AIMS Energy

AIMS Energy, 14(3): 521–547.
DOI: 10.3934/energy.2026022
Received: 13 December 2025
Revised: 27 March 2026
Accepted: 08 April 2026
Published: 19 May 2026

https://www.aimspress.com/journal/energy

Perspective

Solar energy resources in Jordan: The current situation, the potentials, and a future perspective

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Abstract: Jordan is classified as a low-to-middle income country, in which the primary energy sources are imported crude oil and natural gas. Energy expenses represent a high percentage of the country's GDP and are amongst the greatest hindering factors for industrial expansion and regional/international competitiveness. Solar energy is a key resource that should clearly be utilized to significantly improve both the country's economy and energy security. Jordan has been ranked in third place among Arab countries, but globally, countries like China and the US lead in solar capacity, while others like Chile show very high potential. This paper outlines the status of solar energy in Jordan, its potential, and the outlook for future growth. It also touches on national targets, investment trends, and the broader policy and institutional context shaping the sector's development. These data were collected by local and international reports, strategies, and policies related to the solar energy status in Jordan. The review suggests that solar energy in Jordan is moving in a promising direction, though certain policies, infrastructure, and capacity-related hurdles remain. Unlocking its full potential will likely depend on ongoing commitment, smart investment, and broader collaboration.

Keywords: solar energy; PV; PV regulations

1. Introduction

Energy is a necessity for life on earth, and energy security is among the most urgent issues, despite people often taking it entirely for granted. A simple and affordable energy supply is urgently needed, especially in developing nations where availability and coverage remain an issue [1]. Energy consumption is directly correlated with the quality of healthcare, life expectancy, and access to education, all of which are key factors contributing to a person's overall quality of life [2]. With a goal of making a high quality of life ubiquitous, both effective and rapid efforts are required to increase access to modern energy facilities in developing nations. As mentioned in [3] achieving a high quality of life ubiquitous requires both effective and rapid efforts to increase access to modern energy facilities in developing nations. Moreover, the authors in [4] mentioned that the increase of the access to energy is essential for promoting social and economic growth, cost effectiveness, reducing poverty, and advancing global energy security as also confirmed in [5].

Jordan is classified as a low-to-middle-income country with a population of about 11.84 million [6]. Natural resources, including water, fossil fuels, and other industrial materials, are limited. Therefore, Jordan's primary energy sources are imported crude oil and natural gas from nearby Arab nations [7]. Jordan's economy is primarily service-based, with tourism and business services playing central roles. The manufacturing sector, including industries such as pharmaceuticals, also makes a significant contribution to overall economic activity [8]. In recent years, Jordan's demand for energy in all forms has increased due to improvements in living standards, population growth, regional refugee inflows, and the diversification of economic activities [9].

Jordan's economy remains vulnerable due to its continued reliance on imported energy resources, particularly oil and gas. This dependence has exposed the country to disruptions and price fluctuations triggered by regional geopolitical events, such as the suspension of preferential oil supplies from Iraq after 2003 and the repeated interruptions in natural gas imports from Egypt between 2011 and 2018 [10]. These challenges underscore the need to develop secure alternatives and expand the share of locally produced renewable energy to strengthen the Kingdom's energy security and economic resilience.

Although the renewable energy drive in Jordan is often conceptualized from the viewpoints of resource diversification or the availability of resources, contemporary studies of the energy transition process argue that the process should be viewed as a socio-political phenomenon that is determined by geopolitical configurations, external finance, or security issues. According to Schuetze, the "energy security" drive has traditionally remained at the heart of the energy transition process in Jordan; nevertheless, the geopolitical configuration of the energy relationship or the political relationship between the regional and the national levels can also hinder the energy transition process or create new forms of dependency or concentration of power. This is relevant for the analysis of the Jordanian renewable energy expansion from a non-technical viewpoint [11].

Another important aspect related to energy is greenhouse gas emissions, which is an urgent problem globally, raising the need for alternative energy sources other than oil and fossil fuels. According to the UN report [12], there are four emissions scenarios, all expressed as the change in downwelling radiation (in watts/meter-sq, nominal year 2100) toward the surface that results from an increase in the atmospheric concentration of certain greenhouse gases, named "representative concentration pathways" or RCPs. As shown in Figure 1, there are four RCPs: 2.6, 4.5, 6.0, and 8.5. The ranges of associated warming over 1000 total scenarios are given on the right axis.

