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A Review on Solar Power Plants to Meet Electrical Energy Self-Consumption

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Abstract: Electricity generation from solar energy has increased rapidly in recent years and continues to increase. One of the main reasons for this increase is the spread of self-consumption model solar power plants. With self-consumption model solar power plants, businesses can sell their excess electricity while meeting their own electrical energy needs. In recent years, many small and large-scale studies have been carried out in order to increase the diversity of use of solar energy. In particular, studies on various solar panels are increasing day by day, and various studies are carried out in terms of their efficiency. As a sample for public buildings, in this study, a 1 MW system was designed to meet the electricity needs of TKİ by obtaining electricity from the sun. In this study emphasizes that solar energy, which is among the most advantageous energy production methods for the future in public buildings, is of great importance for the whole world and living things.

Keyword: Solar Energy, Photovoltaic Systems, Concentrated Solar Power, Sustainable Energy

JEL Classification: S42

1. Introduction

This article aims to comprehensively examine the energy sector in Turkey, particularly focusing on the use of solar energy. In pursuit of this objective, topics such as Turkey's energy production and consumption profile, energy policies, solar energy utilization, and the development of the solar energy sector will be addressed. Turkey's energy sector has experienced rapid growth in recent years. According to the data from the Turkish Statistical Institute (TÜİK), Turkey's energy consumption has increased by approximately 180% between 2002 and 2021. Nonetheless, the country heavily depends on imported energy resources, with about 70% of its energy supply being imported (TÜİK, 2023).

Solar energy has gained importance due to its environmental friendliness, unlimited potential, and increasing global adoption. Turkey, with its strategic geographical location, possesses substantial solar energy potential. Solar energy occupies a significant position among Turkey's renewable energy sources. The country's average sunshine duration is approximately 2600 hours per year (Koç, 2019), and its solar energy potential is around 1,500 kWh/m² per year (Ministry of Energy and Natural Resources, 2023). The use of solar energy is rapidly increasing in Turkey. By 2018, the installed solar energy capacity across the country reached 5 GW. It is targeted to reach 10 GW by 2023 (IEA, 2020). Nevertheless, the widespread implementation of solar energy faces some obstacles, such as high investment costs, infrastructure deficiencies, and regulatory challenges (Yolcan & Ramazan, 2020).

The use of solar energy can enhance Turkey's energy supply security and reduce the energy trade deficit. Additionally, as a domestic and renewable energy source, solar energy can decrease the country's dependence on energy imports. Research on the impact of solar energy technologies on Turkey's energy sector indicates that these technologies can contribute to increasing the share of solar energy in the country's energy production (Kılıç & Kekezoğlu, 2022). Furthermore, solar energy technologies can reduce operating costs and lower energy prices. For these reasons, the development and widespread adoption of solar energy technologies in Turkey are vital.

This article aims to investigate the status of Turkey's energy sector, the development and utilization of solar energy technologies, the economic and environmental impacts of solar energy investments, and the potential effects of solar energy usage on Turkey's energy sector. Solar energy technologies, among the most prevalent and rapidly growing renewable energy sources, convert solar radiation into electrical energy through photovoltaic panels and solar thermal systems. Furthermore, advancements in these technologies have resulted in reduced costs and improved efficiency. Consequently, solar energy has become a significant component of global energy supply (IEA, 2020).

The energy sector and energy consumption play significant roles in Turkey's economic and social development. The country imports a substantial portion of its energy resources, posing a threat to energy supply security. Therefore, Turkey aims to diversify its energy supply and utilize domestic resources more effectively (Çalışkan, 2009). The energy policies and legal regulations in Turkey address issues such as energy supply security, price stability, sustainability, the promotion of renewable energy sources, and the reduction of environmental impacts from energy consumption. As of 2021, Turkey's installed solar energy capacity reached 7.5 GW, and the wind energy capacity exceeded 11 GW (TUREB, 2023). Additionally, hydroelectric, biomass, and geothermal energy are among the renewable energy sources utilized in the country.

