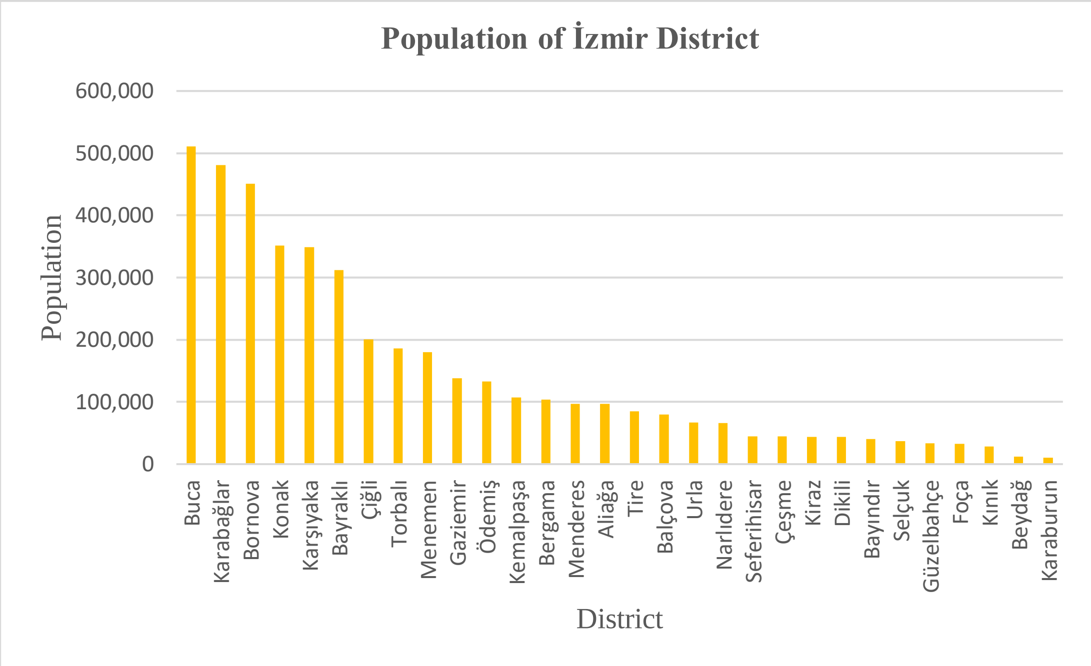
	Population	Annual population growth rate (‰)	Population Density
Turkey	83.154.997	13,94	108,05
İzmir	4.367.251	10,76	363,57



Graph 4. 1. Population of İzmir by Year

(Source: TURKSTAT)

The population of İzmir is 4 million 367 thousand 251 people in 2020. It is one of the most immigrant receiving cities of our country. It is 3rd province with the most population. When we look at the population of İzmir district, the largest district is Buca (510,695), the smallest district is Karaburun (10,759). According to IZKA Report, İzmir in city center and rural areas for 2025, it was emphasized that the problems caused by the uncontrolled urbanization brought about by the rapid and uncontrolled population growth experienced should be eliminated and taken under control. While the population in the city center is expected to be 4 million 748 thousand in 2025, it is estimated that the rural population will be 357,420. Considering both the center and the rural areas of the city, it is stated that the possible population of İzmir will reach 5 million 106 thousand in 2025.



Graph 4. 2. Population of İzmir District

(Source: nüfusu.com)

4.2. Climate of Study Area

İzmir province shows climatic characteristics according to the tectonic characteristics of the coastal Aegean strip with its gulf structure, which is open to marine effects and has an inner sea feature in the Middle Latitude zone. The Mediterranean climate character is dominant because it is located in the Middle Latitude zone and is a coastal city.

Summers are hot and dry, winters are warm and rainy, and spring months are transitional. It has high sun potential. The wind situation creates an important potential due to the coastal strip open to the sea and the combination of different topographic structures. The annual average temperature varies between 16ºC (Bergama) and 17ºC (Bayındır). Considering the extreme values measured in İzmir, it is understood that the temperature varies between a maximum of 45.1ºC (Torbalı) and a minimum of -13ºC (Ödemiş)(MS). There are sunny days throughout the year in İzmir (Figure 4.2). İzmir has average 300 sunny days in year by its geographical location.

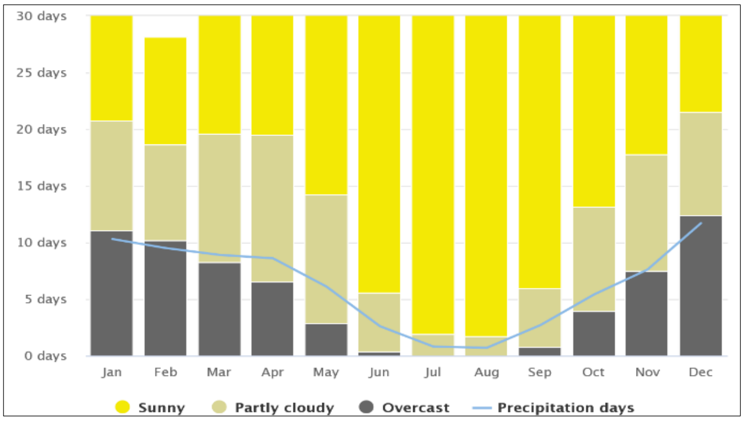


Figure 4. 2. Weather Conditions in Study Area

(Source: metoblue)

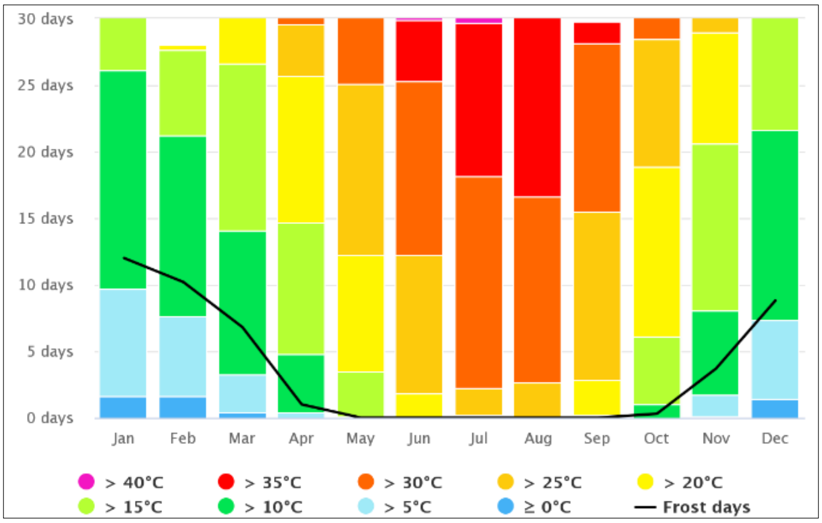


Figure 4. 3. Diagram of Maximum Temperature

(Source: metoblue)

The maximum temperature diagram for İzmir shows that how many days per month reach certain temperatures. There are different temperature value but even in winter, study area has good temperature values according to number of days. Depending on the sunshine duration and sufficient amount of rainfall, the soil structure has a suitable climate in terms of agriculture. Renewable energy sources have a significant potential in terms of solar (Figure 4.3).

4.3. Land Capability Class of the Study Area

Use of resources as efficient and sustainable is an important issue in terms of ensuring economic development. Since land is the most fundamental capital of agriculture and the main sectors of the economy is not reproducible unlike other production factors. So, its sustainable use is of particular importance. In general, within the framework of land management, land suitable for agricultural production should be protected in accordance with their qualifications. Land capability classes and distributions should form the basis for the planning (Land Classification Report for İzmir, 2013).

Land use capability classes are divided into 8 part.

I. Excellent for cultivation with different types of techniques and high productivity potential

II. Very good for cultivation and this class has limiting factors

III. Cultivation with some limiting factors and medium productivity potential

IV. Limited potential for cultivation with lots of limited factors, low to medium productivity

V. Lots of limiting factors, especially drainage and untreated wet or rock-out flat land

VI. Cannot be cultivated, except the pasture or forestry. Limiting factors include topography, soil depth and rocky soils

VII. Cannot be cultivated, only appropriate for forestry and pasture uses

VIII. Cannot be cultivated, appropriate for protected area or wildlife uses

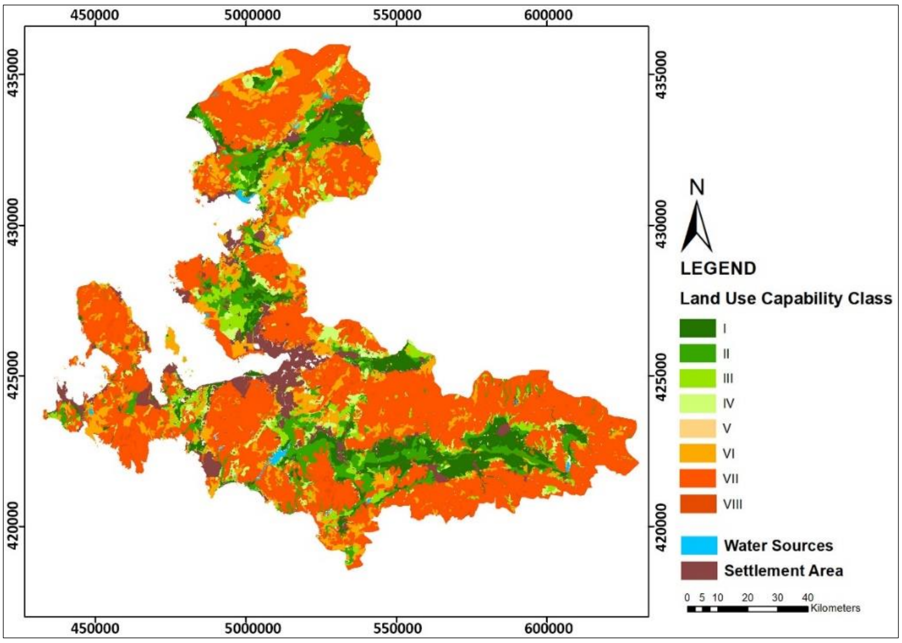


Figure 4. 4. Land Use Capability Class of the İzmir

(Source: Land Classification Report for İzmir, 2013)

As a result of the study with the thematic map, the Land Capability Class with the highest surface area with a ratio of 56.31% VII. Class. However, I. and II. has been observed that the part of 19.31%. It is classified according to the land use capability of İzmir province soils. Accordingly, the land that covers the largest area (642.5344 ha) in İzmir province is VII. Class. In the 2nd rank is (156.0513 ha) VI. Class and in the 3rd rank is (111.564 ha), II. Class land is existing.

Table 4. 2. Land Use Capability Class of the İzmir
(Source: Land Classification Report for İzmir, 2013)

Land Use Capability Class	Area (%)
I	9,53
II	9,78
III	5,52
IV	4,13
V	0,04
VI	13,68
VII	56,31
VIII	1,01
	100

In İzmir province lands, where lands suitable for both agricultural and non-agricultural uses are located together, it is necessary to protect the less and valuable agricultural lands at the stage of making land use decisions.

4.4. Potential of Solar Energy in İzmir

İzmir is one of the prominent provinces in terms of the development of renewable energy resources such as solar, wind, geothermal, biomass and biogas, with its geographical location, ecological structure, development in agriculture and industry sector. Most of the energy sources used today occur as a result of events that are influenced by the solar factor. Solar resource which is one of the most important renewable energy sources; it has become an issue on which studies have been carried out with its features such as not having a polluting effect on the environment, being able to implement it within the country itself, not being dependent on foreign countries, not having a complex system and having low costs.

Oil and natural gas consumption of İzmir is in 3rd rank on after Istanbul and Ankara. İzmir consumes approximately three times the energy it produces. The 58.9% which constitutes the majority of the electrical energy consumed is used in industrial facilities according to the data of the Turkish Electricity Distribution Corporation. This value is well above the average of Turkey which is about 45%. Among the building types, the biggest consumption share belongs to the houses with 20.1% (IZKA, 2010).
According to the numerical values related to energy consumption for Turkey and İzmir;

Table 4. 3. Energy consumption per person according to usage areas (kwh)
(Source: TURKSTAT)

	Energy consumption per person according to usage areas (kwh)
Turkey	2899
İzmir	4658

The value of İzmir ranks 9th among the provinces.

Table 4. 4. Total energy consumption according to usage areas(mwh)
(Source: TURKSTAT)

	Total energy consumption according to usage areas(mwh)
Turkey	3074354
İzmir	19935960

The value of İzmir ranks 2nd among the provinces.

According to 2010, İzmir consumes %8.7 of national electricity production output. Its share of consumption in the output of Aegean Region id %54.9. While the electricity consumption in Turkey grew by %9.7 in 2010 over the previous year, İzmir registered a growth of %11.1. İzmir’s electricity consumption is held by industry (%36), followed by residential units (%34.5), offices (%11.8) and government agencies (%5). The rest of the consumption volume is used for lighting, irrigation and other purposes (İzmir Metropolitan Municipality Report, 2015-2019)

According to values related to solar power for Turkey and İzmir;

Table 4. 5. Yearly Average Sunshine Duration (hour / day)

(Source: MS)

	Yearly Average Sunshine Duration (hour / day)
Turkey	6,8
İzmir	6,79

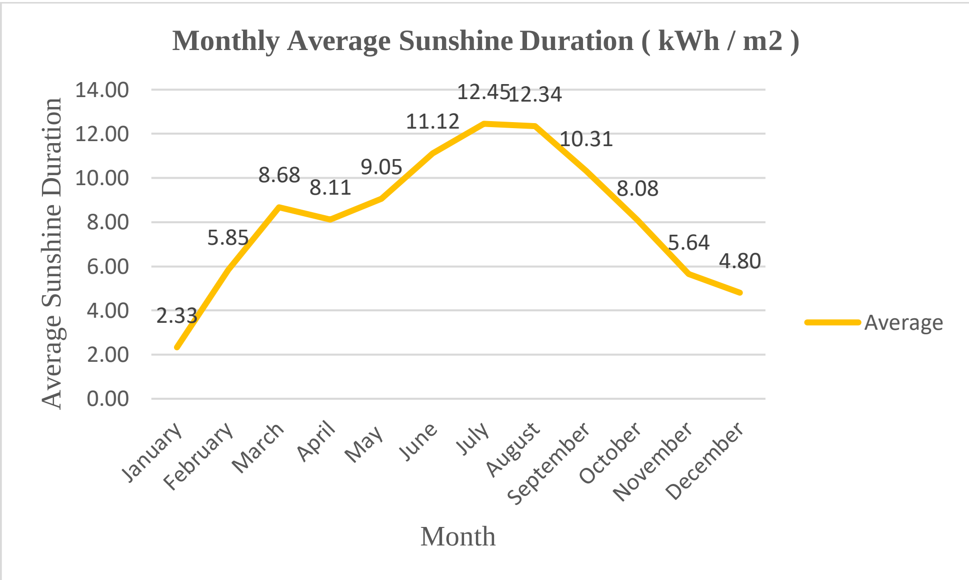
According to solar data, İzmir contains values that are very close to the average of Turkey.

Table 4. 6. Yearly Average Solar Radiation (kWh / m2)

(Source: MS)

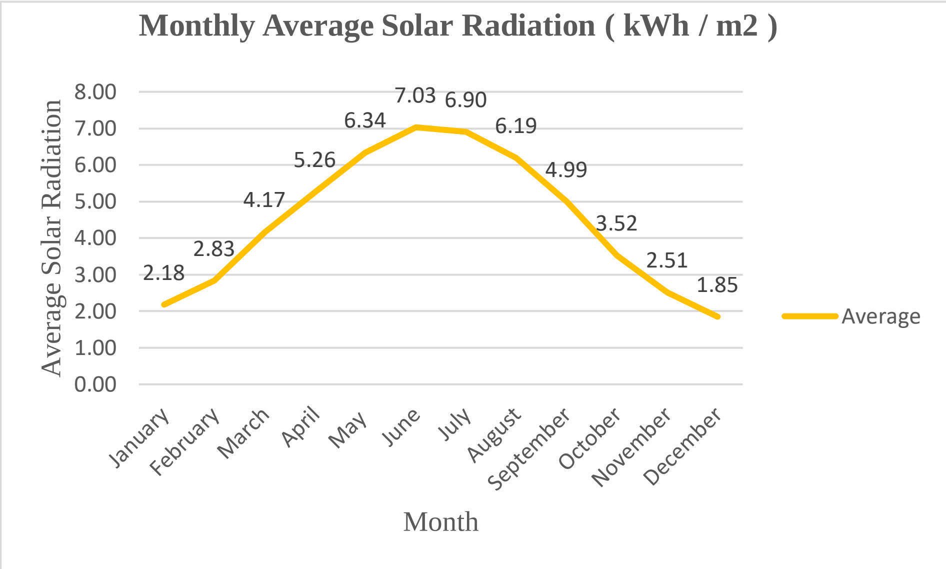
	Yearly Average Solar Radiation (kWh / m^2)
Turkey	4,48
İzmir	4,43

According to 2019 values which are taken from Meteorological Service in İzmir;



Graph 4. 3. Monthly Average Sunshine Duration (kWh / m2)

(Source: MS,2019)



Graph 4. 4. Monthly Average Solar Radiation (kWh / m2)

(Source: MS,2018)

The monthly average sunshine duration has high value on July and yearly average value is 8,23. The monthly average solar radiation has high value on June and yearly average value is 4.48.

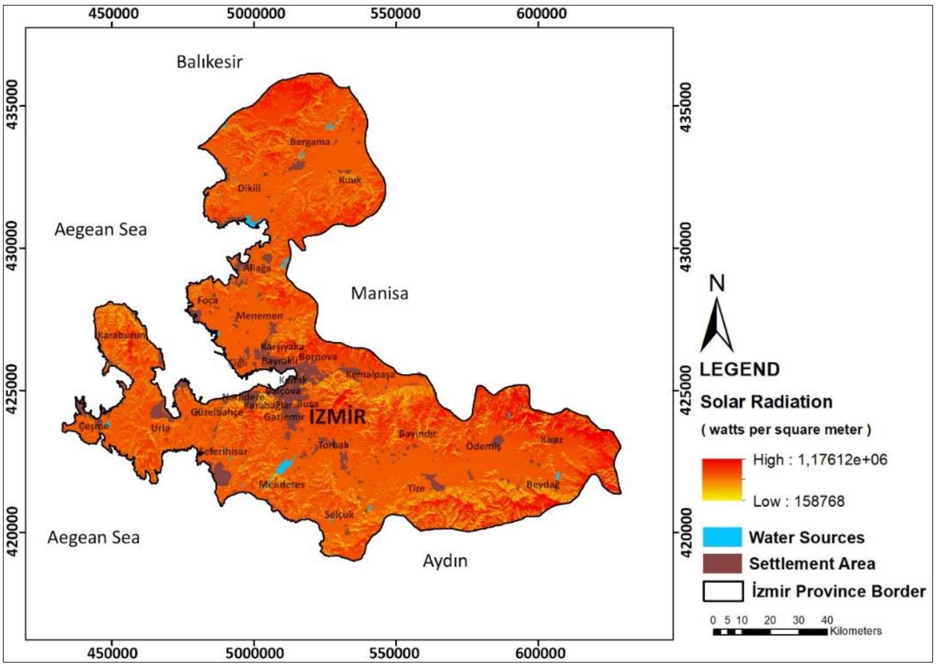


Figure 4. 5. Solar Radiation Map of the Study Area

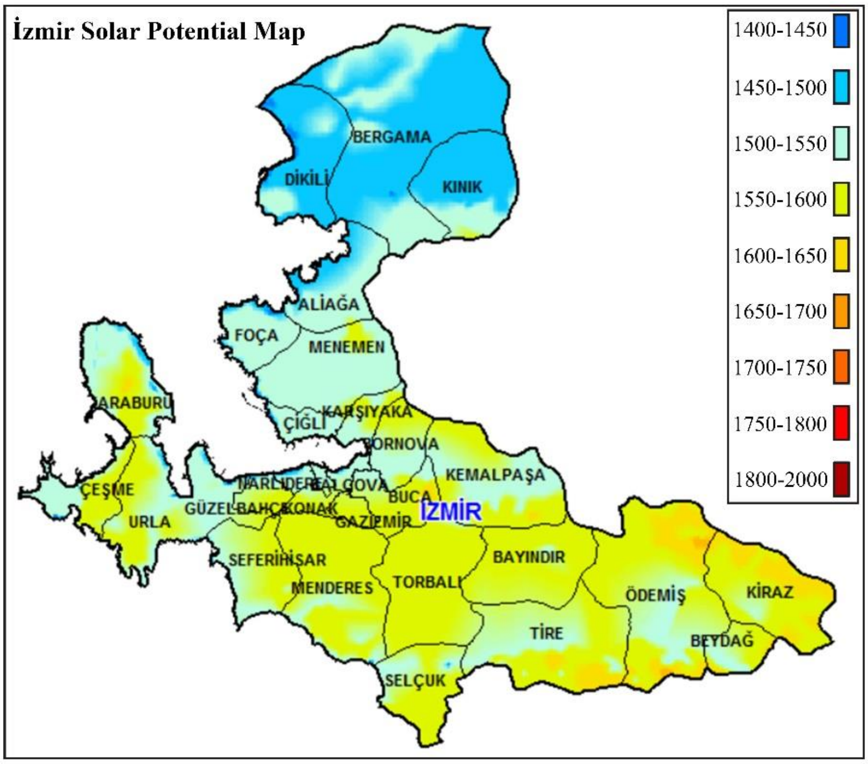


Figure 4. 6. Solar Potential Map of the Study Area

(Source: Energy Atlas)

By using the annual global solar radiation or solar radiation map of İzmir, the solar energy potential by district has been prepared by the General Directorate of Renewable Energy (kWh / m^{2} - year). Total solar radiation map shows the high potential of İzmir. Even in northern districts there is an average of 1500 KWh / m^{2}-year solar radiation, but in southern districts Kiraz, Ödemiş, Tire, Bayındır, Kemalpaşa this average reaches 1800 KWh / m2-year. When the GEPA map of İzmir is taken as reference, Kiraz, Ödemiş, Tire, Bayındır, Kemalpaşa, Torbalı, Menderes districts located in the south stand out with high solar radiation potential for solar power plant installation (Figure 4.5 and Figure 4.6).

The sun is an infinite source of energy for the world as it has an unlimited duration of radiation. This energy source can dominate a wide geography. With the use of solar energy, it is possible to reduce the energy import rate and prevent environmental pollution caused by fossil fuels. Since solar energy is an environmentally clean resource, it is an alternative to fossil fuels. Being the third largest city in Turkey with a population of over four million, İzmir has potential of renewable energy resources but it cannot benefit from this potential sufficiently yet.