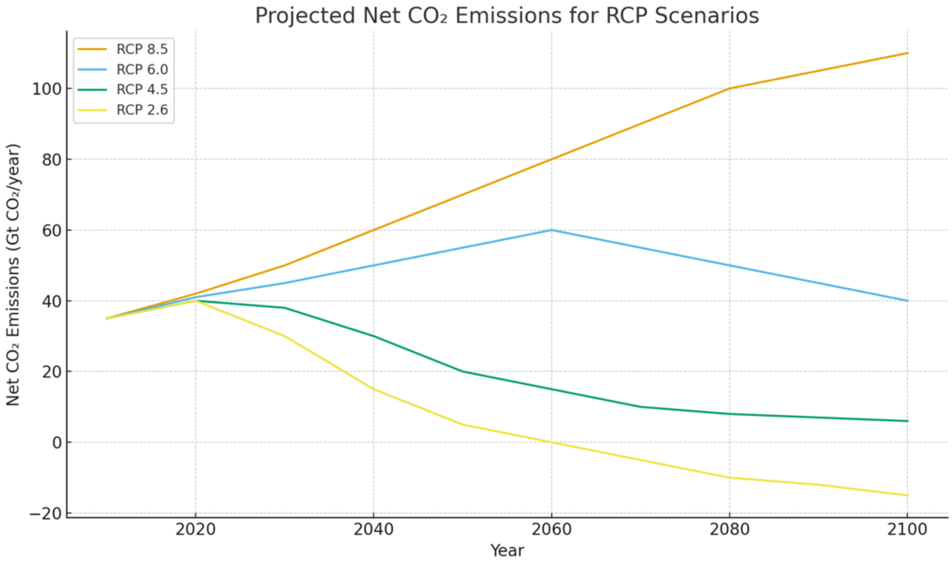


Figure 1. Approximately 1000 scenario runs for four RCPs. From [13] (regenerated).

The highest emission pathway (RCP 8.5), which is widely incorporated in many climate change models for assessment and international agreements like the Paris Agreement, is likely to be the most frequently mentioned pathway by climate change advocates.

The energy sector in Jordan plays a pivotal role in the nation's economic development and sustainability goals. Jordan's energy supply is characterized by a diversified portfolio that includes conventional and renewable sources. The current primary sources of energy in Jordan include natural gas and oil, alongside the growing renewable energy [10]. Heading into the future, Jordan faces two major challenges: growing energy demand and an incomparably limited rate of supply growth. The diversification strategy is aimed at enhancing energy security, reducing dependence on imported fossil fuels, and mitigating environmental impacts.

A remarkable advancement has occurred in the solar energy sector in Jordan between 2015 and 2024, contributing to an increase in the share of renewable energy, including solar energy, to 27% of the country's total electricity generation [14]. However, due to the country's challenging economic conditions and rising energy costs, together with its exceptional solar energy potential, further advancements in the solar energy sector are necessary.

This paper presents an overview of the solar energy situation in Jordan. First, the energy landscape in Jordan is described in connection to various economic, energy, and environmental indicators.

Second, the potential for solar resources in Jordan is analyzed based on solar energy indicators. Third, policies, regulations, installed capacity, investments, and challenges are presented to obtain an overview of the status of solar energy and its exploitation in Jordan. The paper then concludes with an outlook for solar energy in Jordan.

1.1. Method and data sources

This paper presents a critical narrative review of Jordan's solar energy sector, supported by official national reports, international datasets, and selected peer-reviewed literature. The review synthesizes technical, regulatory, and socio-political evidence to provide an integrated assessment of the current status, potential, and implementation challenges of solar energy development in Jordan.