2. Energy

2.1. Energy Sources

Fossil fuels, including coal, oil, and natural gas, account for a substantial portion of global energy consumption and have significant environmental impacts (BP, 2021). In Turkey, these fuels play a vital role in energy production and consumption, with coal, natural gas, and hydroelectric power being the primary sources (EPDK, 2022). Turkey is actively pursuing nuclear energy projects, such as the Akkuyu Nuclear Power Plant and the Sinop Nuclear Power Plant, aiming to generate substantial amounts of electricity upon completion (Yüksel, 2023).

Turkey has a high solar energy potential, but its current usage remains relatively low. Investments in solar energy have increased in recent years, with the total installed capacity reaching 6.66 GW by the end of 2020 (TEİAŞ, 2023). Turkey has experienced significant growth in wind energy utilization, with an installed capacity of 10,607 MW as of 2023 (TEİAŞ, 2023). Turkey's hydropower potential is substantial, with around 708 hydropower plants and a total capacity exceeding 30,000 MW (Enerji Atlası, 2023). Turkey ranks among the top five countries globally in terms of geothermal energy potential (Enerji Atlası, 2023). Turkey has rich biomass energy sources from agricultural, forestry, and industrial waste (ETKB, 2022). Turkey's tidal energy potential remains unexplored, requiring further research (Enerji Atlası, 2023).

2.2. Energy Production

Turkey's electricity consumption is projected to increase, with fossil fuels accounting for approximately 64.2% of the electricity production and renewable energy sources contributing around 35.8% (ETKB, 2023) (Enerji Atlası, 2023).

2.3. Energy Policy

Turkey's energy policy focuses on diversifying energy sources, increasing the share of renewables, utilizing nuclear energy, improving energy efficiency, and contributing to Europe's energy security (Güner & Albostan, 2007) (ETKB, 2020). The government is actively encouraging investments in renewable energy sources and promoting policies to reduce reliance on fossil fuels (ETKB, 2023). Further efforts are needed to accelerate the transition to renewable energy and enhance energy efficiency in the country.

3. Renewable Energy

3.1. Wind Energy

Wind turbines are devices used to convert wind energy into mechanical energy. The main components of wind turbines include the tower, blades, and generators. Placed at elevated locations, wind turbines utilize the power of the wind to rotate the blades, which, in turn, generate electricity through the generators. Wind turbines come in different sizes and shapes depending on the wind energy resources. Some turbines may have single or multiple blades, and others can have varying numbers of blades (Freris & Infield, 2008).

3.2. Solar Energy

Solar energy can be converted into electricity through photovoltaic systems. These technologies directly convert solar energy into electrical energy. Solar rays release electrons in photovoltaic cells, generating an electric current. Photovoltaic systems are applicable on roofs, buildings, and solar farms, becoming increasingly popular due to low maintenance costs, long lifespan, and eco-friendliness (Foster et al., 2009). Solar energy potential measures a region's ability to harness solar energy resources. It depends on factors such as latitude, climate, and solar irradiance. Determining solar energy potential is essential for planning and siting solar energy projects. It helps in assessing a region's capacity to benefit from renewable energy sources (Foster et al., 2009).

3.3. Hydropower Energy

Hydropower energy is obtained by converting the kinetic energy of water into electricity through hydropower plants. These plants allow water collected in dams to pass through turbines, generating electricity. Dams serve to collect and control water flow. Hydropower plants play a crucial role in global electricity production and meet the energy demands of numerous countries (Pandey & Karki, 2017).

3.4. Biomass Energy

Biomass energy is derived from organic matter or biomass sources. These sources include wood, agricultural residues, animal manure, sawdust, paper waste, and other materials. Biomass energy is produced by burning or fermenting biomass resources, converting them into energy (Freris & Infield, 2008).

Biomass energy potential assesses how much a region can benefit from biomass energy resources. It depends on factors such as agricultural activities, forest areas, and other organic waste sources. Determining biomass energy potential is essential for planning and siting biomass energy projects. It helps evaluate a region's energy production potential from renewable sources (Freris & Infield, 2008).