4.4.1. Previous Solar Energy Power Plant Studies in İzmir

There is installed power of 16.154 KW in İzmir as of 2020 and this power is well below the potential of İzmir (Table 4.7).

Table 4. 7. Active Solar Power Plant in Study Area
(Source: Energy Atlas)

Active Solar Power Plant		
Name of Solar Power Plant	**Location of Solar Power Plant**	**Installed Power (KW)**
Irmak Oto İzmir GES	Kemalpaşa	2000
Çağlayan Plastik GES	Gaziemir	1000
Trakya Rüzgar GES	Bergama	1000
Yunt Enerji GES	Bergama	1000
Defne Tarım Tire GES	Tire	900
Boro Enerji Kemalpaşa GES	Kemalpaşa	880
Eshot Gediz Atölyesi GES	Buca	840
Reysaş Lojistik GES	Torbalı	810
Tariş Çiğli GES	Çiğli	650
Ege Orman Vakfı GES	Menderes	500
Kemalpaşa OSB GES	Kemalpaşa	500
Alkor Alüminyum GES	Menderes	500
Karşıyaka Belediyesi GES	Karşıyaka	490
Tire Organize Sanayi Bölgesi GES	Tire	490
Efe Endüstri GES	Kemalpaşa	470
İzmir Atatürk OSB GES	Çiğli	440
Cemer Kent Ekipmanları GES	Torbalı	400
Gediz Üniversitesi GES	Menemen	400
Granit Dayanıklı Tüketim GES	Torbalı	380
Bozyaka Pazaryeri GES	Karabağlar	340
Bornova Belediyesi GES	Bornova	300
Bademli Kooperatifi GES	Ödemiş	240
Ali Süreyya Perçin Tavuk Çiftliği GES	Foça	220
Katip Çelebi Üniversitesi GES	Çiğli	200
Philip Morris GES	Torbalı	200
Bayraklı Ekrem Akurgal Yaşam Parkı GES	Bayraklı	190
Seferihisar Belediyesi GES	Seferihisar	170
Selçuk Belediyesi Sebze ve Meyve Hali GES	Selçuk	150
Urla Şarapçılık GES	Urla	100
Sa-ha Sabri ve Halim Alanyalı GES	Kemalpaşa	78

(cont. on next page)

Table 4.7. (cont.)

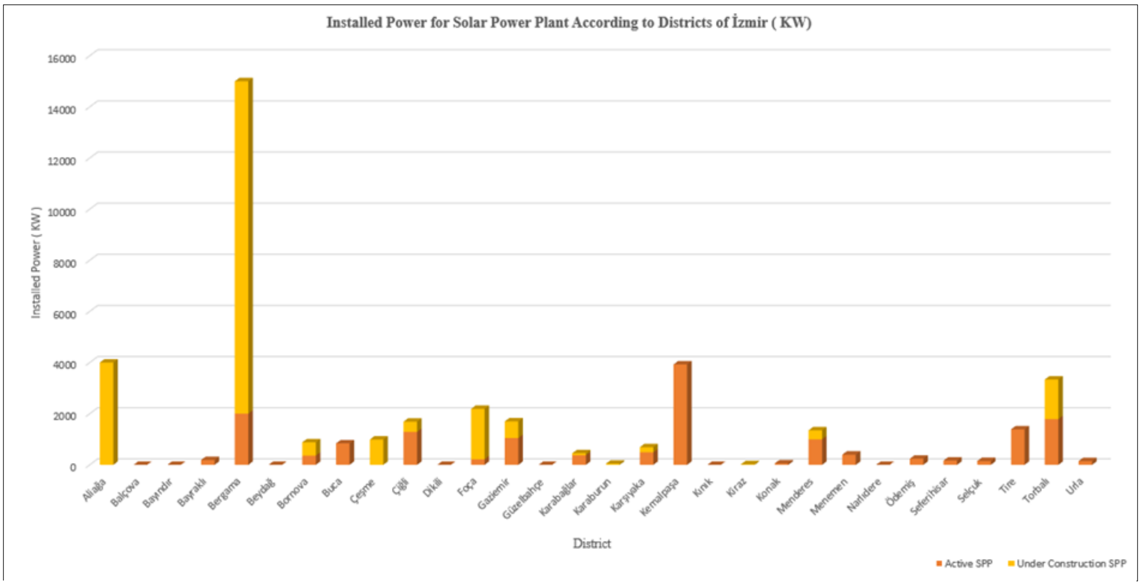
Öztuğ Metal GES	Bornova	63
Egedeniz Tekstil GES	Konak	60
Tekpa Mühendislik GES	Gaziemir	50
Turla Tarım GES	Urla	48
Karabağlar Yeşil Ev GES	Karabağlar	22
Karabağlar Parkı GES	Karabağlar	17
İlhan Okan GES	Bergama	3
Kasım Kutlu GES	Aliağa	3
TOTAL		**16.154**

There is under construction power of 23.800 KW in İzmir as future (Table 4.8).

Table 4. 8. Solar Power Plants Under Construction in Study Area
(Source: Energy Atlas)

Solar Power Plants Under Construction		
Name of Solar Power Plant	***Location of Solar Power Plant***	***Installed Power (KW)***
Bergama Ahmetbeyler Köyü GES	Bergama	13000
Berak Enerji Aliağa GES	Aliağa	4000
Foçalı GES	Foça	1970
Uz Pamuk GES	Torbalı	1000
Karayolları 2. Bölge Müdürlüğü GES	Çeşme	990
JTI Tütün GES	Torbalı	550
DSİ 2. Bölge Müdürlüğü GES	Bornova	420
Adnan Menderes Havalimanı GES	Gaziemir	400
Çiğli Belediyesi GES	Çiğli	400
Menderes Belediyesi GES	Menderes	350
Gaziemir Belediyesi GES	Gaziemir	250
İzmir BŞB Karşıyaka GES	Karşıyaka	200
Yaşar Üniversitesi GES	Bornova	120
Yeşilyurt Kültür Merkezi GES	Karabağlar	75
Karaburun Belediyesi GES	Karaburun	50
Kiraz Çok Programlı Lisesi GES	Kiraz	25
TOTAL		**23.800**

According to information; the most active installed power is in Kemalpaşa and Bergama. When we look at the solar power plants under construction, the most prominent districts are Bergama and Aliağa.



Graph 4. 5 Installed Power for SPP Acording to Districts

(Source: Energy Atlas)

4.5. Planning Regulations About Renewable Energy for İzmir

The problems experienced in the urban planning of İzmir and the new building stock requirement emerging with the urban transformation is another important factor that makes the use of renewable energy resources important priority for the city. Unplanned urbanization and lack of infrastructure have created an urban pattern that cannot provide energy conservation, the need for energy has gradually increased. Electrical energy and fossil fuels are primarily preferred for heating and lighting in buildings in İzmir. But, when the energy sector and İzmir are evaluated together; potential of İzmir about the renewable energy sector is the first thing that comes to mind. İzmir is a renewable energy center due to its high potential in wind, geothermal, biomass, and solar energies, as well as the advantages provided by its geographical position.

According to the İzmir-Manisa Planning Region 1 / 100.000 Scale Environmental Plan Explanation Report; decisions were made to facilitate the construction of facilities for energy production, especially with the use of renewable energy resources, and decisions were made for the construction of relevant facilities in areas with potential in this respect, and priority was given to these resources. Apart from that, when the power plant is needed, these requests can be evaluated and decided during the environmental impact assessment process together with the sub-scale planning studies. In the developed planning decisions, in line with the principle of observing the protection-use balance, it is aimed to increase, disseminate and encourage the use of renewable energy resources in the planning Area and to develop the necessary measures for the sustainability of resources.

According to the statement report of 1/25000 scale of İzmir Metropolitan Municipality, Department of Development and Urbanization, Master Plan Directorate; there is strategical sentences for supporting the use of renewable energy sources (solar, wind, geothermal). The provisions regarding the implementations of energy production areas have been arranged and declared with the plan notes. This plan has been adopted as a plan decision in which only renewable energy plants can be included in the area designated as the Energy Investment Zone.

According to the İzmir Metropolitan Municipality Strategic Plan Report 2015-2019; sub-scale zoning plans prepared in line with the opinions of the relevant institutions and organizations, without the need for a 1/25000 scale Master Development Plan changing within the scope of the license to be granted in energy production facility areas based on renewable energy resources are approved by the relevant administration.

The relevant administration approves sub-scale zoning plans prepared in accordance with the views of relevant institutions and organizations, without the need for a 1/25000 scale Master Development Plan change within the scope of the license to be granted in energy production facility areas focused on renewable energy resources. It is critical to protect the natural and cultural structure of the area, as well as its regional characteristics and potentials, when deciding where to locate energy production areas based on renewable energy sources.

Renewable energy is identified as one of the strategic sectors in the "Strategic and Emerging Sectors for İzmir" report prepared by the İzmir Development Agency; *"Recently, energy resources have emerged as a sector that should be exploited with the potential of İzmir, especially in the fields of electricity production, urban heating, tourism, and greenhouse cultivation. In the province of İzmir, sustainable, renewable energy and bioenergy resources such as wind, geothermal, and solar have already reached a certain level of production, service, and distribution. Further development of these areas would help the province's other sectors grow."*

According to İzmir-Manisa Planning Region, 1/100.000 Scale Environmental Plan Change Evaluation Report which is prepared by TMMOB chamber of city planners; transformation into development areas which are agricultural areas, forest areas, areas that need to be protected due to their natural character; cities do not include sectoral decisions such as energy policies; accordingly, it was emphasized that urban and rural areas should include decisions that will destroy the highly productive lands and historical and natural areas.

According to Izmir Metropolitan Municipality 2020-2024 Strategic Plan; there are aims to related energy as ‘creating an environmentally sensitive life in cities’. It is necessary to create systems that are evaluated together with nature and to increase the use of renewable energy sources. Conservation of natural areas, making decisions in line with the productivity levels of the lands, preventing rent-oriented projects that will prevent agricultural activities, and creating planned, safe and environmentally sensitive cities have been emphasized.

CHAPTER 5

APPLICATIONS AND ANALYSIS

There are three factors that affect the location selection of solar power plants. These are the efficiency of the activity, the environmental effects of the activity and legal regulations. Generally, environmental factors are ignored and efficiency is emphasized when it comes to obtaining energy from solar power. However, all factors should be taken into consideration when determining the criteria for minimizing the damages in terms of both the environment and human health, and the national legislation should be examined in terms of restrictive and encouraging aspects. Although there are no specific rules for choosing the suitable location.

For suitability area analysis, all predetermined criteria were evaluated and a large-scale suitability area analysis was performed. Analyzes have been made for the location of solar power plants and the criteria used for the analyzes have been determined within the scope of the literature review.

1. **Solar Radiation**
2. **Aspect**
3. **Slope**
4. **Settlement Area**
5. **Main Road**
6. **Forest**
7. **Water Source**
8. **Drainage**
9. **Fault Line**
10. **Land Use Capability Class**

The suitability model is based on 10 raster datasets which are integrated through overlay analysis using the geographic information science. The data will be used for spatial analysis. Using the global data, the slope, aspect and solar irradiation are the more important criteria for selecting the sites for the solar power plant and the Digital Elevation Model (DEM) will be used to obtain the aspect, slope, drainage and solar irradiation. Other criteria which will be taken into consideration are the distance from the settlement area, water sources, forest, fault lines, main road and drainage. The criteria of land use capability class as 10th criteria and first suitable map which are using 9 criteria will be group for analysis with its condition. The final suitability analysis map will be produced. This last final map will emphasize the land capability class is most important for suitability.

The first step was to define criteria for finding the suitable areas for solar power plant in the study area. This step would be done making a literature review on this topic. The required data has started to collect. While some of the data were taken from the relevant institutions, some of them were taken from the CORINE (Coordination of Information on the Environment) data and the DEM data formed the basis for the basic criteria.

Before starting the analysis process, the criteria were reviewed and converted into formats that should be used in the analysis phase. Since there are some restrictions for these criteria during analysis, a model must be created for these constraints and intersect, extraction, buffer, euclidien distance, multiple ring buffer, reclassify etc. tool commands can be used. These criteria evaluates different analysis methods. After the criteria to be used and the constraint factors of the criteria are evaluated, the steps are followed sequentially according to the flowchart of the methodology. All criteria are collected in a general data format with their constraints. AHP method is applied to determine the weight of each criterion. All criteria are overlapped with the ArcGIS software and analyzed together with weighting. The model is verified by overlapping the most suitable areas in Google Earth.

5.1. Raw Data Collecting and Processing

The purpose of the thesis is to determine suitable areas for solar power plant for the area. For this aim, how analyses proceeded and how data sources were used are illustrated in Figure 5.1. There are 5 suitability classes that are not suitable, less suitable, modaretly suitable, suitable, particularly suitable. The criteria prepared grid format and projection is WGS_1984_UTM_Zone_35N. The resolution is 30m-30m.

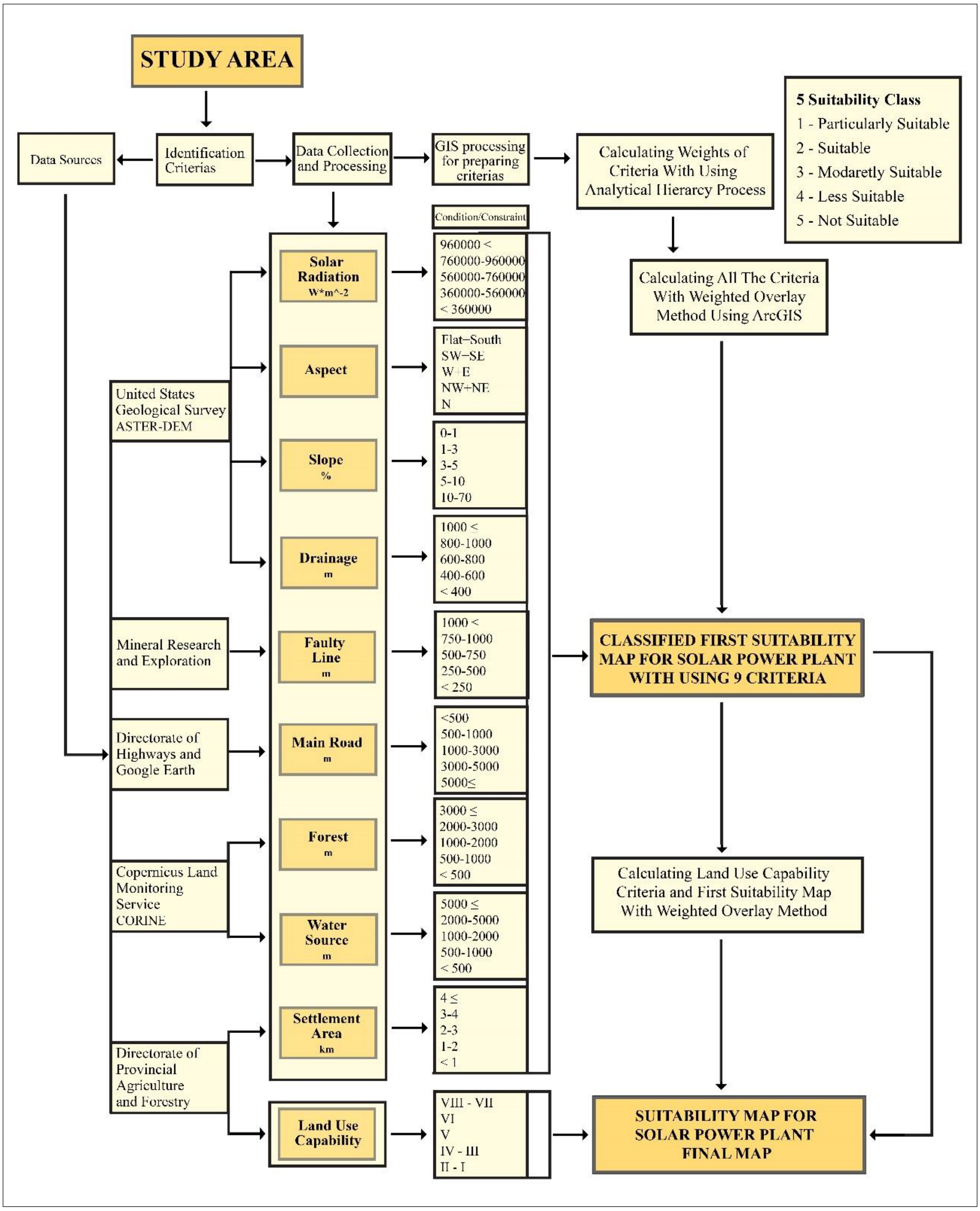


Figure 5. 1. Data Processing of the Study

5.2. Identification of Criteria

It plays an important role in determining the standards and approaches to be used in evaluating the locations where solar power plants will be built. The current condition would be better represented with the map to be obtained if these criteria are chosen correctly.

5.2.1. Solar Radiation Criterion - C1

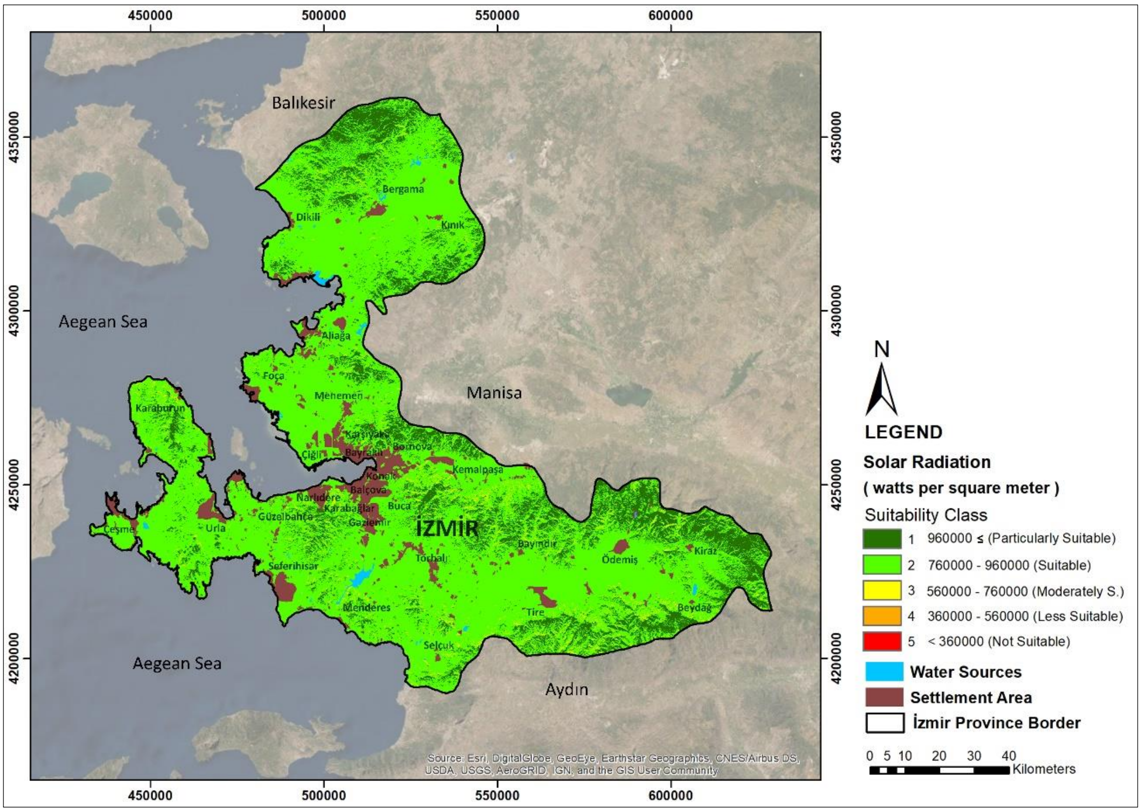


Figure 5. 2. Solar Radiation Suitability Map

Before applying solar energy to an environment, it is critical to understand the strength of solar radiation in that area. To reduce design and maintenance costs, solar radiation data should be as reliable and complete as possible. Solar radiation in that area is one of the most critical criteria for solar power plants. One of the most critical criteria is solar potential, as it has a direct impact on the amount of energy that can be generated from the power plant that will be built (Mensour etc., 2019). The amount of energy and the amount of solar radiation are directly proportional.

Solar irradiation and sunlight duration maps can be produced using the Solar Radiation tool in ArcGIS software. After the Solar Radiation map was reclassified, assignments were made to classes according to their values. Solar Radiation value has been examined in many literatures for choosing the appropriate location of solar energy panels and areas with a value of 700000 and above as watts per square meter have been considered as a value that may be within the appropriate scope (Mierzwiak etc., 2017) (Yushchenko, 2018). The indices of the solar radiation map represent these intervals as watts per square meter; <360000, 360000-560000, 560000-760000, 760000-960000, 960000≤.

When the distribution of the region is analyzed, it can be concluded that the potential in the study area is high, as can be seen from the solar radiation values of the İzmir province. The solar radiation values are high in the districts located close to the provincial border in the north, south, and east directions of İzmir according to the meteorological situation analysis.

5.2.2. Aspect Criterion– C2

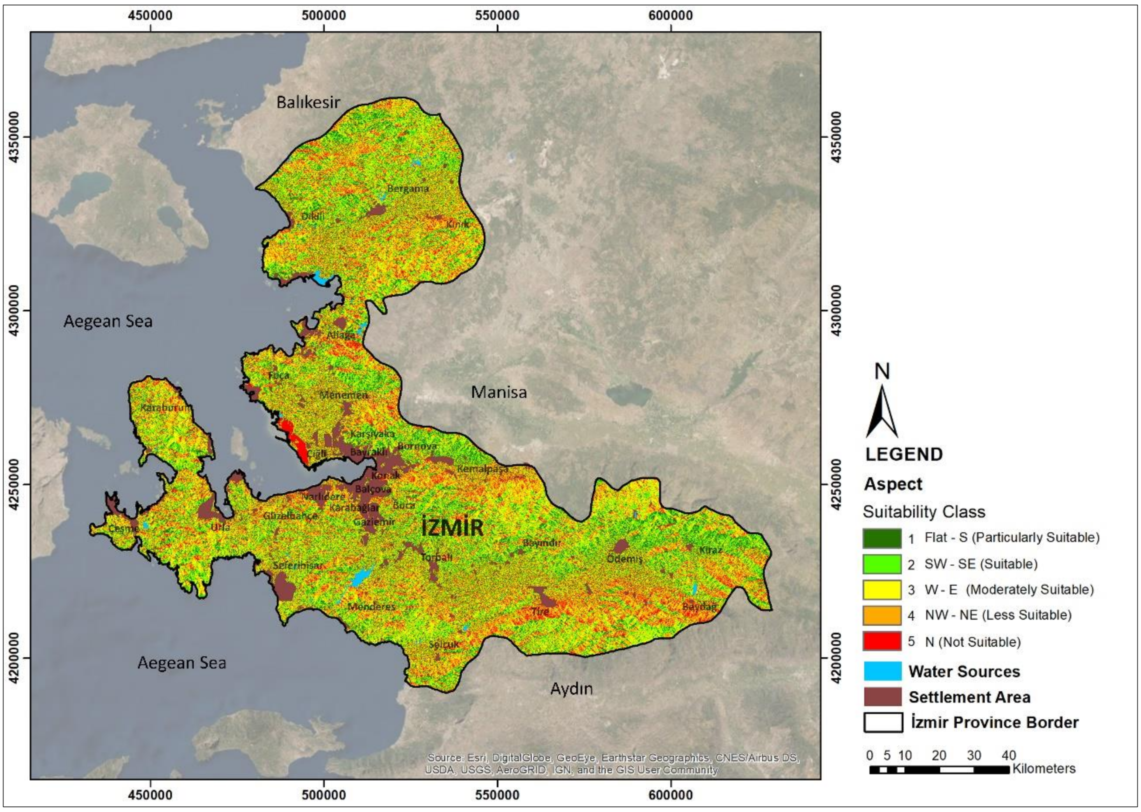


Figure 5. 3. Aspect Suitability Map

The direction and angle of the solar panels should be determined accurately in order to obtain year-round efficiency in applications related to solar energy systems. Aspect is an important factor for solar power plants. For the areas where the power plant will be established, the areas where there are no elevations to shade between the east, west and south directions should be selected. Especially southern and flat areas are the most suitable areas for location selection. South facing lands provide high sun angle according to seasonal conditions (Ayday, 2016). For this reason, applications should be about positioning solar panels facing south to capture maximum sunlight.