The sources that this paper depends on can be categorized into three major categories:

- Official national sources: The primary data sources are annual reports and strategic documents of the Ministry of Energy and Mineral Resources (MEMR), the National Electric Power Company (NEPCO), the Energy and Minerals Regulatory Commission (EMRC), and the Department of Statistics (DOS) in the Kingdom of Jordan.
- International organization datasets: To provide global benchmarking and verified technical indicators, the study utilized reports from the International Renewable Energy Agency (IRENA), the International Energy Agency (IEA), and the World Bank's Global Solar Atlas.
- Academic and specialized literature: Peer-reviewed academic journals were searched via Google Scholar using keywords such as "solar energy in Jordan", "renewable energy in Jordan", "Jordan solar potential", "PVOUT in Jordan", and "energy security Jordan". This category also targeted recent social science and political economy perspectives (e.g., Schuetze and Hussein, 2023; Abu-Zreig and Hussein, 2025) to provide a critical perspective.

The review primarily focuses on the period 2010–2024, capturing the shift from early renewable policy formulation (2012 Law) to the current state and implementation challenges. Sources were included based on three criteria: the existence of Jordanian energy indicators (global horizontal irradiation, direct normal irradiation, installed capacity), being published by an identifiable government or international regulatory body, or peer-reviewed academic status.

To ensure the highest reliability of reported statistics, the following order of priority was applied when datasets conflicted:

- Primary national reports: MEMR and NEPCO annual reports.
- Regulatory utility statistics: EMRC and Electricity Sector Regulatory Commission (ERC) tariff and generation codes.
- International peer-reviewed academic journals.

2. Overview of Jordan's energy landscape

2.1. Jordanian energy sector in numbers

In 2021, approximately 93% of Jordan's energy requirements were imported, meaning that approximately 8% of the country's GDP was spent on the energy bill [15]. Jordan's energy demand has increased dramatically during the past 20 years, and fossil fuels (crude oil and natural gas) have been used and promoted to keep up with it, while renewable energy utilization remained at 1% up to 2015. The energy share of renewable energy only began to rise post-2015, as the nation's overall use of renewable energy steadily grew [16].

In 2023, Jordan produced roughly 24,182 GWh of electricity, with the energy mix consisting of 61.1% natural gas, 26.28% renewable energy, and 12.62% oil shale. The total installed capacity for renewable energy reached 2,681 MW, predominantly from solar and wind sources.

The Jordanian government liberalized its energy market in November 2012 and changed fuel prices in accordance with the international price market. The price of gasoline continues to be adjusted each month in accordance with global pricing. Jordan's decision to stop providing subsidies for fossil fuels promotes the use of renewable energy [17].

The only active hydrocarbon fuel sources in Jordan are the 1987-discovered Risha natural gas field and the Hamzah oil field, both of which have very limited production [18]. In addition, Jordan has abundant oil shale deposits, which began being commercially used in mid-2023 through the Attarat Power Plant, located in Attarat Um Ghudran. The plant has a net capacity of 470 MW and meets up to 15% of the country's annual electricity demand [19].

Jordan has a significant solar energy potential due to its location in the Sunbelt region: the daily average solar irradiance on a horizontal surface ranges between 5 and 7 kWh/m^2, and the yearly average of solar energy is approximately 1800 kWh/m^2 [3].

Figure 2. Jordanian energy sector in 2023 in numbers. Source [20].

Figure 2 summarizes the energy sector in Jordan as issued by the annual report of the Minister of Energy and Mineral Resources (MEMR) [20]. According to Figure 2, the primary energy consumed in Jordan in 2023 was 9856 ktoe, and the cost of the imported energy was 2357 million JD. Approximately 26.28% of the electricity generation in 2023 was generated from renewable energy, which forms the majority of the 39.5% of the electricity that was generated from local sources.

2.2. Electricity sector organization

Figure 3 illustrates the structure and bodies that make up the electricity sector in Jordan. Under this structure, the private sector is responsible for a substantial portion of the power generation and distribution network. The public sector is exclusively in charge of transmission, with limited involvement in generation. The sector is regulated by an independent ERC with its main duty being the control and adjustment of electricity tariffs [21].