3.5. Geothermal Energy

Geothermal energy is obtained from thermal energy sources beneath the Earth's surface. Geothermal resources can include volcanic activities, geothermal areas, and hot springs. Geothermal energy can be used to produce electricity by utilizing the heat and steam from these sources (Boden, 2017).

Geothermal energy potential assesses how much a region can benefit from geothermal energy resources. Potential depends on factors such as volcanic activities, density of hot springs, and heat from sources. Determining geothermal energy potential is essential for planning and siting geothermal energy projects. It helps evaluate a region's energy production potential from renewable sources (Boden, 2017).

3.6. Tidal Energy

Tidal energy is derived from the tidal movements in the sea. This energy can be harnessed to produce electricity. Tidal energy potential assesses how much a region can benefit from tidal energy resources.

4. Solar Energy

4.1. What are the Basics of Solar Energy?

Solar energy is clean, unlimited and renewable energy created by the Sun as a result of nuclear reactions. Solar energy is obtained by using photovoltaic (PV) systems and concentrated solar power (CSP) systems.

4.2. Solar Energy Systems

Photovoltaic (PV) systems are devices that convert solar energy directly into electrical energy. Concentrated solar power (CSP) systems generate electricity at high temperatures by concentrating solar energy. Hybrid solar energy systems provide higher efficiency by combining PV and CSP systems (Smets et al., 2016).

4.3. Solar Energy Technology

Photovoltaic panels consist of semiconductor materials that convert solar energy directly into electrical energy. Solar cells are the basic building blocks that convert solar energy into electrical energy. Solar energy storage systems store excess energy with batteries or thermal storage systems (Zekry et al., 2018).

4.4. Solar Energy Planning

Solar energy system planning includes factors such as determining the need, selecting a suitable area, determining panel capacity and fulfilling legal requirements (Boxwell, 2012).

4.5. Solar Energy and Environment

Solar energy is an environmentally friendly and sustainable energy source. It does not directly cause environmental pollution or greenhouse gas emissions during its production, but panel production can lead to environmental impacts (Boxwell, 2012).

4.6. Solar Energy and Economy

Solar energy investment can provide savings in the long term. Although the investment costs are high, its affordability increases with falling solar energy prices and incentive programmes. At the same time, the solar energy sector has great potential in terms of job opportunities (Foster et al., 2009).

4.7. Solar Energy and Society

Community support is important for the success of solar energy projects. Awareness should be raised about the benefits and advantages of solar energy systems and projects should be planned in accordance with the needs of the society.

4.8. Solar Energy and Policies

Solar energy policies are designed to encourage the installation and use of solar energy systems. Incentive programmes and policies contribute to the wider diffusion of solar energy systems and economic growth (Kahraman, 2010). However, it is important that policies are implemented effectively and technological developments are appropriate.

5. Literature Review

5.1. Introduction

Literature review is one of the basic components of academic and scientific research and is the process of systematic and comprehensive collection, evaluation and analysis of existing information, studies and data on a particular topic. This process provides researchers with the opportunity to conduct well-founded research supported by new and up-to-date information, taking into account previous studies on the subject and the results obtained.

5.2. Renewable Energy Resources

Renewable energy is energy derived from energy sources that are continuously regenerated by natural processes and are inexhaustible. Renewable energy sources are derived from natural resources such as solar energy, wind energy, hydroelectric energy, geothermal energy, biomass energy and marine energy (Jacobson, 2009). Renewable energy sources are of great importance in terms of providing clean and sustainable energy production in harmony with nature. Renewable energy is of great importance in terms of sustainability of energy resources, energy security and combating climate change. It is aimed to reduce greenhouse gas emissions resulting from the burning of fossil fuels and to meet the energy demand from clean and sustainable sources at an increasing level (Change, 2018).

Renewable energy sources allow energy production to be realised in different ways. This diversity increases energy security and allows countries and regions to become more independent in providing access to energy. Solar energy is obtained by converting sunlight into electrical energy by photovoltaic cells or concentrated solar energy systems (Parida et al., 2011). Wind energy is produced by wind turbines converting kinetic energy into electrical energy (Manwell et al., 2010). Hydroelectric energy is obtained by converting the kinetic or potential energy of water into electrical energy, while geothermal energy generates heat energy and electrical energy by utilising the temperature deep in the earth's crust (Rybach & Mongillo, 2006). Biomass energy produces electricity, heat and biofuel by utilising the energy content of organic matter and wastes (Demirbas, 2009).