In this study, İzmir aspect map was created using the aspect tool with Aster DEM data in ArcGIS software and reclassified. After the aspect map was reclassified, assignments were made according to the suitability classes. The aspect point has been studied in many literatures for the appropriate location of solar panels. South oriented and flat lands are the most suitable, following this the suitability degree in southeast and southwest oriented lands (Mierzwiak, 2017). The indices of the aspect map represent these intervals; North, Northwest-Northeast, West-East, Southwest-Southeast, Flat-South.

5.2.3. Slope Criterion – C3

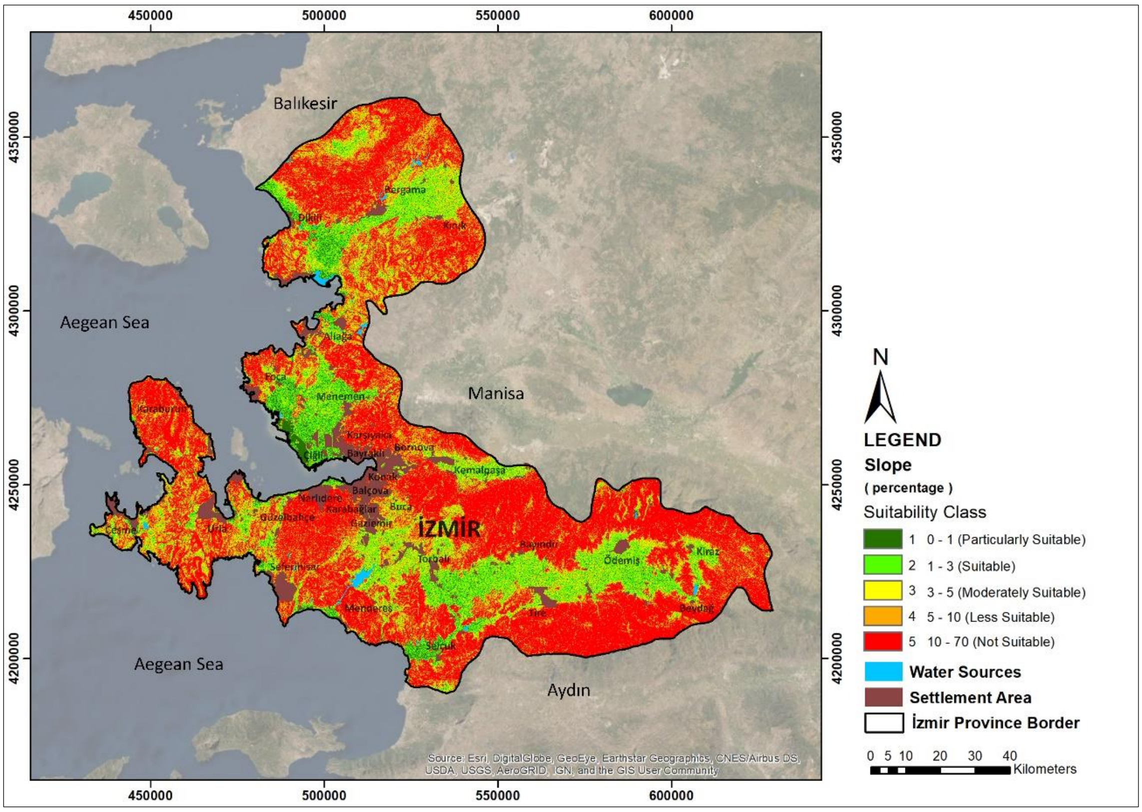


Figure 5. 4. Slope Suitability Map

Solar power plants are highly affected by the slope of the land. It is considered as an important criterion in land determination as it greatly affects the feasibility and cost of GES projects. Different slope values are suggested for areas where solar power plants can be installed. If the terrain structure is wavy, shading increases, the cost of installation and installation work becomes difficult. For solar power plants, flat land and south direction are required. (Bravo et al., 2007; Gastli et al., 2010).

In this study, the slope map of İzmir was created using the slope tool with the Aster DEM data in the ArcGIS software and reclassified. After the slope map was reclassified, assignments were made to the classes according to the slope percentage. The slope value has been examined in many literatures for the suitable area for solar power plant and the value of 3% has been considered as a value that can be suitable (Uyan, 2013 and Mensour etc., 2019). The sharp changes in land slope can cause solar power plant, thus the land slope should not be greater than 10% (Yousefi etc., 2018). The indices of the slope map represent these intervals as percentage; 0-1, 1-3, 3-5, 5-10, 10-70 (İzmir's max slope value is 69.72).

When the distribution of the area is examined; It can be said that the lands that are not suitable in terms of slope (10% and above) are dominant in the study area. It classification result; Bergama and Dikili surroundings, Menemen and Çiğli surroundings, Kemalpaşa, Torbalı, Tire, Selçuk, Ödemiş and Kiraz surroundings, Güzelbahçe and Urla surroundings were found to have places suitable for slope.

5.2.4. Settlement Area Criterion – C4

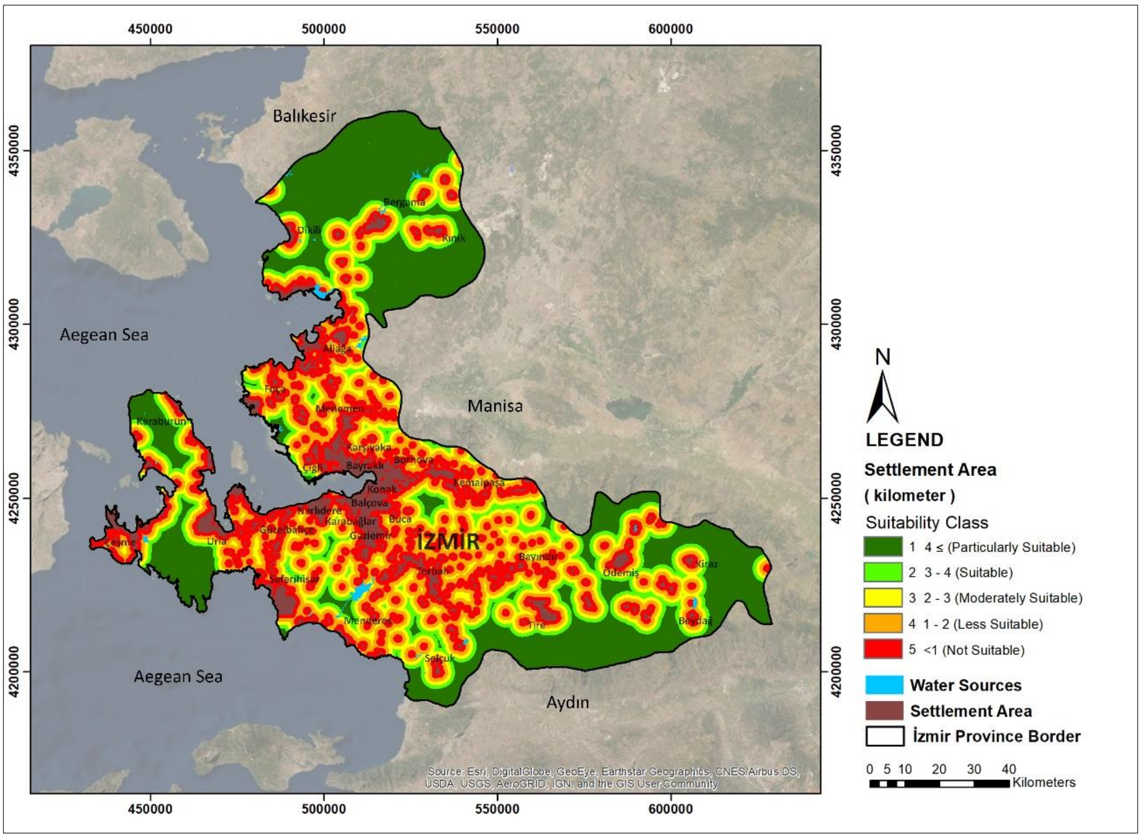


Figure 5. 5. Settlement Area Suitability Map

While the rapid population growth causes an increase in residential areas, the need for energy also increases but the distance from residential areas can sometimes be neglected when choosing the suitable area for solar power plants. The settlements are active in terms of human activities and the air pollution caused by human activities causes the modules to become dirty more quickly, increasing the maintenance and cleaning costs. In addition, the establishment of solar power plants near the residential areas reduces the labor cost as it will facilitate access for security, maintenance, repair and cleaning (Uyan, 2017).

In this study, regarding the distances that should be from residential areas, the suitable area of solar power plant has been examined in many literature and it has been seen that the distance of 500 meters is a sharp measure (Mierzwiak etc, 2017 and Yuschenko etc., 2018). The indices of the settlement area map represent these intervals as kilometer; <1, 1-2, 2-3, 3-4, 4≤.

5.2.5. Main Road Criterion – C5

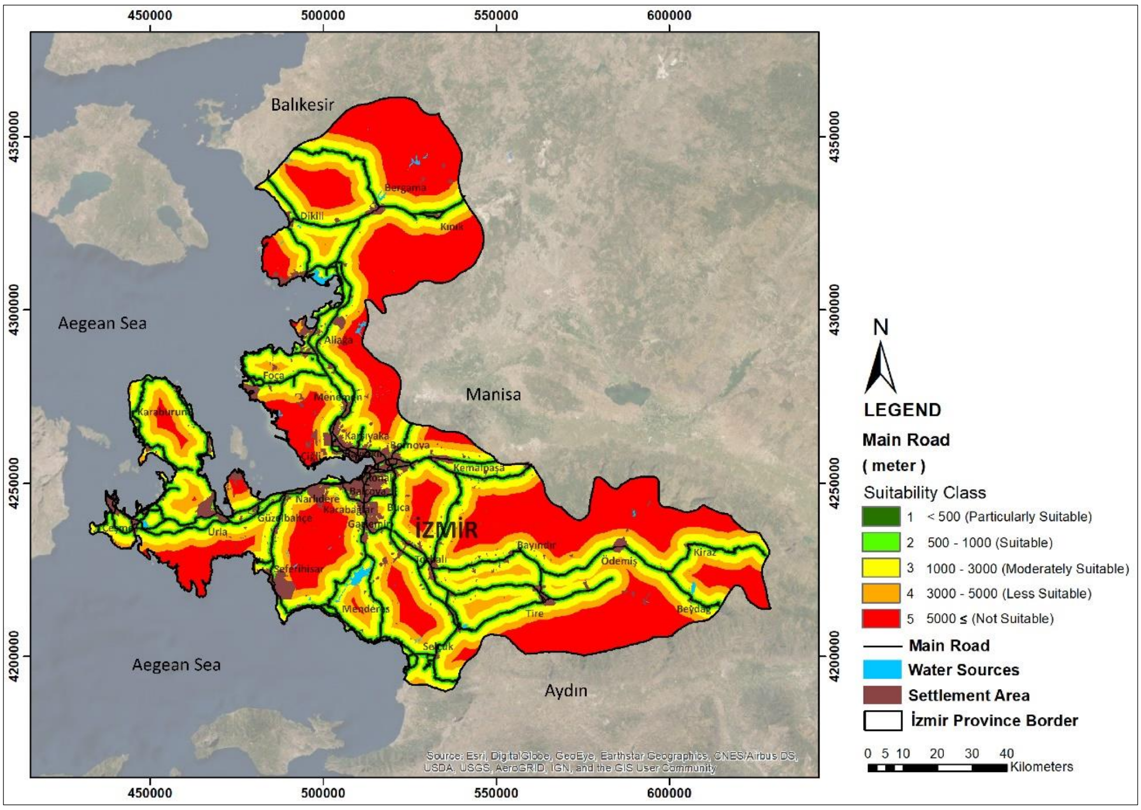


Figure 5. 6. Main Road Suitability Map

Transportation network is important for accessibility and security reasons. In terms of the efficiency of the solar power plant, it is an important factor to carry out the construction activity during the construction and installation phase, to deliver the necessary materials and to easily access trucks and construction equipment. Proximity to the main transportation arteries provides an advantage and it is an important point that access to these roads is through secondary roads and the physical condition of these roads is good. Otherwise, the cost of building new roads or improvements to existing roads will increase (Mierzwiak etc, 2017).

In this study, regarding the distances that should be from main roads, the suitable area of solar power plant has been examined in many literature and it has been seen that the distance of 500 meters is a sharp measure (Mensour etc, 2019). The indices of the main road map represent these intervals as meter; 5000≤, 3000-5000, 1000-3000, 500-1000, <500.

5.2.6. Forest Criterion– C6

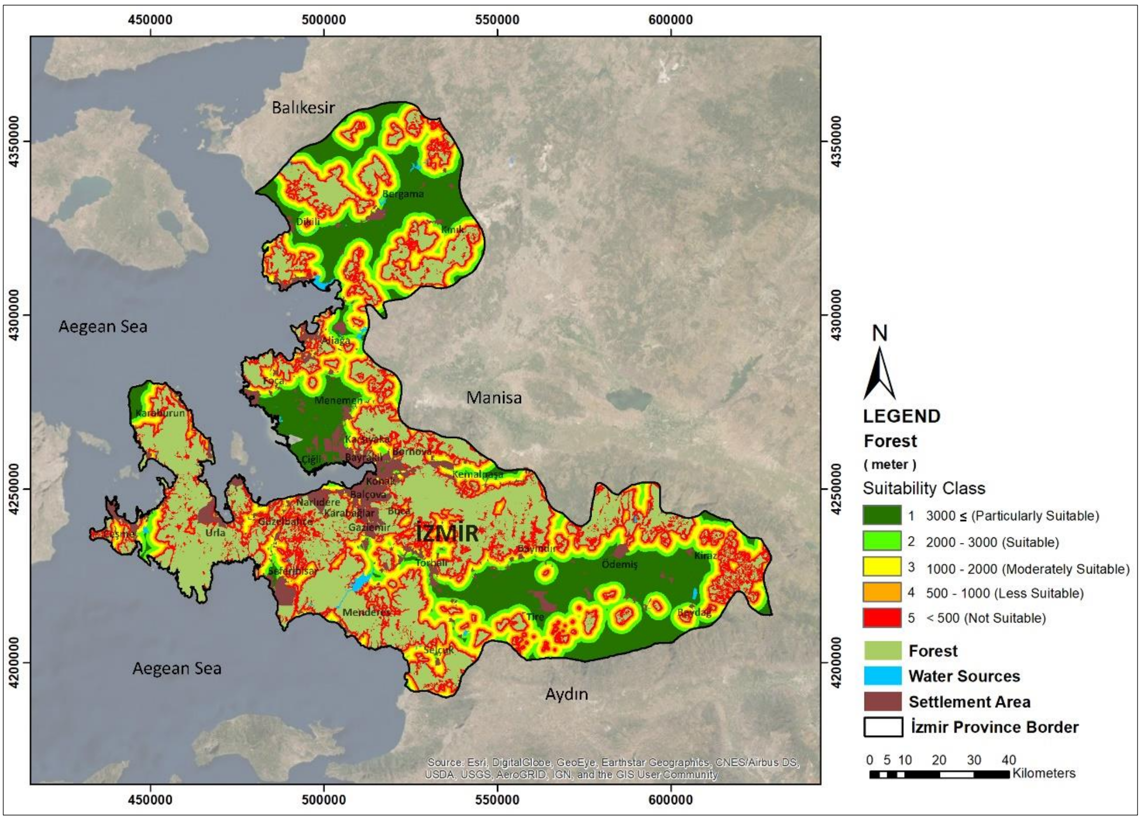


Figure 5. 7. Forest Suitability Map

In the environmental impact assessment reports required for the establishment of power plants, it is requested that forest areas are not destroyed. The biggest concern is the destruction and cleaning of the solar energy panels that are expected to be implemented in forest areas. Degradation of forests can damage species habitat and affect the sustainability of the forest area. In addition, different distances with different values are applied to further minimize the possible negative impact.

In this study, regarding the distances that should be from forest areas, suitable area of solar power plant has been examined in many literature and it has been seen that the distance of 500-1000 meters should be the maximum distance (Yousefi, 2018). The indices of the forest map represent these intervals as meter; <500, 500-1000, 1000-2000, 2000-3000, 3000≤. When the 3000 m distance from the forest areas is evaluated, suitable areas have emerged that are distant from Bergama, Menemen and Ödemiş densely.

5.2.7. Water Source Criterion– C7

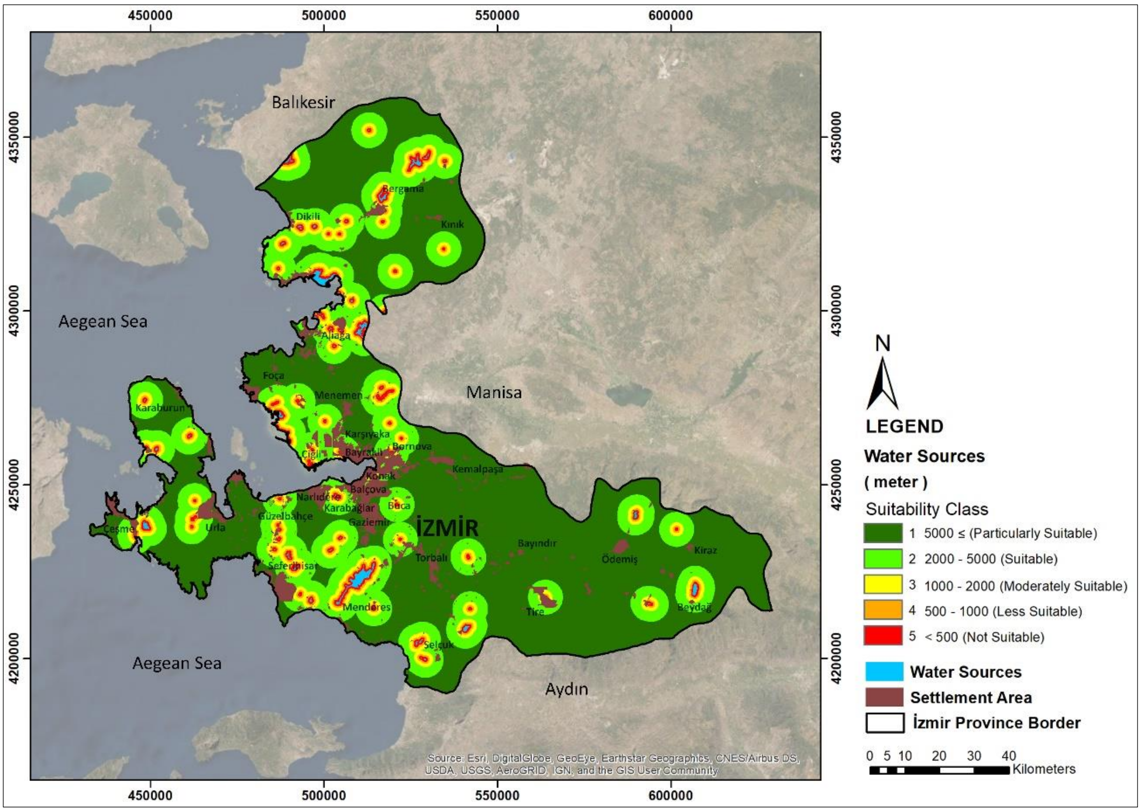


Figure 5. 8. Water Source Suitability Map

The proximity to the river areas makes it easier to clean the plants, reducing the cost. As a second factor, the negative effects of moisture, evaporation, flood affect productivity and cause an increase in costs by damaging the power plants when floods occur. In addition, the plants established in these areas will cause the flora and fauna living here to be affected. In addition, since floods and overflows pose a danger for SPP areas, the distance to these areas has been taken into consideration (Norollahi et al.,2016).

In this study, regarding the distances that should be from water sources, the suitable area selection of solar power plant has been examined in many literature and it has been seen that the distance of 500 meters should be the maximum distance (Yousefi, 2018). The indices of the water sources map represent these intervals as meter; <500, 500-1000, 1000-2000, 2000-5000, 5000≤.