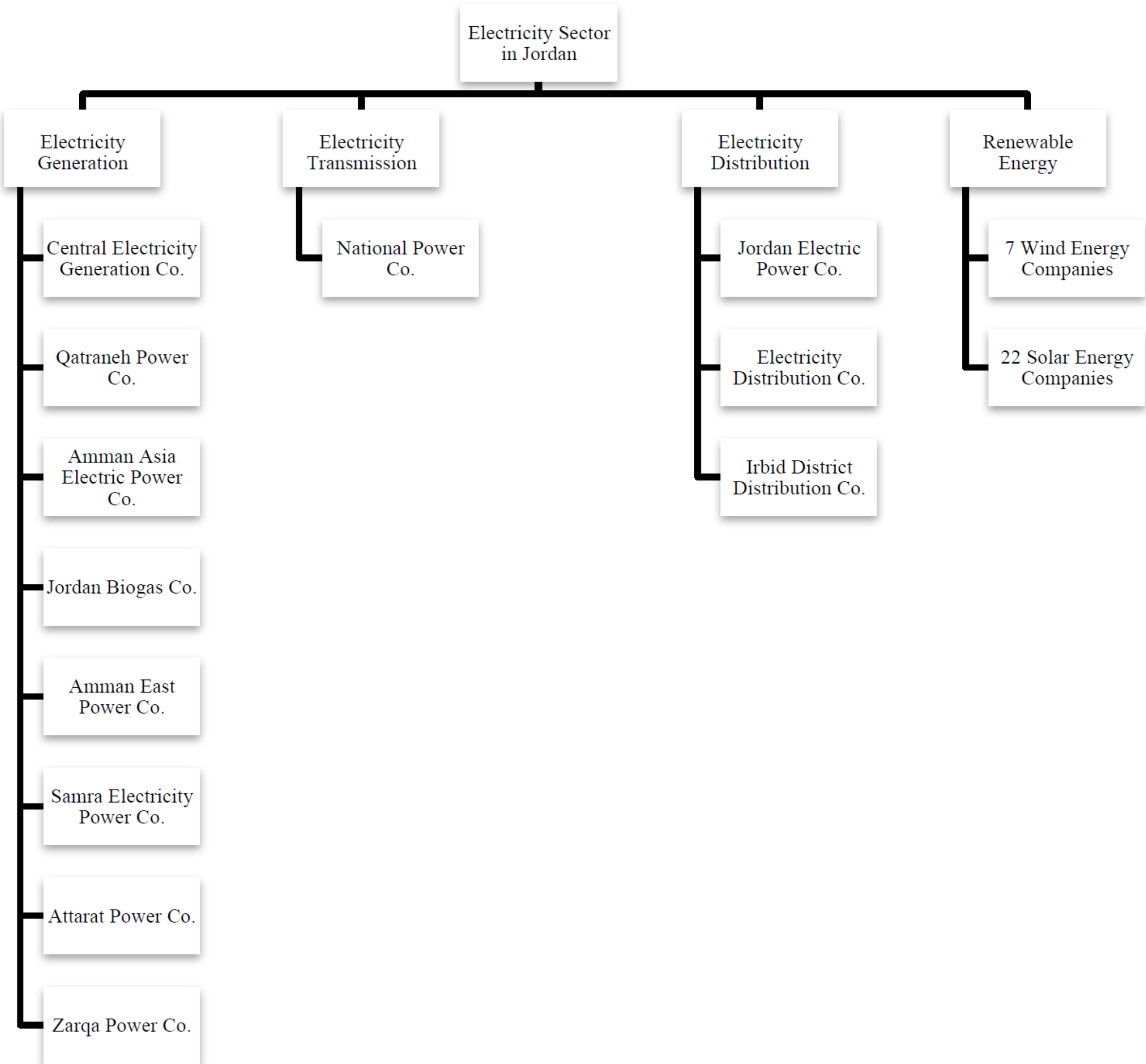


Figure 3. Electricity sector organizations in Jordan. Source [22].

The institutions responsible for regulating, generating, transmitting, and distributing electricity all over the country are divided into:

1. NEPCO:

NEPCO is a public shareholding company owned by the Jordanian government. Its duties include building, running, and maintaining the transmission systems inside the kingdom's borders. It also manages the electric transmission network, which links the national electrical system to those of the neighboring countries. Additionally, it protects the national energy supply by adding new generation facilities.