5.3. Solar Energy

Solar energy is obtained by converting the sun's rays into thermal energy or electrical energy and this conversion is realised by photovoltaic (PV) cells or concentrated solar power (CSP) systems (Kalogirou, 2004). Solar energy applications are used in a wide range of applications from power generation, heating and cooling systems, water treatment and agricultural uses.

Regarding the application of solar energy, there are continuous developments in solar panel technologies, which are an important component of photovoltaic systems. New generation solar panels offer higher efficiency, lower cost and flexible structures, enabling wider use of solar energy (Zhao et al., 2016). Solar heating is realised with systems such as solar water heaters and solar air heaters, while solar cooling is provided by solar cooling systems and chillers (Kalogirou, 2013).

5.4. Energy Transition and the Role of Renewable Energy

Energy transition is the process of making energy systems more sustainable, low-carbon and efficient through changes in energy production, distribution and consumption processes (Verbong & Geels, 2010). This process is of great importance for ensuring energy security, combating climate change, economic growth and expanding energy access (Cherp et al., 2017). Energy transition is supported by increasing the use of renewable energy sources, energy efficiency practices and energy policies (Jacobsson & Karltorp, 2013).

In the field of energy infrastructure, energy transition strategies include the modernisation of energy grids and the development of energy storage systems. Smart grids and energy management systems are of great importance for optimising energy consumption and using energy resources more efficiently (Farhangi, 2010). Energy storage systems increase energy security by facilitating the integration of renewable energy sources and provide flexibility of energy systems (Dunn et al., 2011).

Renewable energy sources play an important role in energy conversion. Renewable energy sources such as solar, wind, hydroelectric, biomass and geothermal energy support the energy transition by reducing the environmental impact of energy production and increasing energy security. Renewable energy also contributes to economic growth and social development by reducing energy costs and expanding energy access (Bhattacharyya & Palit, 2016). Renewable energy should be supported by energy policies, technological innovation and public-private partnerships to accelerate the energy transition (Creutzig et al., 2017).

5.5. Solar Energy Policies

Solar energy policies serve the purposes of expanding solar energy, reducing costs and accelerating technological developments (Jacobs & Sovacool, 2012). Solar energy policies are important for increasing energy security, combating climate change and sustainable economic growth (IEA, 2020). These policies are used to incentivise investments in the solar energy sector and to achieve renewable energy targets (Haas et al., 2011).

5.6. Future of Solar Energy Technologies

Expected developments in solar energy technologies include photovoltaic (PV) cells with higher efficiency rates, energy storage systems with lower cost and higher energy density, and the integration of smart grids (IEA, 2022; Lewis, 2016). These developments will help accelerate the energy transition by significantly increasing the share of solar energy in power generation (Creutzig et al., 2017).

The development of PV cells with higher efficiency rates will improve the cost-effectiveness of solar technology and require less space for energy production. New technologies such as perovskite solar cells and tandem PV cells have the potential for higher efficiencies and offer great opportunities to increase the share of solar energy in energy production (Green et al., 2019).

Innovations in energy storage systems will allow solar energy to be used as a more reliable energy source despite daily and seasonal fluctuations. Advances in lithium-ion battery technology and new energy storage technologies will help to integrate solar energy into the grid in a stable and cost-effective manner (Aneke & Wang, 2016).

5.7. Conclusion

This literature review has compiled the available information on renewable energy sources, solar energy systems and their working principles, energy transition and the role of renewable energy, solar energy policies and the future of solar energy technologies. As a result of the review, it is seen that the rapid developments in solar energy technologies have accelerated the energy transition and renewable energy sources have a greater importance.