5.2.8. Drainage Criterion – C8

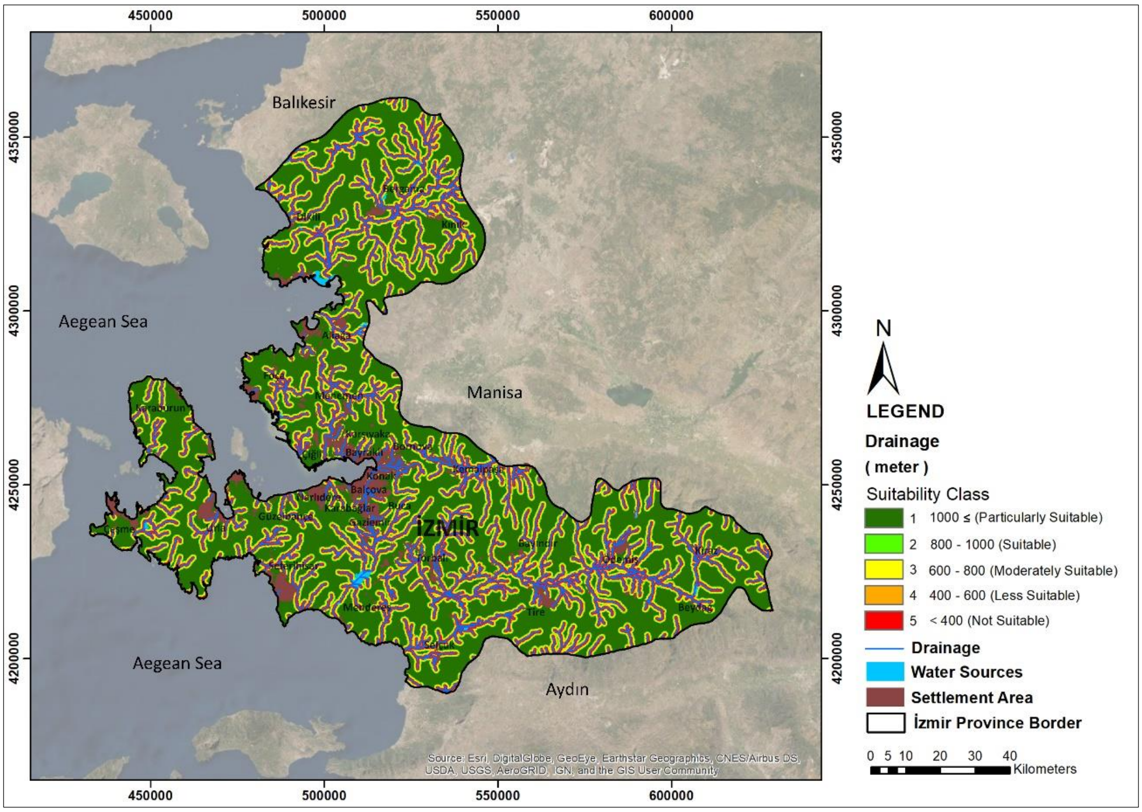


Figure 5. 9. Drainage Suitability Map

The destruction of drainage channels causes floods. Due to the natural structure of the region, the power plants to be established in areas with high risks increase the risk in that region even more. In this respect, it is necessary to avoid choosing a place in areas where flood risk areas which have high affect.

Regarding the distances to water sources, the suitability are of solar power plant has been examined in many literature (Yousefi, 2018). The indices of the drainage map represent these intervals as meter; <400, 400-600, 600-800, 800-1000, 1000≤.

5.2.9. Fault Line Criterion– C9

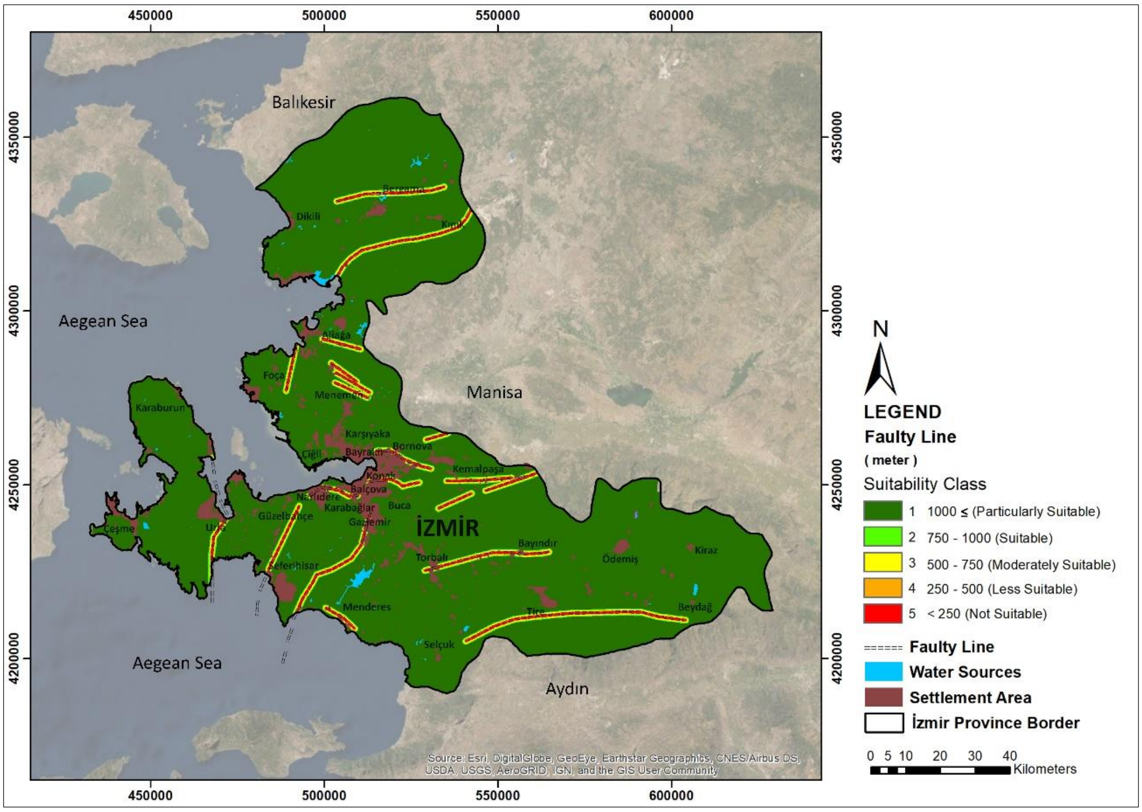


Figure 5. 10. Fault Line Suitability Map

İzmir is located in the 1st degree earthquake zone. Since earthquake zones have a high potential in terms of seismic activity, the distance to the fault line should be taken into consideration when determining the location for solar power plants. It is an important criterion to reduce the destructive effect that seismic activity will have on the plant. An area closer to a fault line is prone to a higher risk of earthquakes and consequent damage.

In this study, regarding the distances that should be from the fault lines, the suitability area of solar power plant has been examined in many literature and it has been seen that the distance of 250 meters should be the minimum distance (Yousefi, 2018).

The indices of the fault line map represent these intervals as meter; <250, 250-500, 500-750, 750-1000, 1000≤.

Since the study area is the entire city of İzmir and it is impossible to discern the specifics on the map, a sample of area has been implemented for understanding the criteria (Figure 5.11).

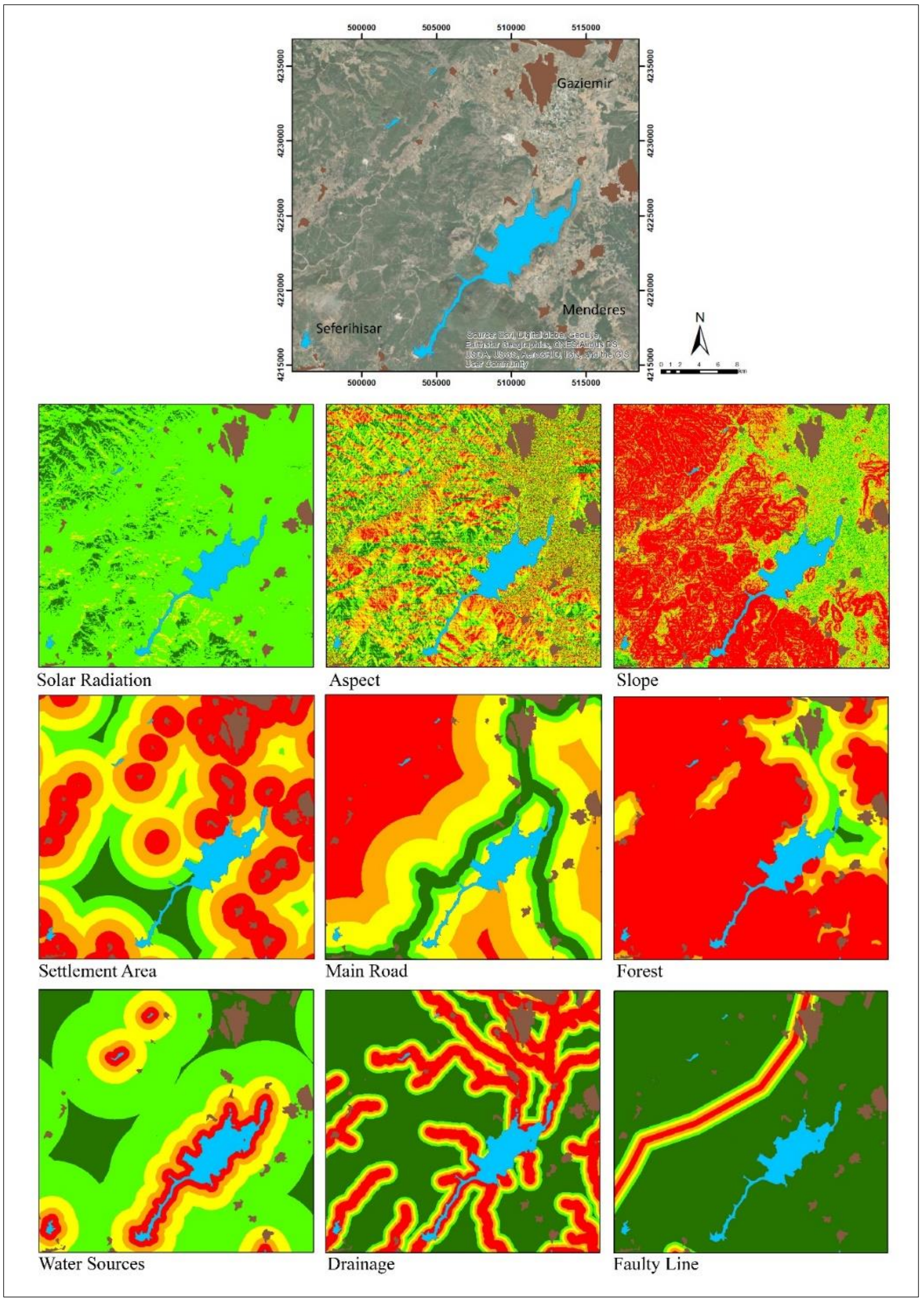


Figure 5. 11. Zooming An Area for Detail

5.2.10. Land Use Capability Class – C10

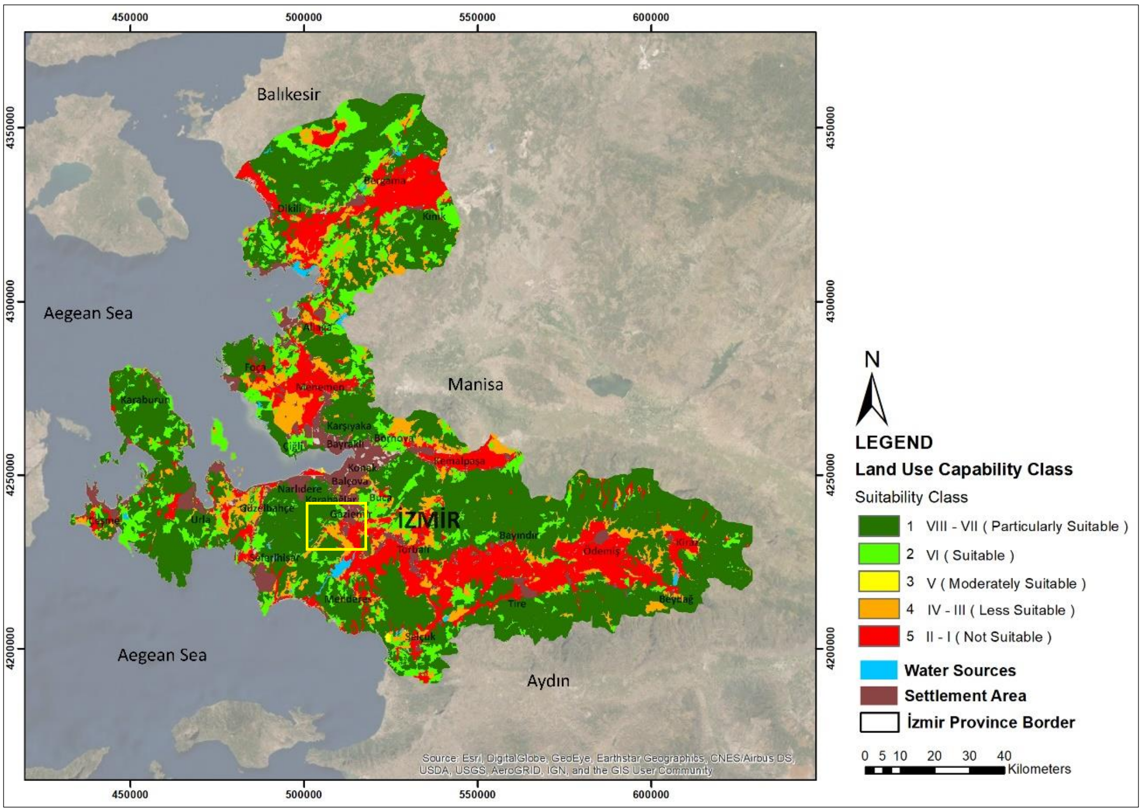


Figure 5. 12. Land Capability Class Suitability Map

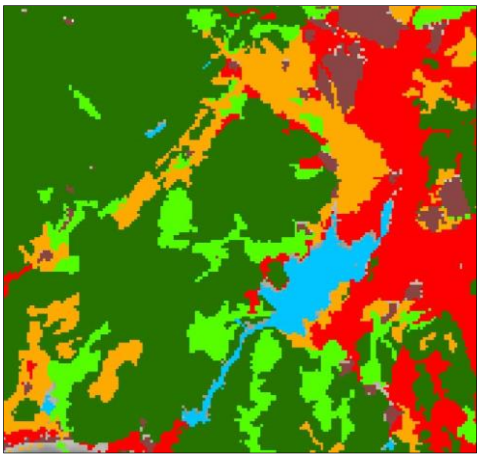


Figure 5. 13. Zooming An Area for Detail

Land Capability Classification plays a very important role in making land use plans. The purpose of this classification is to bring together all the data that are used to obtain protection measures and the use of appropriate agricultural processing techniques in a way that does not cause soil structure degradation and erosion in agricultural lands.

İzmir has important areas that cannot be neglected as a land. Although it is the most important factor in planning, we can say that it is a criteria that is generally neglected and damaged. Agricultural areas and pasture lands are leased and allocated, but it is of great importance that the applications in these classes are made at the right degrees (Uyan, 2017 and Gasparovic et al.,2019). According the literature, the indices of the land use capability class map represent these intervals; I-II, III-IV, V, VI, VII-VIII.
Energy Transmission Lines and Transformer Centers data could not be obtained from institutions but these criteria should also to be evaluated for İzmir from after this study.

5.3. Criteria Weights

In this section, the qualitative data regarding the criteria will be analyzed in GIS and a map of the suitable areas as to where a solar power plant can be established in İzmir province. After identifying the criteria, one of the critical steps is determining the relative importance or the weighting of individual criteria. Recently, different weighing methods are used to determine the weights of criteria. In this study, AHP as a most popular and structured method is used. It is characterized by comparison of alternatives according to certain criteria (Saaty and Vargas, 2012).

The comparison between two elements using AHP can be done in different ways. However, the scale of relative importance between the two alternatives is the most widely used, as Saaty suggests. The scale, referring to values ranging from 1 to 9, determines the relative importance of an alternative compared to another.

Table 5. 1. Saaty's Scale of Relative Importance

Scale	Numerical Rating	Reciprocal
Equally	**1**	**1**
Equally to Moderately	2	1/2
Moderately Importance	**3**	**1/3**
Moderately to Strongly	4	1/4
Strongly Importance	**5**	**1/5**
Strongly to Very Strongly	6	1/6
Very Strongly Importance	**7**	**1/7**
Very Strong to Extremely	8	1/8
Extremely Importance	**9**	**1/9**

Base on AHP, developing the weights for criteria require four basic steps:

- Developing a pairwise comparison matrix for each criteria
- Normalizing the resulting matrix
- Averaging the values in each row to get the corresponding rating
- Calculating the consistency ratio

The above steps are fulfilled as following:

First Step: Determining the value for each criteria and pairwise comparison matrix. The value or the relative importance of each criterion than other criteria is determined based on experts' opinion and literature review.

Table 5. 2. Comparison Matrix (Assuming Criterion 1 is superior to Criterion 2)

	Criteria 1	Criteria 2
Criteria 1	1	Numerical Rating
Criteria 2	1/Numerical Rating	1

According the study criteria;

The criterion in the row is being compared to the criteria in the column.

Table 5. 3. Developed matrix of the pairwise comparison of the criteria

Pairwise Comparison Matrix	C1	C2	C3	C4	C5	C6	C7	C8	C9
C1	1,00	1,00	2,00	4,00	5,00	7,00	3,00	7,00	6,00
C2	1,00	1,00	2,00	3,00	5,00	7,00	3,00	7,00	6,00
C3	0,50	0,50	1,00	3,00	5,00	5,00	3,00	7,00	6,00
C4	0,25	0,33	0,33	1,00	3,00	5,00	2,00	5,00	5,00
C5	0,20	0,20	0,20	0,33	1,00	3,00	2,00	4,00	4,00
C6	0,14	0,14	0,20	0,20	0,33	1,00	2,00	3,00	4,00
C7	0,33	0,33	0,33	0,50	0,50	0,50	1,00	2,00	3,00
C8	0,14	0,14	0,14	0,20	0,25	0,33	0,50	1,00	2,00
C9	0,17	0,17	0,17	0,20	0,25	0,25	0,33	0,50	1,00
Total	3,74	3,82	6,38	12,43	20,33	29,08	16,83	36,50	37,00

Each number, starting from 1 to 9, has the value of equal importance to extremely importance between each pairs.

Second Step: Normalization of the resulting matrix

Sum of the values in each column of the pair-wise matrix and dividing of each column in the matrix by its total to generate a normalized pair-wise matrix

Third Step: Dividing the sum of normalized column of matrix by the number of criteria used (n) to generate weighted matrix

Table 5. 4. Standardization/normalization, average/weights

Criteria	C1	C2	C3	C4	C5	C6	C7	C8	C9	Total	Average
C1	0,27	0,26	0,31	0,32	0,25	0,24	0,18	0,19	0,16	2,18	0,24
C2	0,27	0,26	0,31	0,24	0,25	0,24	0,18	0,19	0,16	2,10	0,23
C3	0,13	0,13	0,16	0,24	0,25	0,17	0,18	0,19	0,16	1,61	0,18
C4	0,07	0,09	0,05	0,08	0,15	0,17	0,12	0,14	0,14	1,00	0,11
C5	0,05	0,05	0,03	0,03	0,05	0,10	0,12	0,11	0,11	0,65	0,07
C6	0,04	0,04	0,03	0,02	0,02	0,03	0,12	0,08	0,11	0,48	0,05
C7	0,09	0,09	0,05	0,04	0,02	0,02	0,06	0,05	0,08	0,51	0,06
C8	0,04	0,04	0,02	0,02	0,01	0,01	0,03	0,03	0,05	0,25	0,03
C9	0,04	0,04	0,03	0,02	0,01	0,01	0,02	0,01	0,03	0,21	0,02
Total	1,00	1,00	1,00	1,00	1,00	1,00	1,00	1,00	1,00		

Criteria	C1	C2	C3	C4	C5	C6	C7	C8	C9	Total
C1	0,24	0,23	0,36	0,44	0,36	0,38	0,17	0,19	0,14	2,52
C2	0,24	0,23	0,36	0,33	0,36	0,38	0,17	0,19	0,14	2,41
C3	0,12	0,12	0,18	0,33	0,36	0,27	0,17	0,19	0,14	1,88
C4	0,06	0,08	0,06	0,11	0,22	0,27	0,11	0,14	0,12	1,16
C5	0,05	0,05	0,04	0,04	0,07	0,16	0,11	0,11	0,09	0,72
C6	0,03	0,03	0,04	0,02	0,02	0,05	0,11	0,08	0,09	0,49
C7	0,08	0,08	0,06	0,06	0,04	0,03	0,06	0,06	0,07	0,52
C8	0,03	0,03	0,03	0,02	0,02	0,02	0,03	0,03	0,05	0,25
C9	0,04	0,04	0,03	0,02	0,02	0,01	0,02	0,01	0,02	0,22

Forth Step: Calculating the consistency ratio

Table 5. 5. Weigted of Total and Average Values

Criteria	Weighted of Total Values	Weighted of Criterias (Average)	Total/Average
C1	2,52	0,24	10,386
C2	2,41	0,23	10,309
C3	1,88	0,18	10,516
C4	1,16	0,11	10,501
C5	0,72	0,07	9,910
C6	0,49	0,05	9,197
C7	0,52	0,06	9,234
C8	0,25	0,03	9,205
C9	0,22	0,02	9,306

Table 5. 6. The Random Consistency Index(RCI) (Saaty, 1987)

n	3	4	5	6	7	8	9	10	11	12	13	14	15
RCI	0.58	0.90	1.12	1.24	1.32	1.41	1.45	1.49	1.51	1.48	1.56	1.57	1.59

Table 5. 7. CI, RI and CR Values for Main Criteria

CI=(λmax-n)/(n-1)	RI=This is a table value (for n = 1,452)	CR=CI/RI

Consistency Index	Random Consistency Index	Consistency Ratio
CI	RI	CI/RI
0,11	1,45	0,07
CR should be smaller than 0,10		**<0.10**

The consistency ratio in the AHP decision process applied for the layers was determined as 0.07. In practice CR 0.1 is acceptable (Saaty, 1978). In this study the consistency ratio (CR) is 0.07, according to Saaty (1978) it is acceptable.

As a result of paired comparisons for the main criteria, the consistency ratio (CR) was calculated as 0.072. Since the CR value of less than 0.10 is a proof of reliability, we can say that the results we obtained are reliable. According to results, criteria weights represents the individual criteria weights obtained, applied in the weighted overlay analysis in the GIS environment.

Table 5. 8. Weight of Criteria

Criteria		Weight(%)
C1	Solar Radiation	24,3
C2	Aspect	23,4
C3	Slope	17,9
C4	Settlement Area	11,1
C5	Main Road	7,3
C6	Forest	5,4
C7	Water Source	5,6
C8	Drainage	2,8
C9	Faulty Line	2,4
		100,0

Following this, the 9 criteria evaluated and first suitability map has been created.

Adding to criteria of Land Use Capability Class (Criteria 10) ;

Another criterion for which the sensitivity of the areas where solar power plants will be installed should be the most important is the soils that differ according to the land use capability classes. Other 9 criteria were evaluated together and this criteria was evaluated with the last suitability analysis map produced with a ratio of 50% as the criteria that is most evaluated within the scope of the literature and is important for urban planning.

Table 5. 9. Weight of LUCC

Criteria	Weight(%)
First Suitability Map	50
Land Use Capability Class	50
	100

Following this, the land use capability classes which are one of the most critical components, were weighted with other 9 criteria’s last map, and using weighted overlay analysis for created with the final suitability map.

CHAPTER 6

RESULTS AND DISCUSSIONS

The suitability maps were created using the data obtained by considering the legal regulations and other studies in the literature. Each region has different characteristics, so areas may have more important criteria specific to it. Determining the suitable location for Solar Power Plant (SPP) with using by GIS is necessary for studies. In this study, ArcGIS 10.6 software and Arcgis Pro were used for all GIS operations such as collecting, digitizing, organizing, converting data into pixel-based format, entering weight values into databases and obtaining suitability maps.

The criteria to be used for the suitable area selection process with the AHP method were determined separately by pairwise comparisons. Criteria weight values were assigned to databases of digital data of all criteria, and the data were transformed into pixel-based format. In the pixel-based map, each pixel represents an area of 30 m x 30 m. The pixel calculation was processed with the help of Weighted Overlay Analysis function and the criterion weight values were entered, and the suitability map was obtained by accumulating the data. Suitability models identify the most preferred location for a specific phenomenon. This analysis clearly shows that an area that is not suitable to be particularly suitable. The weighted overlay analysis unlike to other approaches can re-scale back the value to a defined scale. Determination of weights with this method gives very healthy results. The weights of each criterion and sub criteria were calculated using Microsoft Excel program.

Using the Analytical Hierarchy and Process (AHP) method, weighting values are assigned to the computed rasters, and the sum of all these rasters gives the final raster of the most suitable areas for solar power construction. Each criterion used in the study was analyzed to show the level of suitability and the results were divided into five categories for each criterion.

6.1. Results of First Suitability Analysis Map

The map represents suitable areas for the identification and development of the installation sites of solar power plants. For this map, 9 criteria were evaluated (Figure 6.1).

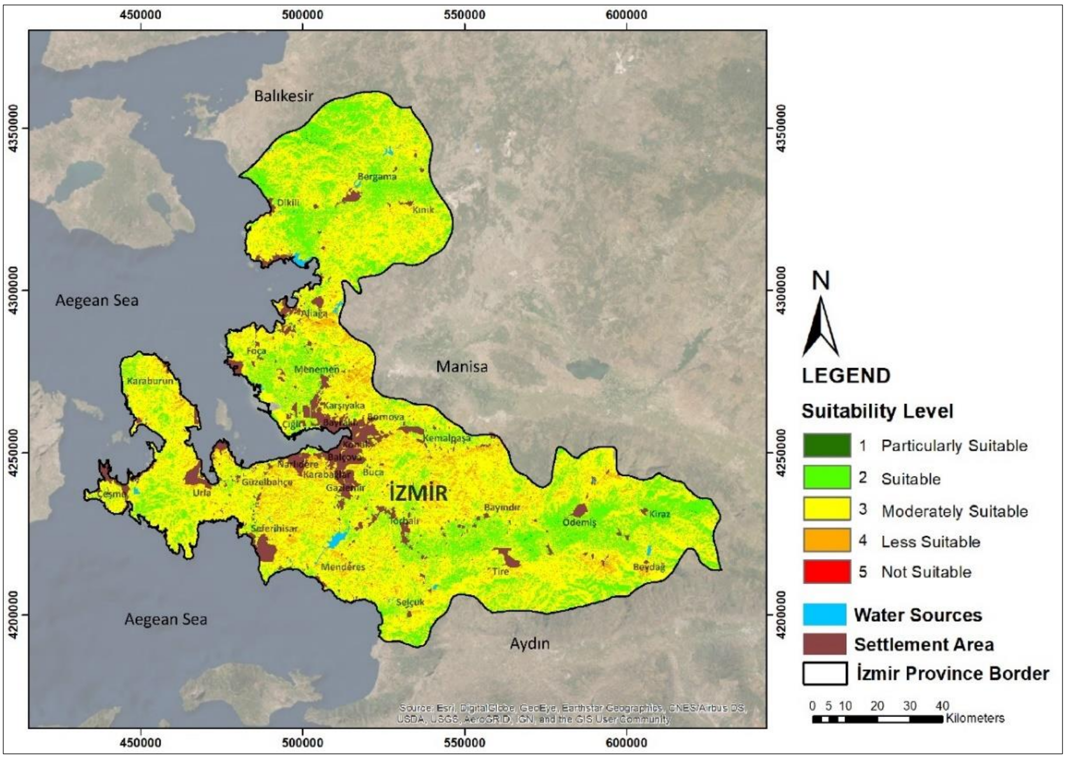


Figure 6. 1 First Suitability map for solar power plant development in İzmir

According to first suitability map which include 9 criteria;

Among the districts of İzmir; Bergama, Kiraz, Ödemiş, Tire, Bayındır, Kemalpaşa, Menemen, Dikili districts are predominantly suitable districts in terms of potential area for SPP installation, but in general, there are areas with high suitability within all district borders.According to the results obtained, an area of 493 hectares of the study area is a very suitable area for the establishment of a solar power plant. Findings in the whole field; 6.3% of the not suitable and less suitable lands, 68.8% of the moderately suitable lands, and 24.9% of the suitable and particularly suitable lands.

Table 6. 1. Area of Different Suitability Class According to First Suitability Map

Suitability Class		Area (km2)	Area (%)	Area(ha)
1	Particularly Suitable	4,94	0,04	493,50
2	Suitable	3004,26	24,86	300426,40
3	Moderately Suitable	8312,42	68,78	831242,00
4	Less Suitable	763,23	6,32	76322,80
5	Not Suitable	0,00	0,00	0,27
Total		12085	100	1208485

Table 6. 2. Percentage of Suitability Class

Suitability Class	Area (%)
1st and 2nd class	24,9
3rd class	68,8
4th and 5th class	6,3

6.2. Results of Suitability Analysis Map Based on Land Use Capability Class (Final Suitability Analysis Map)

According to final suitability map which include first suitable map results and land use capability class criteria (10th);

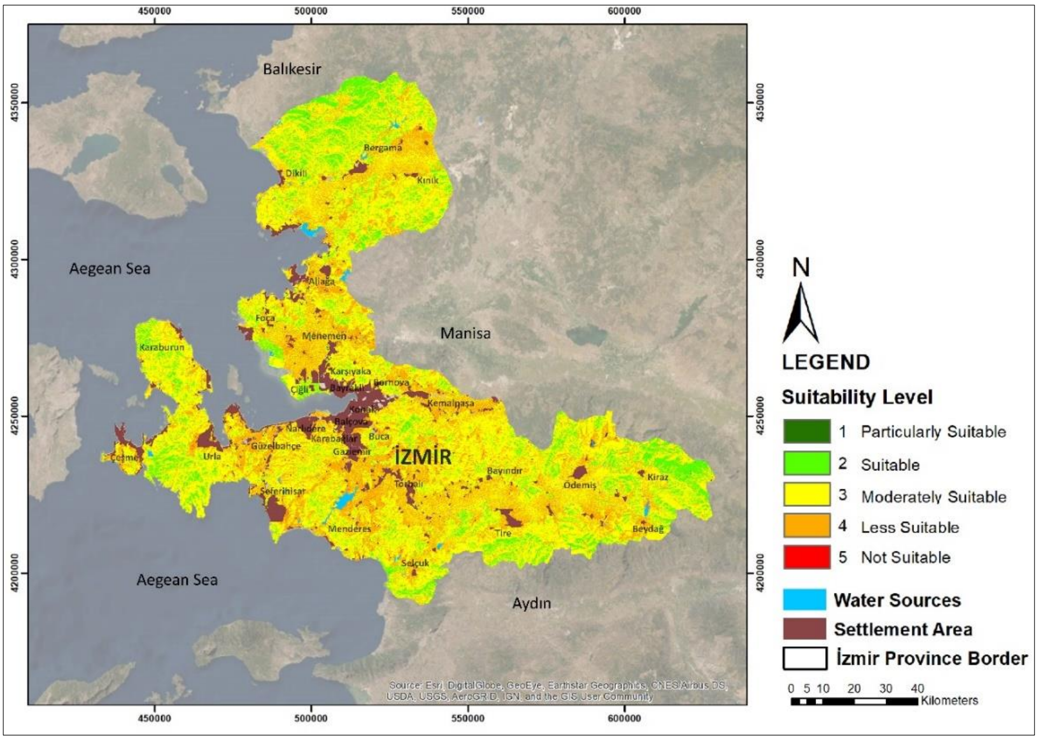


Figure 6. 2. Final Suitability map for solar power plant development in İzmir

Among the districts of İzmir; Kiraz, Tire, Bergama, Urla and its arounds are the suitable districts in terms of potential area for SPP installation. When the land use capability classes are added, we can see that the percentages of the lands in the eligibility class change in İzmir.

Table 6. 3. Area of Different Suitability Class According to Final Suitability Map

Suitability Class		Area (km2)	Area (%)	Area(ha)
1	Particularly Suitable	1,69	0,01	169,11
2	Suitable	1344,69	11,13	134468,57
3	Moderately Suitable	7157,65	59,23	715764,66
4	Less Suitable	3572,89	29,56	357288,51
5	Not Suitable	8,42	0,07	841,79
Total		12085	100	1208485

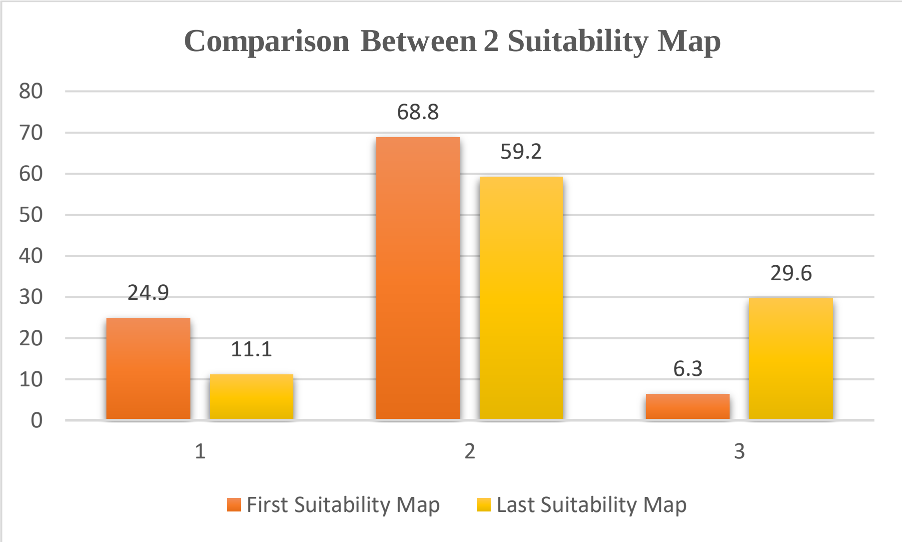
Table 6. 4. Percentage of Suitability Class

Suitability Class	Area (%)
1st and 2nd class	11,1
3rd class	59,2
4th and 5th class	29,6

According to the results obtained, an area of 169 hectares of the study area is a very suitable area for the establishment of a solar power plant. Findings in the whole field; 29,6% of the not suitable and less suitable lands, 59,2% of the moderately suitable lands and 11,1% of the suitable and particularly suitable areas.

6.3. Comparison Between 2 Suitability Map

After evaluating according to the 10th criteria (land use capability class), a careful analysis should be done for provincial geographies and soil structures with fertile agricultural lands such as İzmir. There are important differences in study area. Especially, differences are in areas which is 1st and 2nd suitability class. When look for the 4th and 5th class, there is rate change (Graph 6.1). This result is enough to emphasize the need for more careful studies in terms of agricultural and soil efficiency data.



Graph 6. 1. Comparison Between 2 Suitability Map (First and Final Suitability Map)

1: 1st and 2nd suitability class

2: 3rd suitability class

3: 4th and 5th suitability class

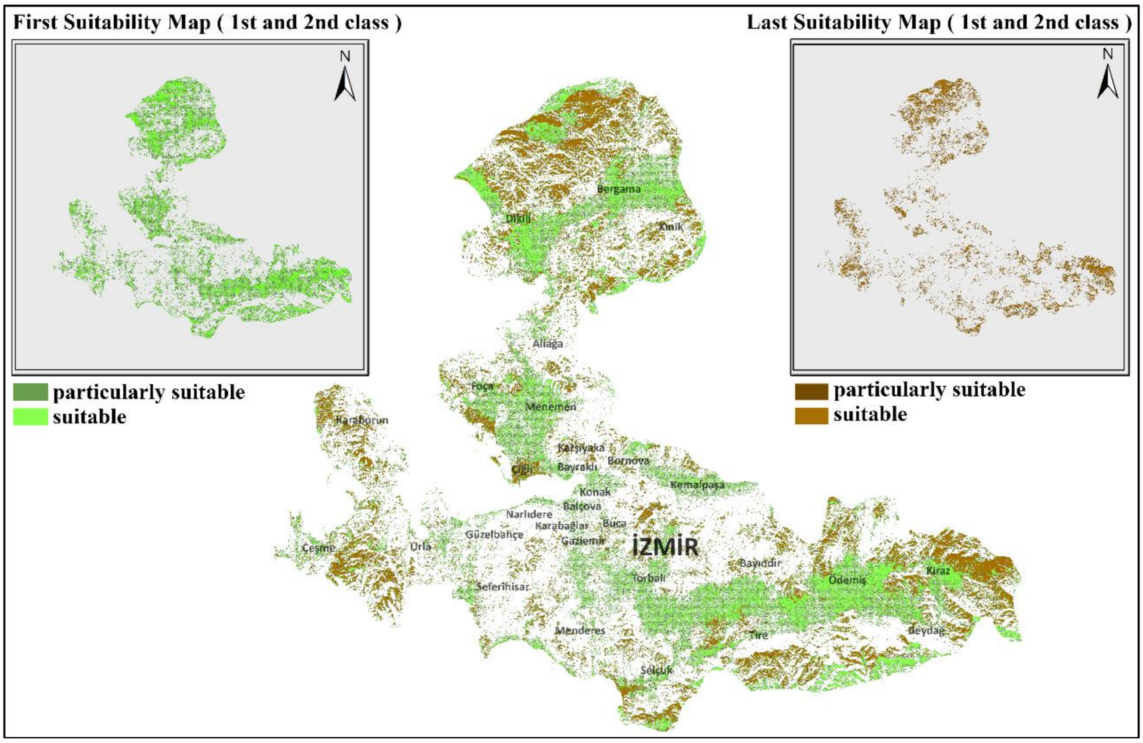


Figure 6. 3. Comparison Between 2 Suitability Map (1st and 2nd Class)

When looking at 1st and 2nd suitability class, there is a visually noticeable change with the addition of the last criteria land use capability class. There are dense regions and some districts are in the foreground. In addition to ignoring this scenario, solar power plants built on lands are expected to have a negative impact on land use capability, causing these lands to be misused and agricultural lands to lose yield over time. Considering the rates of fertile lands which are very important potential for İzmir, it can be said that if a policy is not implemented, the destruction can be serious.

In some districts, although the solar radiation data is high, the suitability level may be low in those districts due to different constraints. Proceeding according to a single parameter may produce wrong results. Proceeding for the installation of a solar energy panel by only looking at the solar data and without evaluating the other dynamics of the city may lead to wrong results. There are different characteristics in districts so SPP location suitability class can change in this direction.

6.4. Comparison Between Existing Solar Power Plants and Potential Areas

The dates of former images before solar energy panels were installed were determined and taken on Google Earth before they were installed. The class of the suitability written on the map which were determined by evaluating which class they are in according to analysis. It was evaluated on the final map where land use capability class was evaluated. There are changes on suitability class. Adding to land use capability class, SPP suitability class changes can seem directly in some regions as Table 6.6.

Table 6. 5. SPP Installed Area According to Suitability Analysis Maps with Evaluated of LUCC

Location of SPP	Number of SPP	SPP Installed Area		Land Use Capability Class
		Suitable Class According to First Suitability Analysis	Suitable Class According to Last Suitability Analysis	
Menemen Süleymanlı Pond and Around	1	3	3	VI
	2	3	3	VI
Aliağa Bozgöl Northeast Direction	1	2	4	III
	2	2	2	VII
	3	2	2	VII
Torbalı Göllüce Settlement and Around	1	2	4	VI and I
	2	2	2	VII
İzmir-Ödemis Roadside	1	1 and 2	2 and 3	II and III

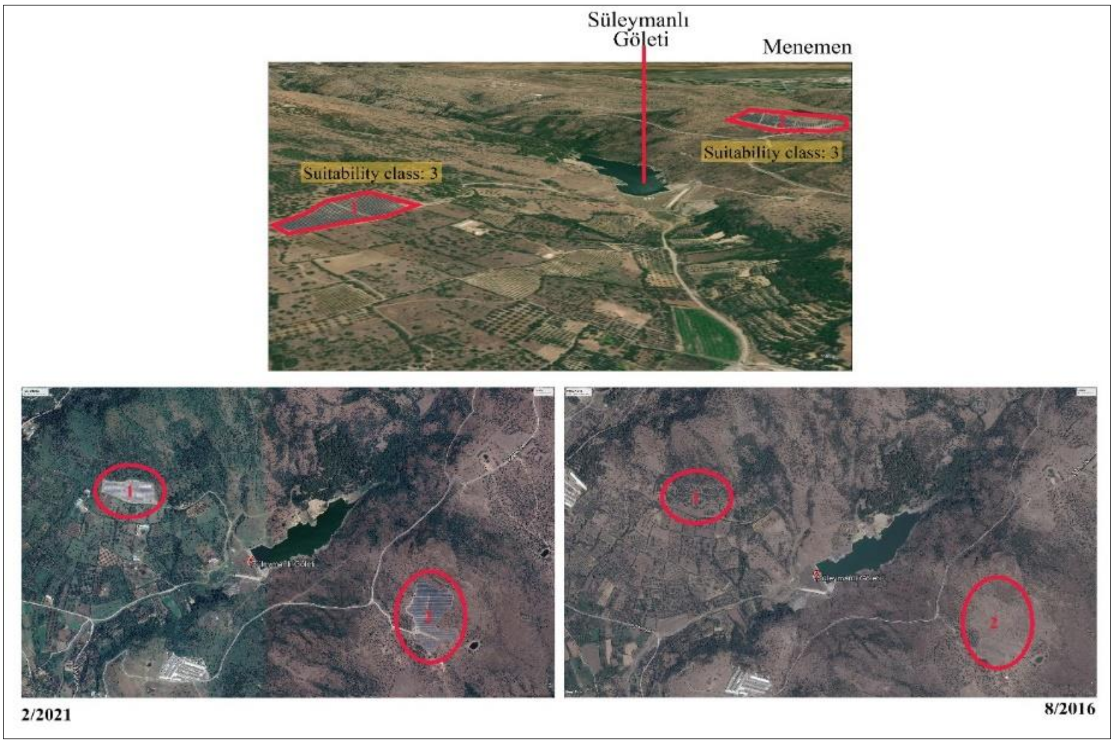


Figure 6. 4. Menemen Süleymanlı Pond and Around According to Different Time
(Source: Google Earth)

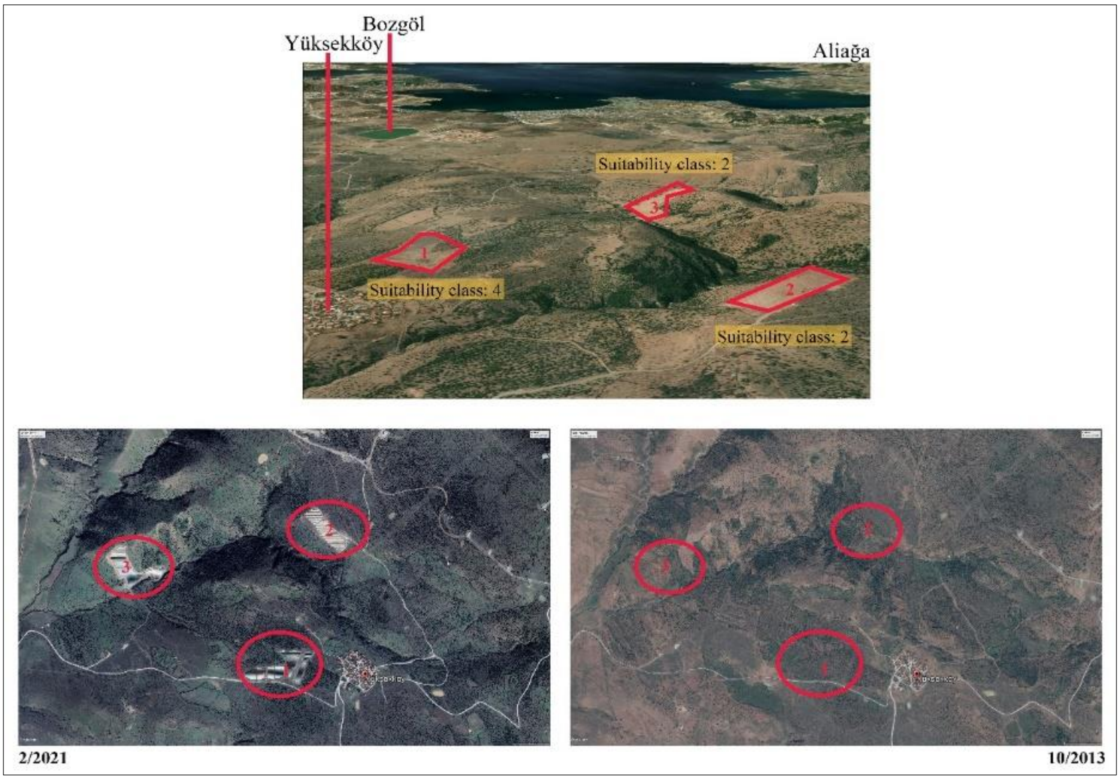


Figure 6. 5. Aliağa Bozgöl Northeast Direction According to Different Time
(Source: Google Earth)