6. Application

6.1. Photovoltaic Solar Power Plants

Photovoltaic (PV) solar power plants are systems that convert sunlight directly into electrical energy. They mainly consist of components such as photovoltaic panels, inverters, mounting structures and electrical connections. Photovoltaic solar power plants can be used wherever there is energy production and consumption. The areas of application are diverse and include residences, commercial and industrial facilities, agricultural areas, remote areas and areas without access to energy. Example projects include Tengger Desert Solar Park (China), Kamuthi Solar Power Plant (India), Noor Abu Dhabi Solar Power Plant (United Arab Emirates), Topaz Solar Farm (USA), Cestas Solar Power Plant (France).

6.2. Concentrated Solar Power Plants

Concentrated solar energy (CGE) power plants generate energy using mirrors or parabolic surfaces that collect and focus sunlight. CGE technology enables the collection of solar energy at high temperature and uses this energy for electricity generation. Example projects include Ivanpah Solar Power Plant (USA), Noor Ouarzazate Solar Complex (Morocco), Solana Solar Power Plant (USA), Andasol Solar Power Plant (Spain), Puerto Errado 2 Thermosolar Solar Power Plant (Spain). Concentrated solar power plants are seen as an important part of the energy transition and are expected to find more applications in the future. The development and dissemination of these plants will contribute to increasing sustainability and environmentally friendly options in energy production.

6.3. Hybrid Solar Power Plants

Hybrid solar power plants are systems in which more than one energy generation technology is used together. They usually generate energy by combining solar energy with other energy sources such as wind, biomass, hydroelectricity or fossil fuels. Hybrid solar power plants are used in various application areas where energy production must be provided continuously. Hybrid solar power plants are widely preferred in off-grid systems used to meet energy needs, especially in rural areas and areas without access to the energy grid. In addition, in industrial areas where energy production is in high demand, hybrid systems are used to reduce energy costs and ensure energy security. Example projects include Morocco Noor-Ouarzazate and Stillwater Solar-Geothermal Hybrid Plant.

6.4. Building Integrated Photovoltaic (BIPV) Systems

Building integrated photovoltaic (BIPV) systems are photovoltaic panels designed and installed as part of building elements to convert solar energy into electricity. The application areas of BIPV systems cover various types of buildings such as residences, office buildings, commercial and industrial buildings. These systems can be integrated into the design of new structures or installed as an addition to existing buildings to improve energy efficiency and reduce energy costs. Successful applications of BIPV systems include Solar Impulse Foundation (Switzerland), Pearl River Tower (China), Zero Energy Building (Singapore), CIS Tower (UK).

6.5. Solar Water Heating Systems

Solar water heating systems are environmentally friendly and energy efficient systems that heat water using solar energy. Solar water heating systems can be used in various areas such as residences, hotels, hospitals, schools, sports facilities and industrial facilities. The advantages of these systems are energy saving, environmental sustainability and reduction in energy costs. Successful applications of solar water heating systems include The Drake Landing Solar Community (Canada), Balaruc-les-Bains Thalassotherapy Centre (France), Konya Solar Village (Turkey).

6.6. Turkish Coal Enterprises Soma SPP Project Installation

The Turkish Coal Enterprises Corporation, which has almost 165 years of experience considering its history in the Zonguldak Basin, was established under the Ministry of Energy and Natural Resources with the announcement of the Law on the Organisation of TKİ Corporation dated 22 May 1957 and numbered 6974 in the Official Gazette dated 31 May 1957 and numbered 9621. The 5 MW SPP to be installed in Çan Lignite Plant (ÇLİ) Directorate, which was tendered in 2022, is still under construction. In addition, it is planned to include the facilities with a power of 5 MW each to be established in Garp Lignites Enterprise (GLİ) and Aegean Lignites Enterprise (ELİ) directorates in the multi-year investment programme.

7. Analysis

7.1. Performance Analysis of Solar Energy Systems

Evaluating the performance and energy efficiency of solar energy systems is critical to the success and availability of these systems. The energy efficiency of photovoltaic (PV) systems is defined as the ratio of total generated electricity to incident solar radiation. The energy efficiency of PV systems depends on a number of factors, including cell type, module configuration, weather conditions, dust accumulation and system maintenance (Green et al., 2014). Energy efficiency is directly related to the savings in energy consumption provided by these systems (Bongs et al., 2009).