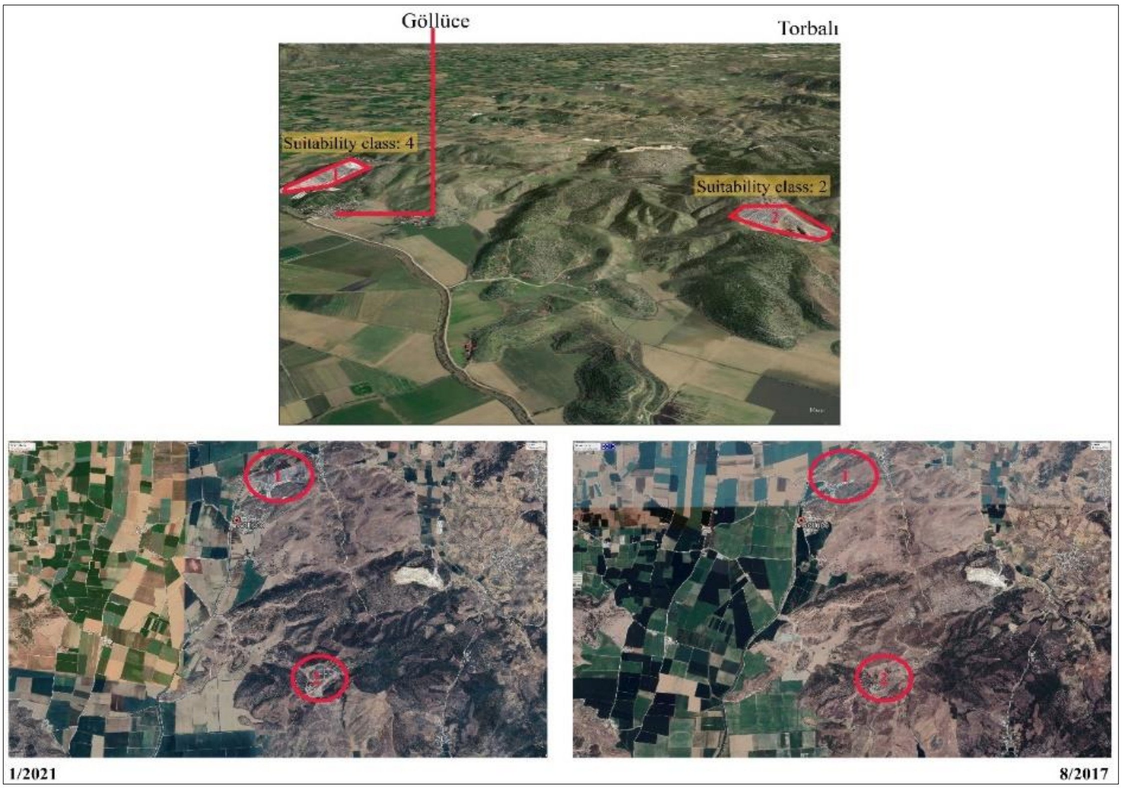


Figure 6. 6. Torbalı-Göllüce Ssettlement and Around According to Different Time
(Source: Google Earth)

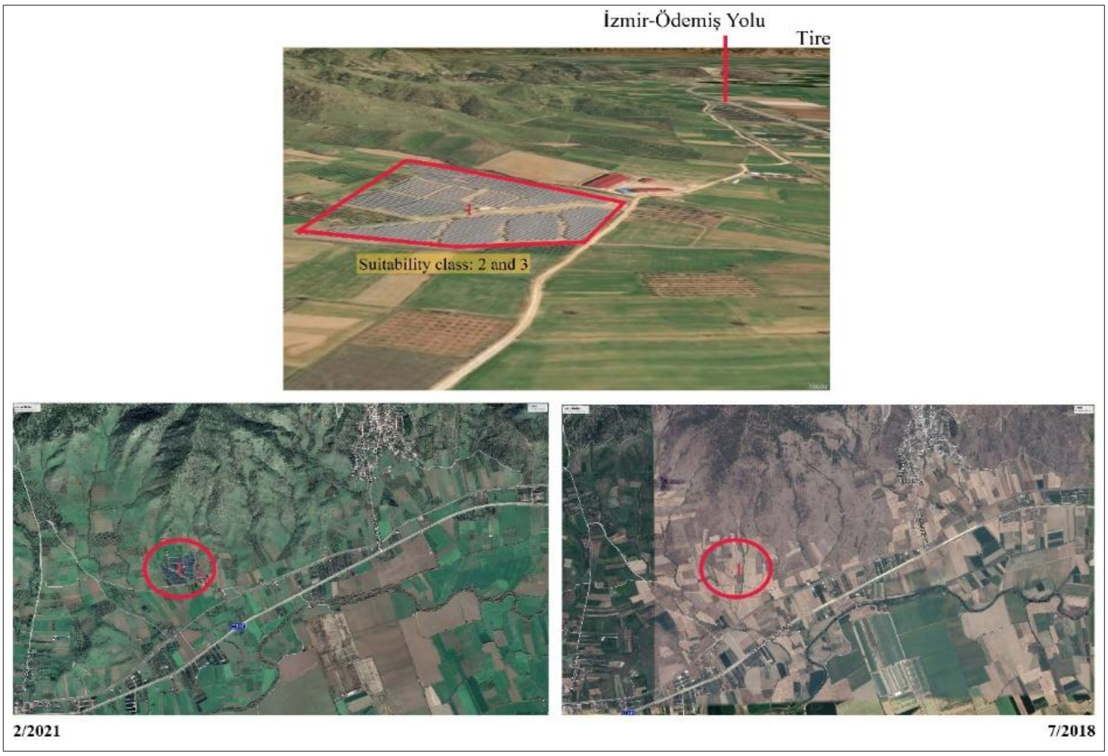


Figure 6. 7. İzmir-Odemis Roadside According to Different Time
(Source: Google Earth)

According to results of 1st suitability class (particularly suitable), density was observed in Bergama and Kiraz districts. These regions have suitable criteria values and suitable land use capability class values as VI. and VII. class.

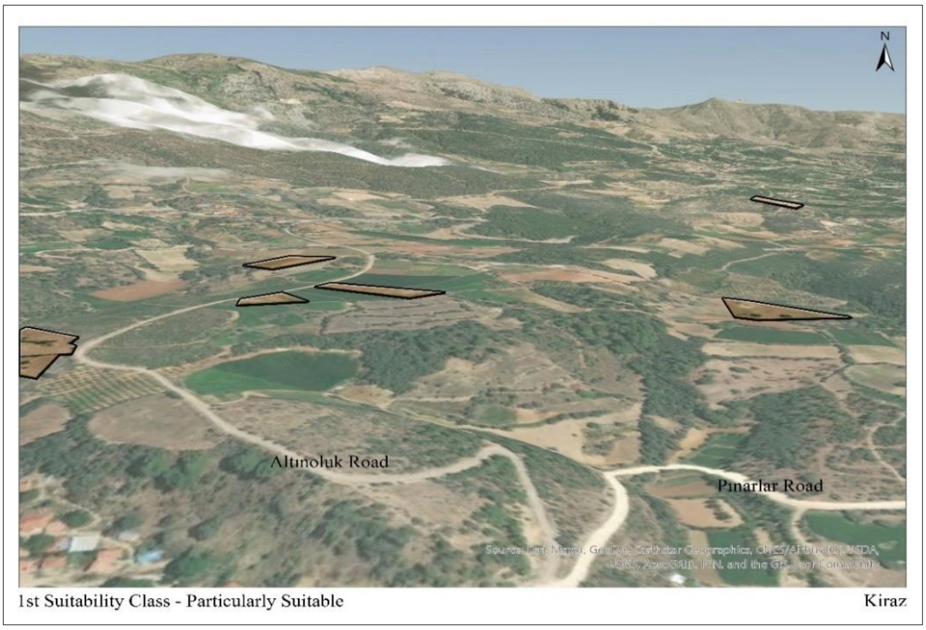


Figure 6. 8. Examples of 1st Suitability Class Area for Kiraz
(Source: Google Earth)

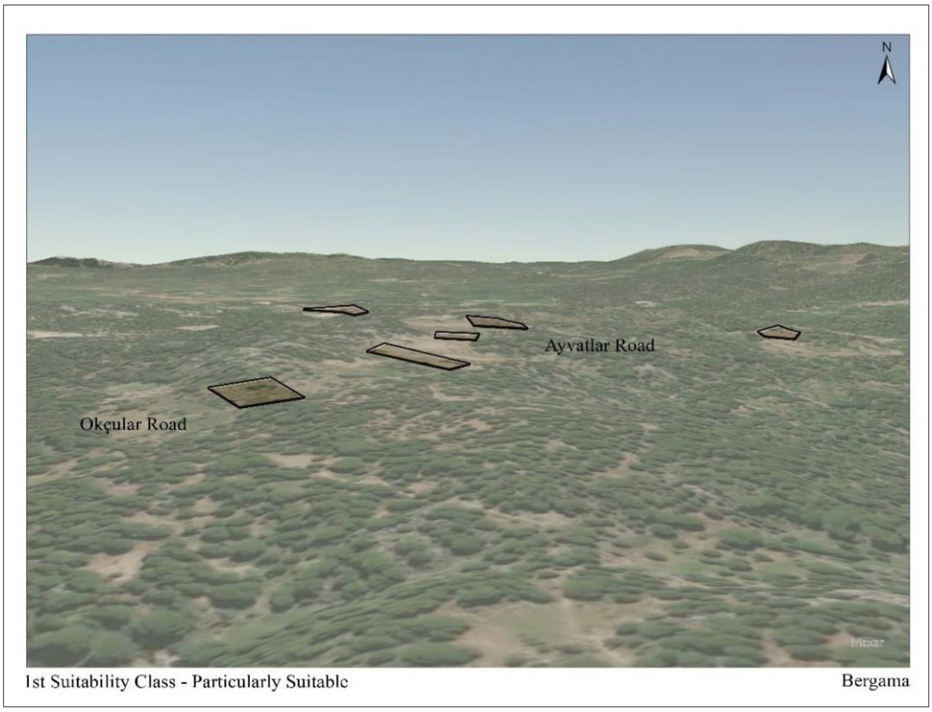


Figure 6. 9. Examples of 1st Suitability Class Area for Bergama
(Source: Google Earth)

The validation of the resulting map is needed to decide if the sites chosen are particularly suitable in practice. From the satellite images, most of the areas in the sites consist of capability class of VI. and VII., suitable topographic and physical features in areas. This sites on the maps can be used as solar power plant installation areas in reality.

6.5. Evaluation of Site Selection in Terms of Legal and Planning Regulations of Solar Power Plant

It is important to evaluate the legal regulations and application regulations made in choosing the appropriate place for solar energy panels. Utilization of renewable energy should be encouraged to increase the level of use in total energy consumption. It can be expanded by making use of renewable energy compulsory in places where the infrastructure is suitable. To make such applications, first of all, the scope of the relevant legislation and the provisions included in this legislation is very important. Unfortunately, on renewable energy, the legislation applicable in the establishment decisions of solar power plants is insufficient.

There are problems in the implementation of the provisions established within the scope of the Law No. 5403 on Soil Conservation and Land Use. Special policies should be developed and secured for some lands within the scope of this law. In some provisions within the scope of the Law No. 5346 on the Use of Renewable Energy Resources for the Purpose of Generating Electrical Energy, incentive policies for forest areas and pasture areas may cause difficulties in maintaining the balance in nature. In the provisions of the Pasture Law No. 4342, the applicability of the clause allocating the land suitable for use after the land survey is made is weak. Some provisions within the scope of the Forest Law No. 6831, regardless of the condition of the forest areas, are in the nature of a threat with their permission for the establishment of energy resources installation areas. However, these systems should be activated before destroying the forest areas in the regions where renewable energy systems such as solar are installed.

The necessary legislation to ensure the conservation and sustainable use of agricultural land is insufficient. The slow implementation of legal regulations slows down the use of renewable energy sources. Although there is an opportunity for improvement in this regard, unfortunately there are deficiencies in implementation.

The installation of solar energy panels provides dominance over large areas in the field. Therefore, it should be included in the Environmental Plans or Zoning Plans to associate with the whole. Along with the plan decisions taken from the highest scale, technical energy planning should also be included in these plans together with the conformity analysis. However, in these plans, evaluations and decisions should be made about what kind of energy will be produced in ideally selected places, what the social and economic benefits or disadvantages of the energy to be produced and what the impact on the environment for an ecological order will be. There is no common representation regarding energy production in the plan sheets and legend, and common language and concepts for the energy sector are not used. Only strategic suggestions are included in urban planning decisions. These areas, which are scientifically determined on plan decisions, should be treated strategically and in a regular manner, paying attention to location selection rules.

Emphasize on Land Use Planning;

Table 6. 6. Land Use/Not Suitable Area in İzmir
(Source: Provincial Directorate Of Agriculture Report, 2013 and İzmir Provincial Directorate Of Culture And Tourism)

Land Use	Area(ha)
Settlement Area	92,500.59
Water Sources	4,288.56
Forest Area	366,245.64
Protected Area	151,974.10
Pasture Area	7,269.15
Pasture+Forest+Settlement	11,277.56
Total	**633,555.6**

Within the scope of this study, when the land use status of İzmir province was evaluated, the rate determined as 47.6% and it was determined as suitable for using. In line with these ratios, the results have a decrease in half. It is clearly seen that the need for the protection of natural areas and transferring them to future generations will be more than ever for İzmir.

Table 6. 7. Results of After Adding Land Use Rates

	First Suitability Results		Final/Last Suitability Results	
Suitability Class	**Area (%)**	**After Land Use Rates(%)**	**Area (%)**	**After Land Use Rates(%)**
1st and 2nd class	24.9	11.8	11.2	5.3
3rd class	68.8	32.5	59.2	28.0
4th and 5th class	6.3	3.0	29.6	14.0

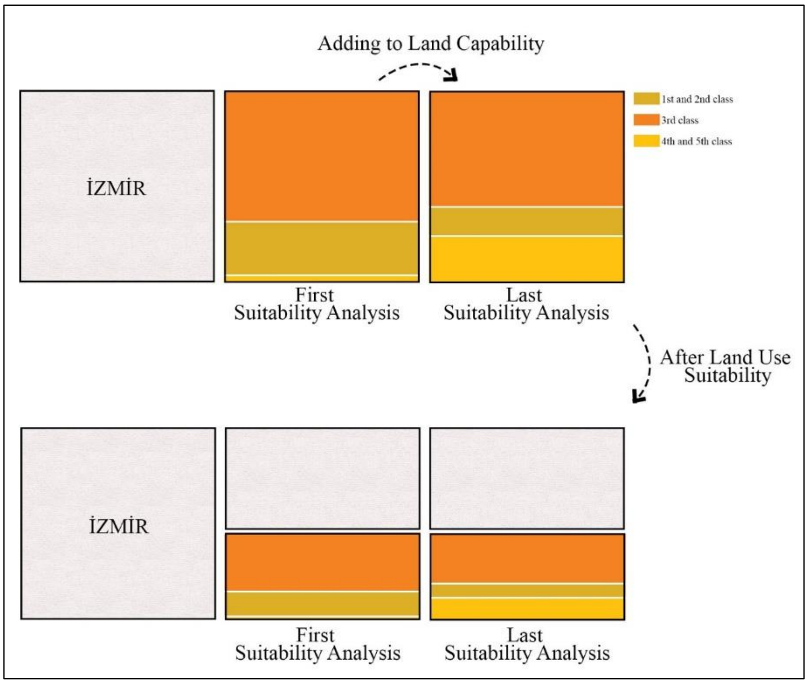


Figure 6. 10. Schematic Image for Study Area Suitability

Land use planning is the systematic evaluation of land potential, land use alternatives, and economic and social conditions in order to identify and implement the most suitable land use options. It is to help for using decisions that will protect them for the future. Land use decisions are very important for city dynamics. İzmir has very important areas from perspectives of protected areas. These should be examined for city planning decisions. Ignoring the land capabilities of natural areas and environments due to the pressure of urban development is a big problem. Minimizing this danger and preserving the productivity criteria of the lands is very important. Therefore, this situation can only be achieved through effective planning and strategic management.

CHAPTER 7

CONCLUSIONS AND RECOMMENDATIONS

Energy consumption, which increases in direct proportion with the population, should reduce the country's external dependence on energy taken into consideration in economic, environmental and social dimensions. Efficient use of renewable energy sources, which are alternative to fossil fuels, is of great importance. For this reason, the importance given to renewable energy and especially solar energy is increasing. Renewable energy sources can be economical, sustainable and environmentally friendly, but if the land selection is made unconsciously, no efficiency can be mentioned. Solar energy is a resource that can make a strong contribution in all respects, but wrong location choices can turn this situation into a disadvantage rather than an advantage. Due to the high potential of solar energy in İzmir, it will contribute to Turkey's energy need economically by meeting the energy need together with the right land selection in the province.

Cities have their own economic, environmental and social dynamics. It is very important for cities to plan a renewable energy usage based on their own dynamics and create policies in this direction. The use of solar energy should participate in the planning practice with the minimization of environmental impact for the energy demand expected to be met in the future. An ideal balance should be provided between the land structure of the city and the energy production locations. Land use plans should be created by evaluating the characteristics of the land and making the most appropriate studies for different uses. In the absence of correct analysis, many sectors can created into conflict. As a result of unplanned land use practices and incorrect technical use, it leads to a dirty urban texture and chaos. In line with the analyzes made in the study area, first of all, the land capability needs to be evaluated and serious differences have emerged. Then, urban dynamics are expected to be protected. This situation revealed that there is an area that should not be touched at the rate of 52% in the study area. When the current rates and land use decisions are evaluated, it can be said that a decrease by half is observed.

Land capacity classification is one of the most important issues in terms of sustainable land use. Proper management in terms of planning ensures continuity in terms of agriculture and is essentially important for the sustainability of the urban ecosystem. Negative effects will arise in line if the characteristics of these land classes is not taken into account. The misuse of lands will seriously affect the sustainability and agricultural production of the lands. Due to the policies followed in Turkey until today and the problems and deficiencies in the implementation of the relevant legislation, for example, the allocation of agricultural lands to non-agricultural use creates a serious problem area.

There are problems by the public and local governments in the practices carried out in the city. In this direction, energy plans and land use decisions should be evaluated together from large scale to small scale. Otherwise; economic concerns may cause environmental and social problems. While the planning wants to continue its activities with the principle of livability and sustainability by examining the city from many dimensions, it can be said that such concerns remain only theoretically decisions.

Investment plans in renewable energy, one of the most important pillars of the green economy will switch to hybrid order. The companies that produce water and wind-based energy will now be able to add solar to the existing power plant area. It will also be able to install solar energy panels at the point where hydroelectric and wind power investments are located. The orientation towards hybrid facilities where wind and solar power plants are combined should be increased. With SPP applications, we can predict that the development in solar energy will continue. There should be distances between the areas or elements that make up the power plant site, except for technical requirements, and the production facility site must be integrated. So, it is the most important thing again land use decisions.

In this study, a GIS-based multi-criteria approach was applied to determine the suitable areas for the development of solar energy, to examine the relationship between the competence level of the land and the solar energy location decisions. In order to determine different areas that may be suitable for solar energy panels, different criteria have been evaluated and a holistic study has been carried out throughout the province of İzmir. As a powerful tool for defining, combining and analyzing criteria, GIS makes a significant contribution to the analytical process for decision-making mechanisms on these issues. AHP method is a method that can be used for different planning purposes at different scales. With the integrated operation of the CBS-AHP model; it can be said that the location of solar power plants can be selected in the best way, this model can be evaluated in terms of environment and land, and it can use important techniques for urban planning. The integration of GIS and MCDA can overcome complex planning problems, bring fast solutions with reliable results. First of all, usage frequencies of MCDA techniques and criteria usage in other studies were determined and selection was made regarding method and criteria considering the characteristics of İzmir city. Then, using spatial analysis and geographic data in different layers, it is focused on selecting the most suitable locations for solar power plants.

Tablo 7. 1. Suitability Explanation for SPP

Criterias	Explanation	Legal Frame
Solar Radiation	should be high	Law No: 5346
Aspect	should be suitable conditions	Law No: 5346
Slope	should be suitable conditions	Law No: 5346
Settlement Area	not installed	Law No: 3194
Main Road	not installed	Law No: 5627
Water Sources	not installed	Law No: 2872 and 3621
Forest	not installed	Law No: 6831
Drainage	not installed	Law No: 6831
Faulty Line	not installed	Law No: 7269
Land Use Capability (Productive Soil)	not installed	Law No: 5403
Electric Transmission Lines	should be close	Law No: 5627
Protected Area	not installed	Law No: 5879
Archeological Areas	not installed	Law No: 5879
Pasture Area	not installed	Law No: 4342
Land Ownership	should be suitable conditions	Law No: 5403
Olive Groove	not installed	Law No: 3573

In Turkey, spatial strategy plans that determine spatial strategies, establish the relationship between spatial policies and strategies related to sectors, and relate development policies and regional development strategies at the spatial level have not been made yet. For this reason, Development Plans and Environmental Plans are directly related to energy investments. These plans generally do not include any analysis and predictions regarding renewable energy use, energy needs, energy demands and energy potential. There is a widespread perception that natural assets or resources are an essential resource that should be used and exploited for development in an unlimited way. This perception makes it difficult to establish a concrete and holistic relationship between soil, air, water and energy at the national level. The general tendency in the plans is to invest new energy facilities are left to the sub-scale plans. There should be necessary opinions and permissions are obtained from the relevant institutions and organizations, and zoning plans are prepared, and the EIA process is run to enable the construction of energy production facilities.

When the site selection of the SPP is evaluated in terms of efficiency criteria, it is stated that the site selection decision is successful, but when it is evaluated in terms of environmental effects, there are important drawbacks. For this reason, it is important to evaluate the environmental dimensions of the SPP and to produce site selection decisions by going through the multi-criteria analysis process. With the help of criteria and indicators determined for the establishment of SPP in spatial planning, the most suitable area decisions for that region. Especially in the sector of energy, there is a need for an energy planning and policy based on its own assets, renewable, innovative, ecological, equitable etc. For this reason, it is necessary to minimize the environmental effects to evaluate renewable energy and especially solar energy potential effectively. In future planning, it will be possible with the implementation of ecological planning decisions. It should be associated especially in Environmental Plans or Zoning Plans, suitability analyzes should be made for the selection of the ideal location and plan decisions should be taken. In these ideal regions, by determining the type of energy; environmental, economic and social evaluations should be made for the future.

To summarize, in order to talk about energy potential, it is necessary to talk about and analyze the land potential first. Therefore, the framework of the provisions included in the legal regulations should be clear and more determined. Unfortunately, if the scope of the legislation is not fully formed, it will affect the efficiency of the practices, environmental effects, the urban element in economic and social dimensions. The presented methodology can be applied to different planning problems involving multiple factors and allows the decision maker to include various criteria and constraints. This study, which has been investigated as a whole for İzmir; it can be taken into account in making planning decisions regarding the implementations to be made on solar energy and renewable energy in İzmir. In terms of planning, a sustainable vision that takes into account the dynamics of the province should be developed and supported. It is possible to say that more precise planning decisions should be made due to the fact that İzmir has a productive land structure. In order to protect the ecosystem of İzmir in the long term, the planning system must be constructed in a correct and sustainable manner.

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APPENDICES

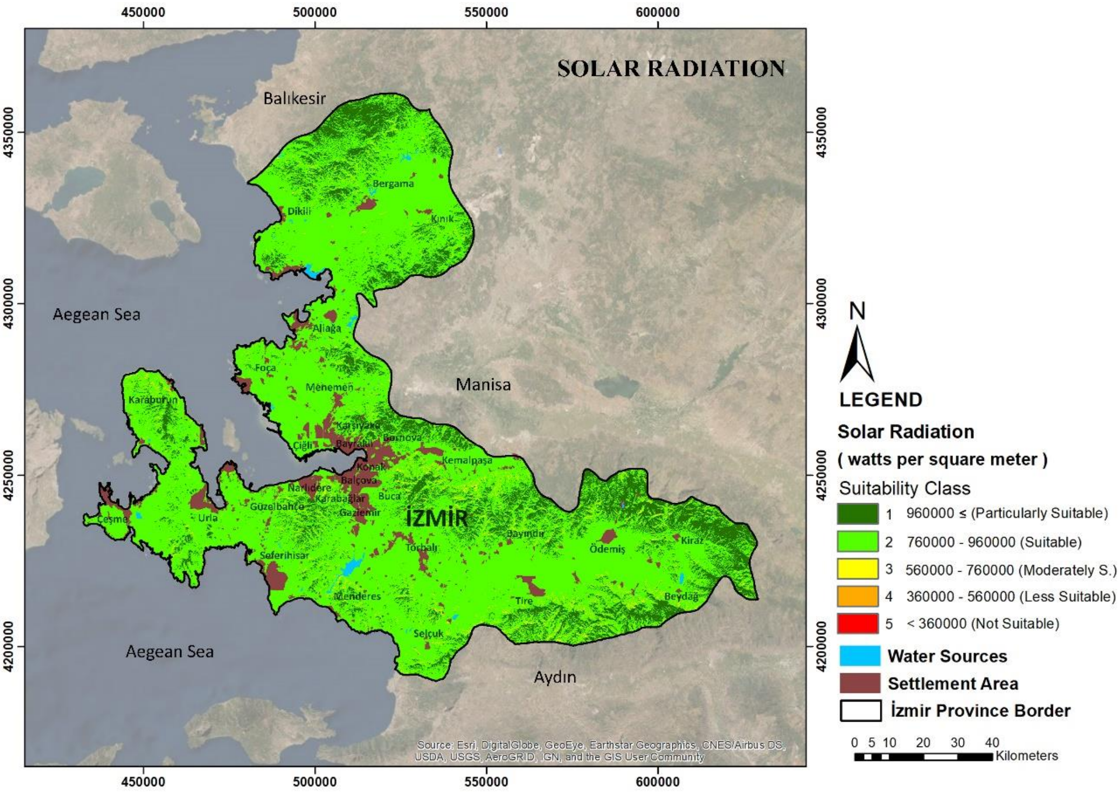
APPENDIX A

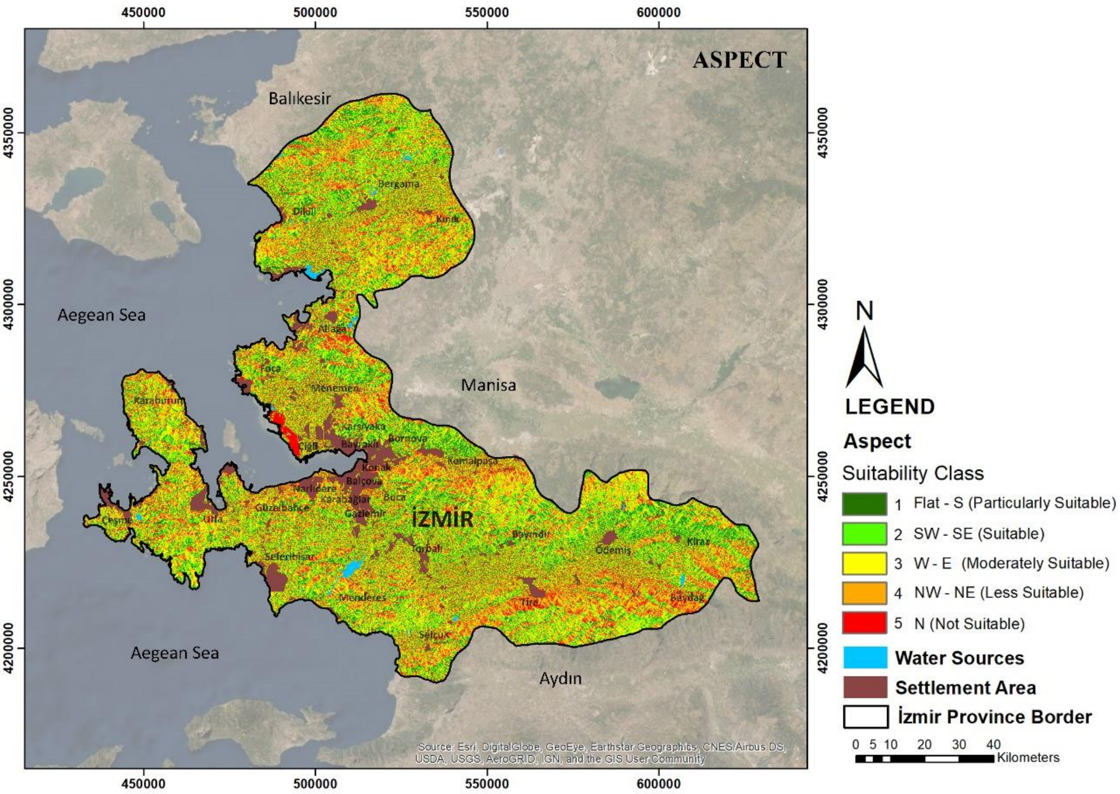
ALL CRITERIA CLASSES, WEIGHTS AND PROCESSING

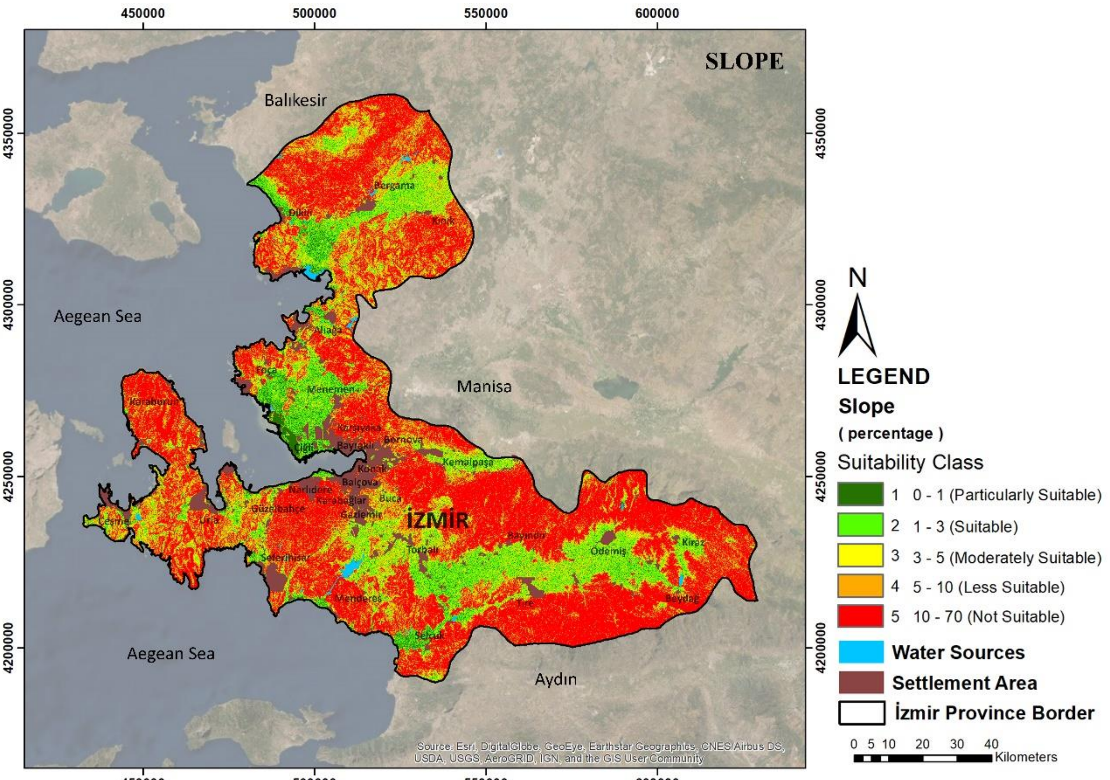
	Criterias	Unit	Intervals	Descriptive Class	Suitability Class	Weight	Data Processing Methods
C1	Solar Radiation	Watts per square meter (W*m-2)	960000 ≤	Particularly Suitable	1	24,3	ArcGIS Software 10.6 Solar Radiation Tool Solar Radiation Classification Reclassification
			760000-960000	Suitable	2		
			560000-760000	Modaretly Suitable	3		
			360000-560000	Less Suitable	4		
			< 360000	Not Suitable	5		
C2	Aspect		Flat+South	Particularly Suitable	1	23,4	ArcGIS Software 10.6 Aspect Tool Aspect Classification Reclassification
			SW+SE	Suitable	2		
			W+E	Modaretly Suitable	3		
			NW+NE	Less Suitable	4		
			N	Not Suitable	5		
C3	Slope	Percentage (%)	0-1	Particularly Suitable	1	17,9	ArcGIS Software 10.6 Slope Tool Slope Classification Reclassification
			1-3	Suitable	2		
			3-5	Modaretly Suitable	3		
			5-10	Less Suitable	4		
			10-70	Not Suitable	5		
C4	Settlement Area	Kilometer (km)	4 ≤	Particularly Suitable	1	11,1	ArcGIS Software 10.6 Buffer Tool Reclassification
			3-4	Suitable	2		
			2-3	Modaretly Suitable	3		
			1-2	Less Suitable	4		
			< 1	Not Suitable	5		
C5	Main Road	Meter (m)	<500	Particularly Suitable	1	7,3	ArcGIS Software 10.6 Buffer Tool Reclassification
			500-1000	Suitable	2		
			1000-3000	Modaretly Suitable	3		
			3000-5000	Less Suitable	4		
			5000≤	Not Suitable	5		
C6	Forest	Meter (m)	3000 ≤	Particularly Suitable	1	5,4	ArcGIS Software 10.6 Buffer Tool Reclassification
			2000-3000	Suitable	2		
			1000-2000	Modaretly Suitable	3		
			500-1000	Less Suitable	4		
			< 500	Not Suitable	5		
C7	Water Source	Meter (m)	5000 ≤	Particularly Suitable	1	5,6	ArcGIS Software 10.6 Buffer Tool Reclassification
			2000-5000	Suitable	2		
			1000-2000	Modaretly Suitable	3		
			500-1000	Less Suitable	4		
			< 500	Not Suitable	5		
C8	Drainage	Meter (m)	1000 ≤	Particularly Suitable	1	2,8	ArcGIS Software 10.6 Hydrology Tool Buffer Tool Reclassification
			800-1000	Suitable	2		
			600-800	Modaretly Suitable	3		
			400-600	Less Suitable	4		
			< 400	Not Suitable	5		
C9	Faulty Line	Meter (m)	1000 ≤	Particularly Suitable	1	2,4	ArcGIS Software 10.6 Buffer Tool Reclassification
			750-1000	Suitable	2		
			500-750	Modaretly Suitable	3		
			250-500	Less Suitable	4		
			< 250	Not Suitable	5		
	First Suitability Map			Particularly Suitable	1	50	
				Suitable	2		
				Modaretly Suitable	3		
				Less Suitable	4		
				Not Suitable	5		
C10	Land Use Capability		VII and VIII	Particularly Suitable	1	50	ArcGIS Software 10.6 Reclassification
			VI	Suitable	2		
			V	Modaretly Suitable	3		
			III and IV	Less Suitable	4		
			I and II	Not Suitable	5		
	Final/Last Suitability Map			Particularly Suitable	1		
				Suitable	2		
				Modaretly Suitable	3		
				Less Suitable	4		
				Not Suitable	5		