7.2. Economic and Environmental Analysis of Solar Energy Projects

Economic evaluation of solar energy projects includes cost analysis and determination of payback periods. Cost analysis includes the evaluation of the initial investment costs, operation and maintenance costs and energy production costs of the project. Initial investment costs include the costs of components such as solar panels, inverters, mounting equipment and fasteners (Branker et al., 2011). Sustainability analysis aims to determine the long-term environmental impacts and sustainability of projects by assessing the energy resources and environmental impacts of projects (Fthenakis & Kim, 2009).

7.3. Results of the Analyses of the Turkish Coal Enterprises Soma SPP Project

After the operation of the pilot plant with a payback period of 3.34 years, TKİ has started to work for 3 plants with a power of 5 MW each in other operating directorates. The 5 MW SPP to be installed in Çan Lignites Operation (CLO) Directorate, which was tendered in 2022, is still under construction.

8. Conclusions and Reccomendations

The energy efficiency and performance of photovoltaic systems play an important role in the widespread use of solar energy today. According to the results of the literature review, the efficiency of photovoltaic systems depends on factors such as cell technology, module structures and proper design of the system (Razykov et al., 2011). Studies show that the energy efficiency of photovoltaic systems is constantly increasing and the decreasing costs in this process accelerate the widespread use of solar energy (Chu & Majumdar, 2012).

Furthermore, monitoring and analysis of the performance of photovoltaic systems plays an important role in optimising energy production throughout the system's operating time (Hansen et al., 2013). Therefore, energy efficiency and performance evaluation of photovoltaic systems are critical for the sustainability and increasing the economic value of solar energy technologies.

Solar heating and cooling systems have a significant potential for reducing energy consumption and increasing energy efficiency (Kalogirou, 2004). According to the results of the literature review, the energy efficiency and performance of these systems depend on components such as energy storage technologies, heat exchangers and control systems (Dinçer & Meral, 2010). The energy efficiency and performance of these systems contribute to energy transition and sustainable development goals by providing low energy consumption and low emissions.

Economic analysis of solar energy projects includes the evaluation of cost and payback periods. According to the results of the literature review, the initial costs of solar energy projects have decreased significantly in the past years, which has increased the competitiveness of this technology (Branker et al., 2011). The payback periods of solar projects vary depending on factors such as energy prices, government policies and incentives (Hernández-Moro & Martinez-Duart, 2013). In general, the cost analysis of solar energy projects and the assessment of payback periods are important in determining the investment attractiveness and economic value of these projects. Environmental impact assessment and sustainability analysis of solar energy projects are evaluated in terms of their ecological impacts and compliance with sustainable development goals. According to the results of the literature review, solar energy projects generally provide low carbon emissions and reduced air pollution (Fthenakis et al., 2008). The environmental impacts of these projects are related to the effects of energy production on local ecosystems and material utilisation (Turney & Fthenakis, 2011). The sustainability analysis of solar energy projects will be useful to assess their compliance with the energy transition and sustainable development goals.

References

Bhattacharyya, S. C., & Palit, D. (2016). Mini-grid based off-grid electrification to enhance electricity access in developing countries: What policies may be required? Energy Policy, 94, 166-178.

Boden, D. R., (2017). Geologic Fundamentals of Geothermal Energy. CRC Press.

Bongs, C., Dalibard, A., Kohlenbach, P., Marc, O., Gurruchaga, I., Zetzsche, M., Tsekouras, P., Wiemken, E., Bourdoukan, P., & Klein, F. (2009). Task Solar Air-Conditioning and Refrigeration.

Boxwell, M. (2012). Solar Electric Handbook. Greenstream Publishing.

Branker, K., Pathak, M., & Pearce, J. M. (2011). A review of solar photovoltaic levelized cost of electricity. Renewable and Sustainable Energy Reviews, 15(9), 4470-4482.