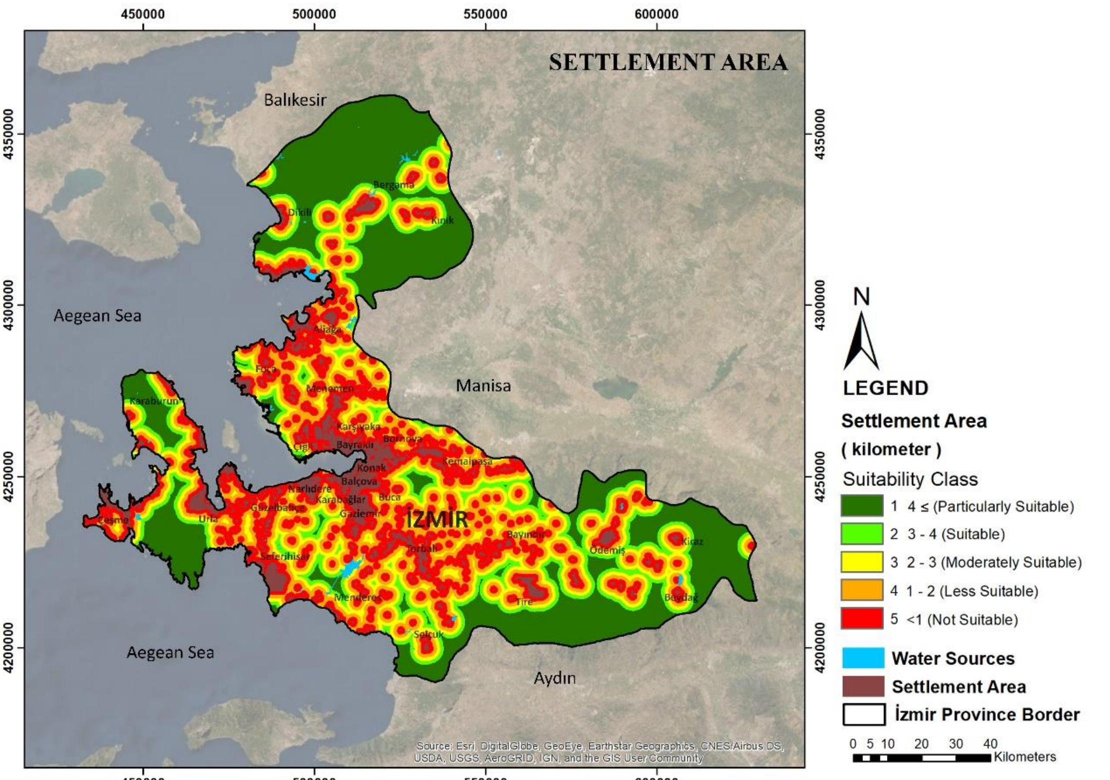
APPENDIX B

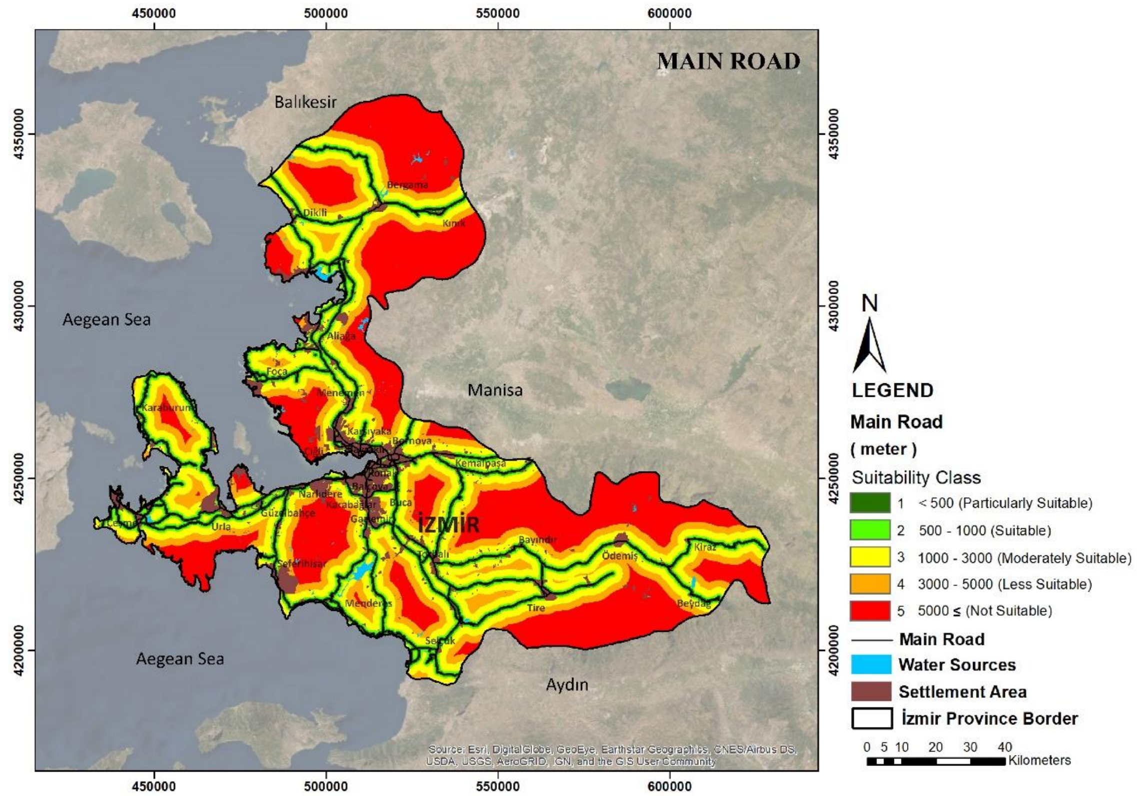
ALL CRITERION AND SUITABILITY MAPS

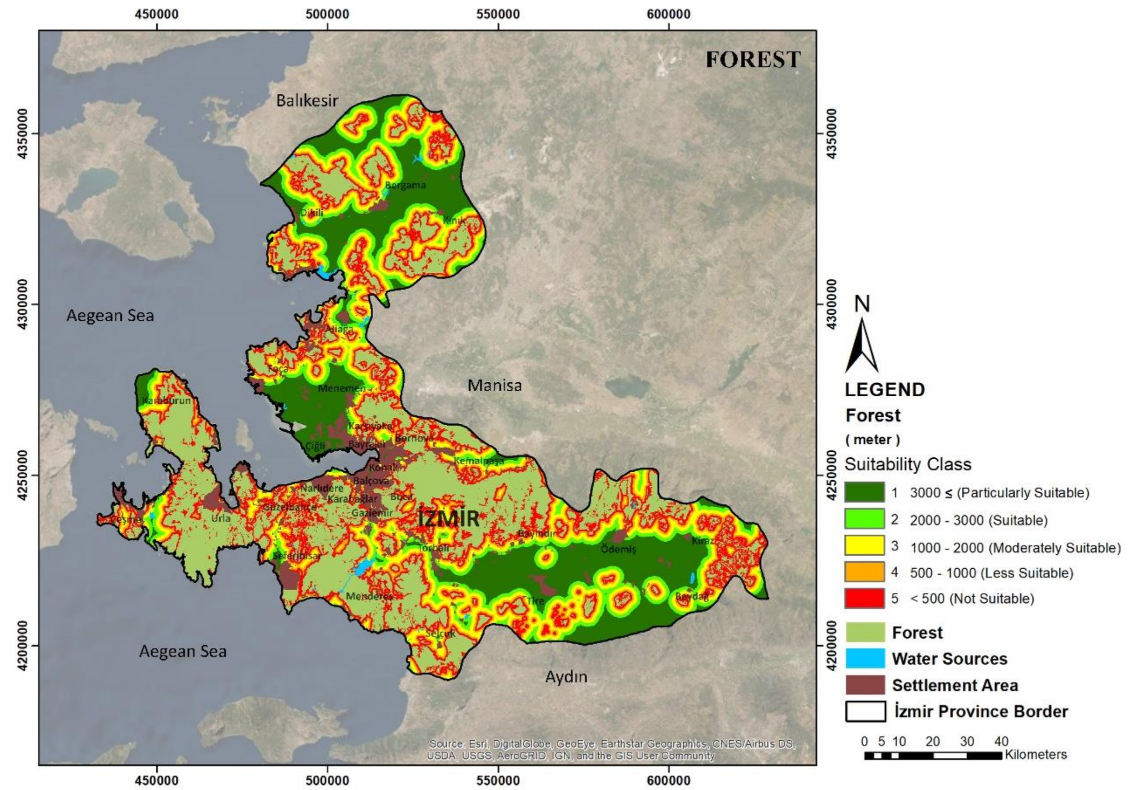


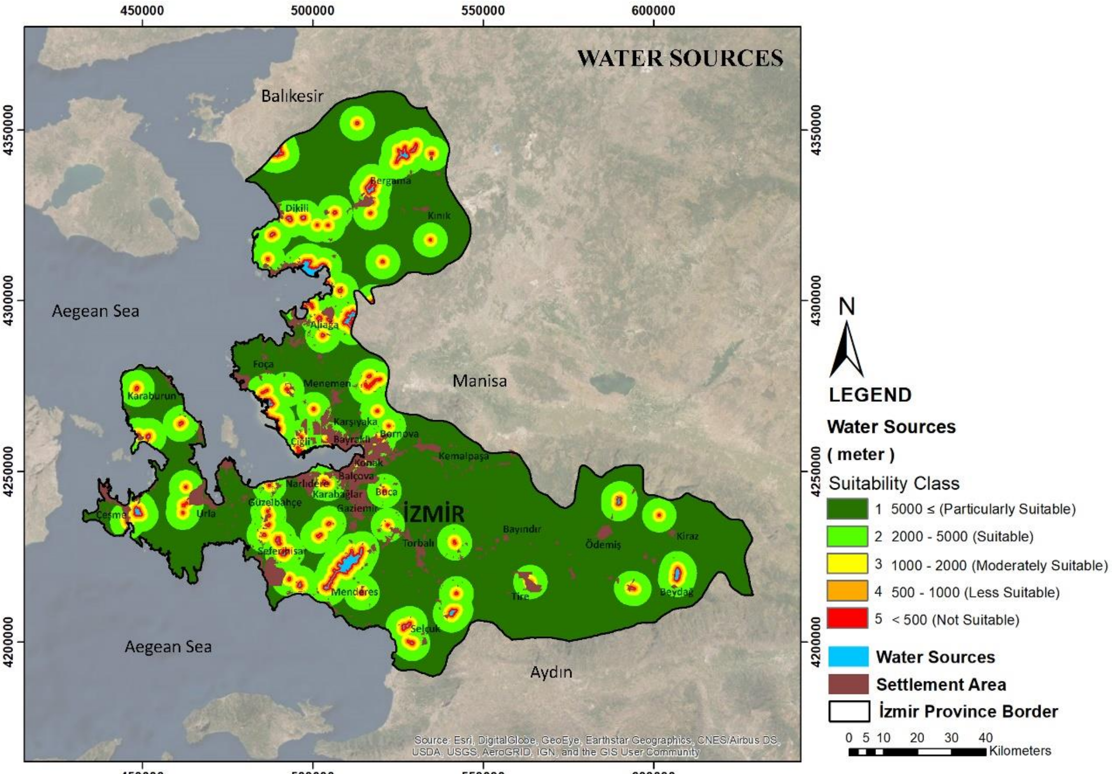


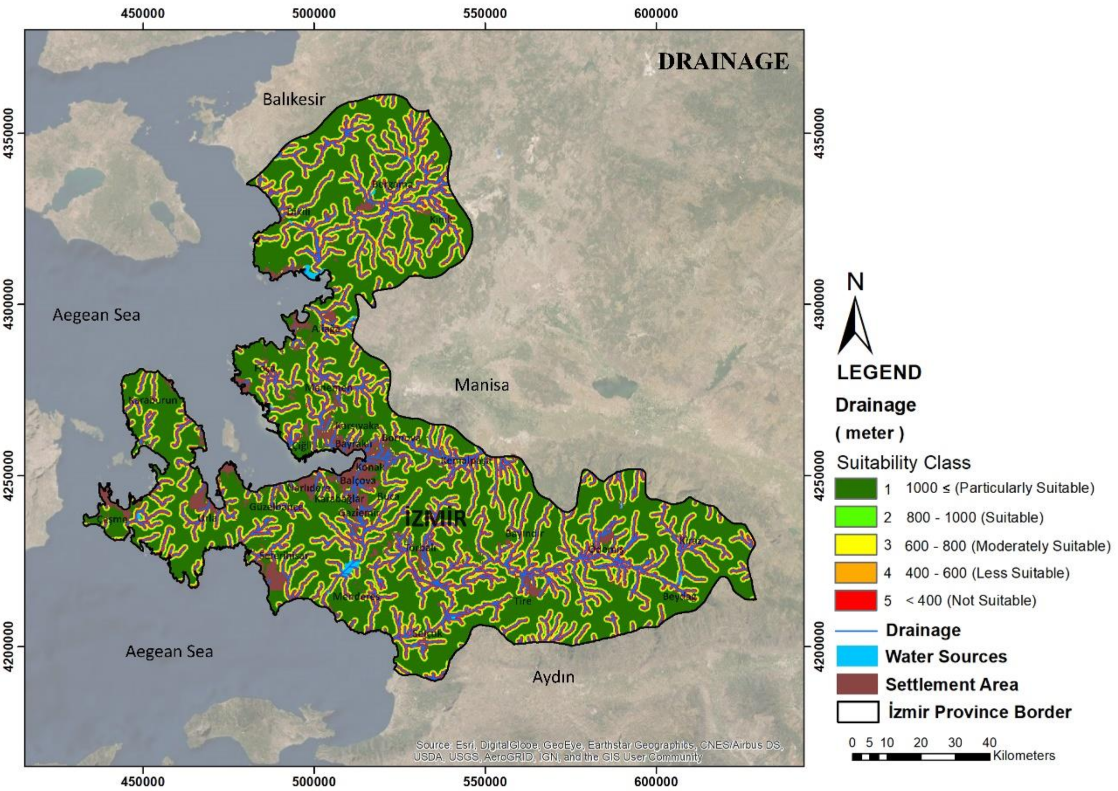

SLOPE
Balıkesir
Aegean Sea
Manisa
İZMİR
Aegean Sea
Aydın
N
LEGEND
Slope
(percentage)
Suitability Class
1 0 - 1 (Particularly Suitable)
2 1 - 3 (Suitable)
3 3 - 5 (Moderately Suitable)
4 5 - 10 (Less Suitable)
5 10 - 70 (Not Suitable)
Water Sources
Settlement Area
İzmir Province Border
0 5 10 20 30 40
Kilometers
450000
500000
550000
600000
4350000
4300000
4250000
4200000
Source: Esri, DigitalGlobe, GeoEye, Earthstar Geographics, CNES/Airbus DS, USDA, USGS, AeroGRID, IGN, and the GIS User Community

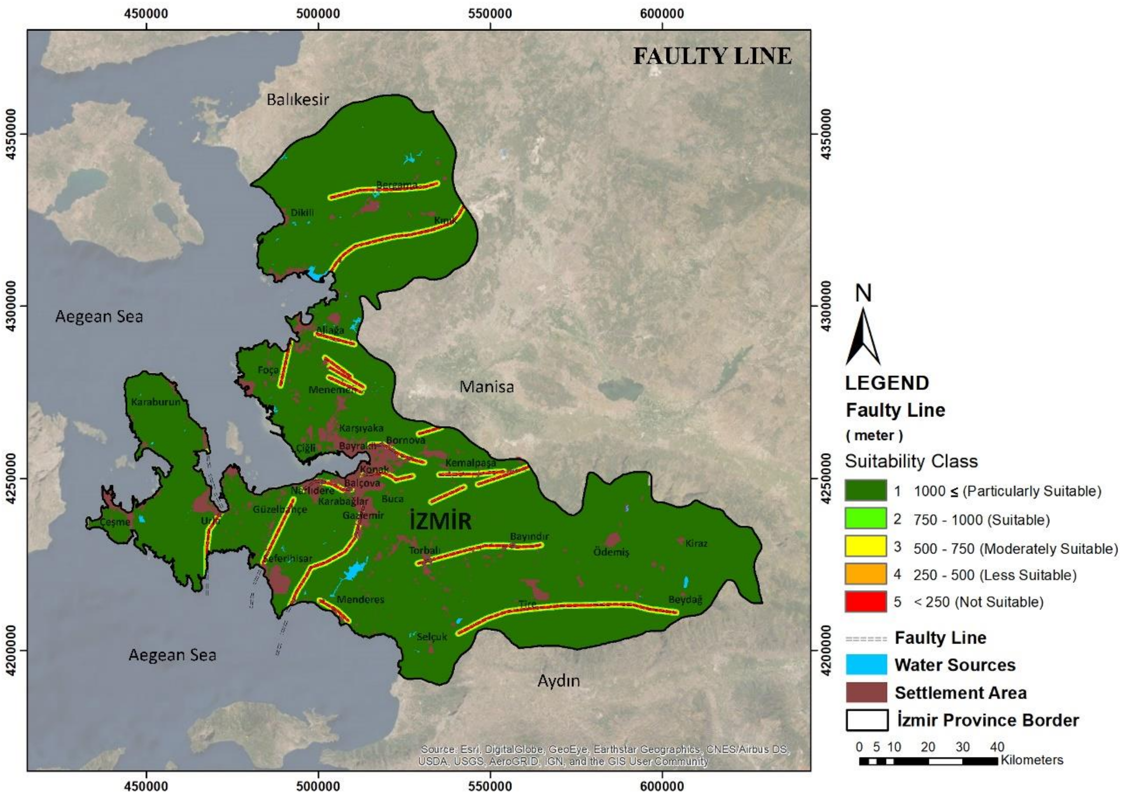

SETTLEMENT AREA
Balıkesir
Aegean Sea
Manisa
İZMİR
Aegean Sea
Aydın
N
LEGEND
Settlement Area
(kilometer)
Suitability Class
1 4 ≤ (Particularly Suitable)
2 3 - 4 (Suitable)
3 2 - 3 (Moderately Suitable)
4 1 - 2 (Less Suitable)
5 <1 (Not Suitable)
Water Sources
Settlement Area
İzmir Province Border
0 5 10 20 30 40
Kilometers
450000
500000
550000
600000
4350000
4300000
4250000
4200000
Source: Esri, DigitalGlobe, GeoEye, Earthstar Geographics, CNES/Airbus DS, USDA, USGS, AeroGRID, IGN, and the GIS User Community


MAIN ROAD
450000
500000
550000
600000
4350000
4300000
4250000
4200000
Balıkesir
Aegean Sea
Manisa
İZMİR
Aegean Sea
Aydın
N
LEGEND
Main Road
(meter)
Suitability Class
1 < 500 (Particularly Suitable)
2 500 - 1000 (Suitable)
3 1000 - 3000 (Moderately Suitable)
4 3000 - 5000 (Less Suitable)
5 5000 ≤ (Not Suitable)
Main Road
Water Sources
Settlement Area
İzmir Province Border
0 5 10 20 30 40
Kilometers
Source: Esri, DigitalGlobe, GeoEye, Earthstar Geographics, CNES/Airbus DS, USDA, USGS, AeroGRID, IGN, and the GIS User Community

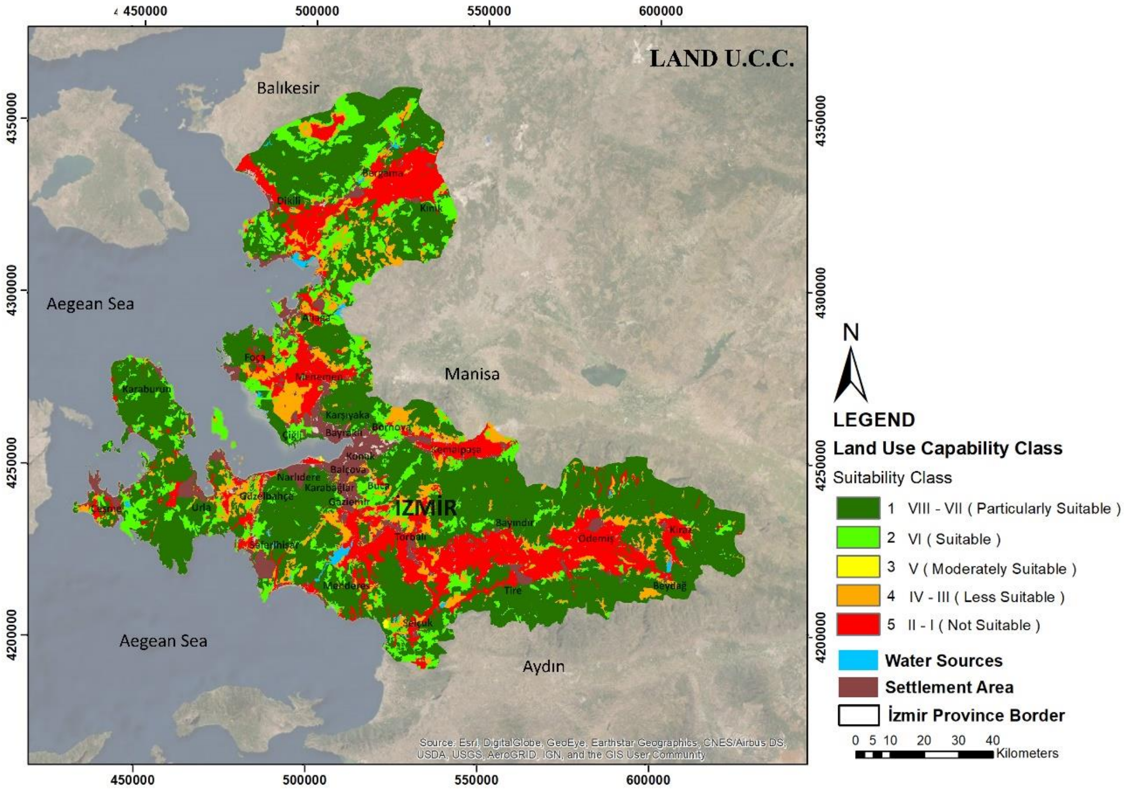

FOREST
450000
500000
550000
600000
4350000
4300000
4250000
4200000
Balıkesir
Aegean Sea
Manisa
İZMİR
Aegean Sea
Aydın
N
LEGEND
Forest
(meter)
Suitability Class
1 3000 ≤ (Particularly Suitable)
2 2000 - 3000 (Suitable)
3 1000 - 2000 (Moderately Suitable)
4 500 - 1000 (Less Suitable)
5 < 500 (Not Suitable)
Forest
Water Sources
Settlement Area
İzmir Province Border
0 5 10 20 30 40
Kilometers
Source: Esri, DigitalGlobe, GeoEye, Earthstar Geographics, CNES/Airbus DS, USDA, USGS, AeroGRID, IGN, and the GIS User Community


WATER SOURCES
450000
500000
550000
600000
4350000
4300000
4250000
4200000
Balıkesir
Aegean Sea
Manisa
İZMİR
Aydın
Aegean Sea
Source: Esri, DigitalGlobe, GeoEye, Earthstar Geographics, CNES/Airbus DS, USDA, USGS, AeroGRID, IGN, and the GIS User Community
N
LEGEND
Water Sources
(meter)
Suitability Class
1 5000 ≤ (Particularly Suitable)
2 2000 - 5000 (Suitable)
3 1000 - 2000 (Moderately Suitable)
4 500 - 1000 (Less Suitable)
5 < 500 (Not Suitable)
Water Sources
Settlement Area
İzmir Province Border
0 5 10 20 30 40
Kilometers

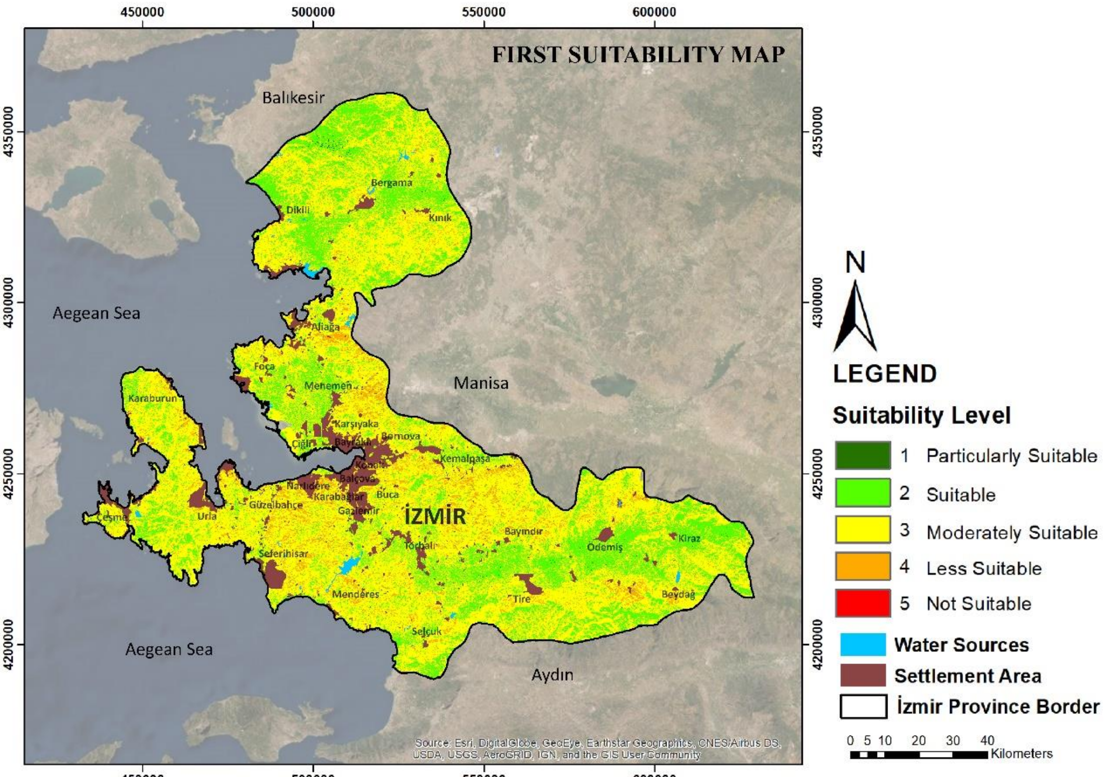

DRAINAGE
450000
500000
550000
600000
4350000
4300000
4250000
4200000
Balıkesir
Aegean Sea
Manisa
İZMİR
Aydın
Aegean Sea
Source: Esri, DigitalGlobe, GeoEye, Earthstar Geographics, CNES/Airbus DS, USDA, USGS, AeroGRID, IGN, and the GIS User Community
N
LEGEND
Drainage
(meter)
Suitability Class
1 1000 ≤ (Particularly Suitable)
2 800 - 1000 (Suitable)
3 600 - 800 (Moderately Suitable)
4 400 - 600 (Less Suitable)
5 < 400 (Not Suitable)
Drainage
Water Sources
Settlement Area
İzmir Province Border
0 5 10 20 30 40
Kilometers

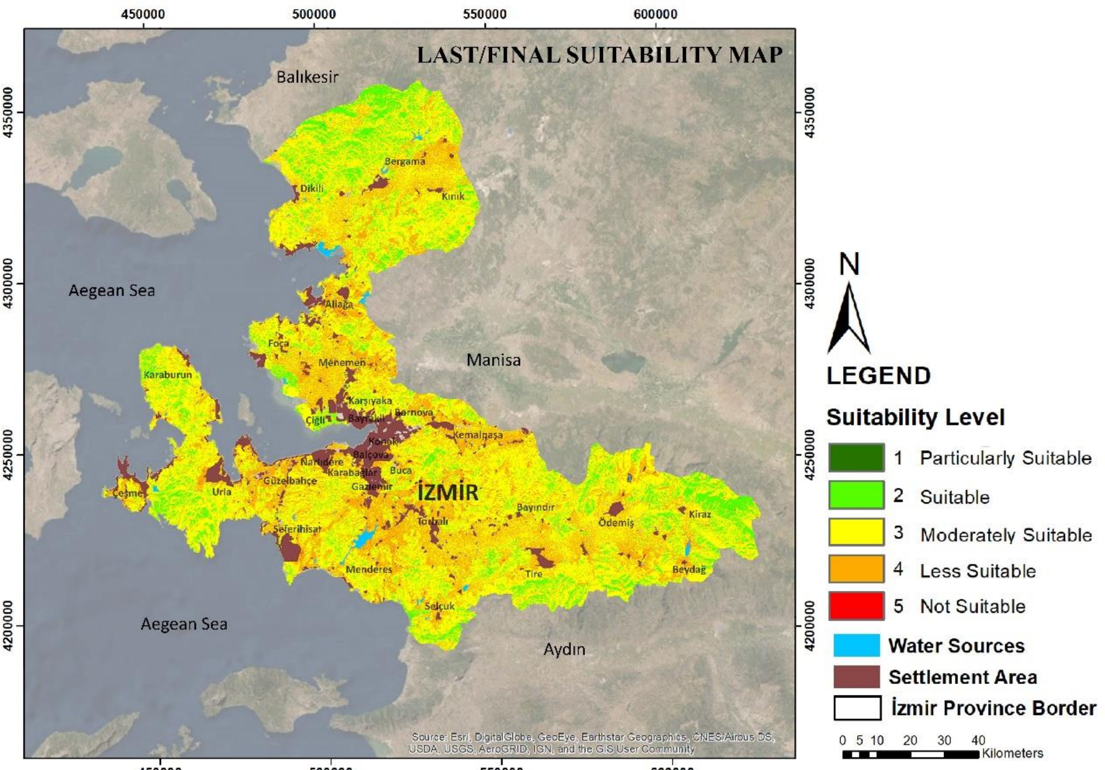


FAULTY LINE
Balıkesir
Aegean Sea
Manisa
İZMİR
Aegean Sea
Aydın
LEGEND
Faulty Line
(meter)
Suitability Class
1 1000 ≤ (Particularly Suitable)
2 750 - 1000 (Suitable)
3 500 - 750 (Moderately Suitable)
4 250 - 500 (Less Suitable)
5 < 250 (Not Suitable)
Faulty Line
Water Sources
Settlement Area
İzmir Province Border
0 5 10 20 30 40
Kilometers



LAND U.C.C.
Balıkesir
Aegean Sea
Manisa
İZMİR
Aegean Sea
Aydın
LEGEND
Land Use Capability Class
Suitability Class
1 VIII - VII (Particularly Suitable)
2 VI (Suitable)
3 V (Moderately Suitable)
4 IV - III (Less Suitable)
5 II - I (Not Suitable)
Water Sources
Settlement Area
İzmir Province Border
0 5 10 20 30 40
Kilometers


FIRST SUITABILITY MAP
450000
500000
550000
600000
4350000
4300000
4250000
4200000
Balıkesir
Aegean Sea
Manisa
İZMİR
Aegean Sea
Aydın
N
LEGEND
Suitability Level
1 Particularly Suitable
2 Suitable
3 Moderately Suitable
4 Less Suitable
5 Not Suitable
Water Sources
Settlement Area
İzmir Province Border
0 5 10 20 30 40
Kilometers
Source: Esri, DigitalGlobe, GeoEye, Earthstar Geographics, CNES/Airbus DS, USDA, USGS, AeroGRID, IGN, and the GIS User Community


LAST/FINAL SUITABILITY MAP
450000
500000
550000
600000
4350000
4300000
4250000
4200000
Balıkesir
Aegean Sea
Manisa
İZMİR
Aegean Sea
Aydın
N
LEGEND
Suitability Level
1 Particularly Suitable
2 Suitable
3 Moderately Suitable
4 Less Suitable
5 Not Suitable
Water Sources
Settlement Area
İzmir Province Border
0 5 10 20 30 40
Kilometers
Source: Esri, DigitalGlobe, GeoEye, Earthstar Geographics, CNES/Airbus DS, USDA, USGS, AeroGRID, IGN, and the GIS User Community

APPENDIX C

INNOVATIVE STUDIES ON SOLAR POWER

Trina Solar
Source: (https://www.stendustri.com.tr/elektrik-enerji/avrupanin-en-buyuk-yuzer-ges-projesine-trina-solar-imzasi-h99246.html, Last Access Date: 17.07.2021)

Trina Solar provides 17 MW of solar panels in France. "Low carbon footprint" modules were used in this project. It will cover the consumption of more than 4,700 households and produce 100% renewable energy. The power plant will also reduce approximately 11,100 tons of CO_2 emissions per year in an area of 17 hectares.

Türkerler Alaşehir JES
Source: (https://www.enerjigunlugu.net/turkerler-alasehir-jese-hibrit-ges-kurulacak-41875h.htm, Last Access Date: 17.07.2021)

A solar power plant will be established at the power plant site to meet the electricity needs of 48 MW geothermal power plants. A total of 22,500 solar panels, each with 400 Wp power, will be installed. Within the project's scope, it aims to establish only a solar power plant in area of approximately 9 hectares within the existing license area, which is a field.

China GES
Source: (https://www.yesilodak.com/yagmurdan-elektrik-ureten-gunes-enerjisi-paneli, Last Access Date: 17.07.2021)

Scientists have developed an innovative "solar panel" technology that converts raindrops into electrical energy. They were able to achieve a solar-to-electricity conversion efficiency of 6.53 percent from solar panels.

Europe and America SolarRoad

Source: (https://khosann.com/artik-otoyollara-gunes-paneli/, Last Access Date: 19.07.2021)

We can generate most of our country's annual electricity needs with solar-powered highways. In a sunny country, it is possible to provide electricity to 5 million people, 8 percent of the population, by laying only 1000 km of solar panels on the roads.