British Petroleum (BP). (2021). Statistical Review of World Energy (BP, Issue. https://www.bp.com/content/dam/bp/business-sites/en/global/corporate/pdfs/energyeconomics/statistical-review/bp-stats-review-2021-full-report.pdf

Çalışkan, Ş. (2009). Türkiye'nin enerjide dışa bağımlılık ve enerji arz güvenliği sorunu. Dumlupınar Üniversitesi Sosyal Bilimler Dergisi, 25, 297-310.

Change, I. P. o. C. (2018). Global warming of 1.5° C: An IPCC special report on the impacts ofglobal warming of 1.5° C above pre-industrial levels and related global greenhouse gas emission pathways, in the context of strengthening the global response to the threat of climate change, sustainable development, and efforts to eradicate poverty. Intergovernmental Panel on Climate Change.

Chu, S., & Majumdar, A. (2012). Opportunities and challenges for a sustainable energy future. Nature, 488(7411), 294-303.

Creutzig, F., Agoston, P., Goldschmidt, J. C., Luderer, G., Nemet, G., & Pietzcker, R. C. (2017). The underestimated potential of solar energy to mitigate climate change. Nature Energy, 2(9), 1-9.

Demirbas, A. (2009). Political, economic and environmental impacts of biofuels: A review. Applied Energy, 86, 108-S117.

Enerji Atlası. (2023). Enerji Atlası.

Enerji Piyasasi Düzenleme Kurumu (EPDK). Elektrik Piyasasi 2021 Yili Piyasa Gelişim Raporu (2021) Issue. https://www.epdk.gov.tr/Detay/Icerik/3-0-167/resmi-istatistikleri

Enerji ve Tabii Kaynaklar Bakanliği (ETKB). (2023). https://enerji.gov.tr/eigm-yenilenebilir-enerji-kaynaklar-gunes

Foster, R., Ghassemi, M., Cota, A. (2009) Solar Energy: Renewable Energy and the Environment. Taylor & Francis Group.

Freris, L. & Infield, D. (2008). Renewable Energy in Power Systems. Wiley.

Fthenakis, V. M., Kim, H. C., & Alsema, E. (2008). Emissions from photovoltaic life cycles. Environmental Science & Technology, 42(6), 2168-2174.

Fthenakis, V., & Kim, H. C. (2009). Land use and electricity generation: A life-cycle analysis. Renewable and Sustainable Energy Reviews, 13(6-7), 1465-1474.

Green, M. A., Ho-Baillie, A., & Snaith, H. J. (2014). The emergence of perovskite solar cells. Nature Photonics, 8(7), 506-514.

Güner, S., & Albostan, A. (2007). YEKSEM. Türkiye'nin Enerji Politikasi.

Haas, R., Resch, G., Panzer, C., Busch, S., Ragwitz, M., & Held, A. (2011). Efficiency and effectiveness of promotion systems for electricity generation from renewable energy sources-lessons from EU countries. Energy, 36(4), 2186-2193.

Hansen, L., Lacy, V., & Glick, D. (2013). A review of solar PV benefit & cost studies. Rocky Mountain Institute.

Hernández-Moro, J., & Martinez-Duart, J. M. (2013). Analytical model for solar PV and CSP electricity costs: Present LCOE values and their future evolution. Renewable and Sustainable Energy Reviews, 20, 119-132.

International Energy Agency (IEA). (2022). Turkey 2021 Energy Policy Review Issue. https://iea.blob.core.windows.net/assets/cc499a7b-b72a-466c-88de-d792a9daff44/Turkey_2021_Energy_Policy_Review.pdf

International Energy Agency (IEA). (2022). Turkey 2021 Energy Policy Review Issue. https://iea.blob.core.windows.net/assets/cc499a7b-b72a-466c-88ded792a9daff44/Turkey_2021_Energy_Policy_Review.pdf

Jacobson, M. Z. (2009). Review of solutions to global warming, air pollution, and energy security. Energy & Environmental Science, 2(2), 148-173.

Jacobsson, S., & Karltorp, K. (2013). Mechanisms blocking the dynamics of the European offshore wind energy innovation system-challenges for policy intervention. Energy Policy, 63, 1182-1195.

Kahraman D., (2010). Güneş enerjisi kaynaklı elektrik üretiminin teknik-ekonomik analizi ve yöresel uygulaması, yayımlanmamış yüksek lisans tezi, Yıldız Teknik Üniversitesi Fen Bilimleri Enstitüsü, Makine Mühendisliği Anabilim Dalı, İstanbul.

Kalogirou, S. A. (2004). Solar thermal collectors and applications. Progress in Energy and Combustion Science, 30(3), 231-295.

Kebede, A. A., Kalogiannis, T., Van Mierlo, J., & Berecibar, M. (2022). A comprehensive review of stationary energy storage devices for large scale renewable energy sources grid integration. Renewable and Sustainable Energy Reviews, 159, 112213.

Kılıç, U., & Kekezoğlu, B. (2022). A review of solar photovoltaic incentives and Policy: Selected countries and Turkey. Ain Shams Engineering Journal, 13(5), 101669.

Koç, A. (2019). Güneş enerjisi potansiyelinin değerlendirilmesi ve Türkiye'de uygulanabilirliği. Elektrik Mühendisliği ve Bilgisayar Bilimleri Dergisi, 18(1), 15-22.

Lewis, N. S. (2016). Research opportunities to advance solar energy utilization. Science, 351(6271).

Manwell, J. F., McGowan, J. G., & Rogers, A. L. (2010). Wind energy explained: theory, design, and application. John Wiley & Sons.

Pandey, B., Karki, A. (2017). Hydroelectric Energy: Renewable Energy and the Environment. CRC Press.

Parida, B., Iniyan, S., & Goic, R. (2011). A review of solar photovoltaic technologies. Renewable and Sustainable Energy Reviews, 15(3), 1625-1636.

Razykov, T. M., Ferekides, C. S., Morel, D., Stefanakos, E., Ullal, H. S., & Upadhyaya, H. M. (2011). Solar photovoltaic electricity: Current status and future prospects. Solar energy, 85(8), 1580-1608.

Rybach, L., & Mongillo, M. (2006). Geothermal sustainability-a review with identified research needs. GRC Transactions, 30, 1083-1090.

Smets, A., Jager, K., Isabella, O., Swaaij, R. V., Zeman, M. (2016). Solar Energy: The Physics and Engineering of Photovoltaic Conversion, Technologies and Systems. UIT, Cambridge.

Steibler, M. (2008). Wind Energy Systems for Electric Power Generation, Wiley.

Türkiye Elektrik İletim Anonim Şirketi (TEİAŞ). (2023).

Türkiye Rüzgar Enerjisi Birliği (TUREB). (2023). https://www.tureb.com.tr/

Turney, D., & Fthenakis, V. (2011). Environmental impacts from the installation and operation of large-scale solar power plants. Renewable and Sustainable Energy Reviews, 15(6), 3261-3270.

Verbong, G. P., & Geels, F. W. (2010). Exploring sustainability transitions in the electricity sector with socio-technical pathways. Technological Forecasting and Social Change, 77(8), 1214-1221.

Yolcan, O., & Ramazan, K. (2020). Türkiye'nin güneş enerjisi durumu ve güneş enerjisi santrali kurulumunda önemli parametreler. Kırklareli Üniversitesi Mühendislik ve Fen Bilimleri Dergisi, 6(2), 196-215.

Yüksel, F. (2023). Türkiye, yarım asırlık nükleer enerji serüveninde 2023 hedefini gerçekleştirmeye hazırlanıyor. Anadolu Ajansı. https://www.aa.com.tr/tr/ekonomi/turkiye-yarim-asirlik-nukleer-enerji-seruveninde-2023-hedefini-gerceklestirmeye-hazirlaniyor/2861436

Zhang, H., Baeyens, J., Degrève, J., & Cacères, G. (2013). Concentrated solar power plants: Review and design methodology. Renewable and Sustainable Energy Reviews, 22, 466-481.

Zhu, L., Wang, L., Pan, C., Chen, L., Xue, F., Chen, B., Yang, L., Su, L., & Wang, Z. L. (2017). Enhancing the efficiency of silicon-based solar cells by the piezo-phototronic effect. ACS Nano, 11(2), 1894-1900.