2. Electric power distribution companies that include:
   - 2.1. Jordanian Electric Power Company (JEPCO): A public shareholding corporation in charge of electricity distribution in the governorates of Amman, Zarqa, Ma'daba, and Balqa.
   - 2.2. Irbid District Electricity Company (IDECO): A public shareholding corporation in charge of electricity distribution in the governorates of Irbid, Mafraq, Jerash, and Ajloun.
   - 2.3. Electricity Distribution Company (EDCO): A public shareholding corporation in charge of electricity distribution outside of JEPCO and IDECO's concession areas, specifically in the Southern, Eastern, and Jordan Valley regions.
3. Electricity generation companies:
   - 3.1. Renewable energy companies, including 7 wind energy companies, 22 solar energy companies, and biogas companies.
   - 3.2. Traditional energy companies; the major ones are:
     - 3.2.1. Central Electricity Generating Company (CEGCO): A 1999-founded public shareholding firm. Its duties include power generation and wholesale sales to the NEPCO. At the end of 2021, the company's generating capacity was 752 MW [23].
     - 3.2.2. Amman East Power Company: The American AES Company and the Japanese MITSUI Company are the owners of the privately held Amman East Power Project. It was established in 2009 and oversees the production and sales of electricity to NEPCO. The company was the first privately funded facility in Jordan to produce electricity in the East Amman power plant/Al-Manakher, which began producing electricity on May 26, 2009. The company's generating capacity has reached approximately 400 MW [24].
     - 3.2.3. Qatrana Electric Power Company (QEPC): A private firm founded in 2010 and owned by the Saudi XENEL firm and the Korean KEPCO Company. The company's mission is to produce and supply electricity to NEPCO. The company's generating capacity is approximately 450 MW [25].
     - 3.2.4. Samra Electric Power Company (SEPCO): A private shareholding company that was established in 2004 and is entirely owned by the government. The company is tasked with producing power and selling it to NEPCO. The company's generating capacity is 1241 MW [26].

3. Solar resources potential in Jordan

The solar potential is determined by appropriate solar energy potential indicators, such as the direct normal irradiation (DNI), diffuse horizontal irradiation (DHI), global horizontal irradiation (GHI), the specific photovoltaic output (PV_{OUT}), and the seasonality index. The DNI is a term synonymous with "beam radiation" and refers to the amount of solar radiation from the direction of the sun, that is, radiation received by a surface normal to the sun [27,28]. DNI is a very important indicator for the energy yield and the performance assessment of concentrating solar power (CSP) and concentrator solar photovoltaic (CPV) technologies, and for determining the global irradiation received by tilted or sun-tracking photovoltaic modules [29,30]. The DHI is synonymous with "diffuse sky radiation" and refers to the radiation received by a horizontal plane from the sun after the direction of radiation has been altered by scattering, excluding circumsolar radiation [27,31]. High DHI values are produced by an unclear atmosphere or cloud reflections. GHI refers to the shortwave solar radiation received by a horizontal plane. It results from the combination of direct and diffuse radiation [27,29]. Although there is also a radiation component that is due to ground-reflected radiation, its effect is not significant. Hence, GHI is calculated as the sum of diffuse and horizontal components of direct radiation, as a mathematical approximation of the beam horizontal component as shown in Eq (1) [19]. The units for all irradiation indicators are usually J/m^2, MJ/m^2, or kWh/m^2, that is, incident energy per unit area on a surface. The incident energy is determined by integrating over a specific time, usually an hour or a day [31,32].

$$GHI = DHI + DNI \cos Z \qquad (1)$$

Z is the solar zenith angle. For this paper, all DNI and GHI values represent integrated daily totals averaged over a long-term period, measured in kWh/m^2/day.

Another indicator, which is a measure of photovoltaic power potential, is the specific PV_{OUT}, measured in kWh/kWp/day, meaning the photovoltaic electricity (AC) delivered by a PV system, normalized to 1 kWp of installed capacity. It represents the long-term yearly average of daily totals of potential electricity production from a 1 kW-peak grid-connected solar photovoltaic (PV) power plant, as described in [28]. Comparable definitions have been reported in [29], while additional support can be found in [30,31]. Apart from the aforementioned indicators that are related to solar energy potential and electricity production, another significant factor is the "seasonality index", defined as the ratio of the highest and the lowest average monthly PV_{OUT} values in an average year [28]. A high seasonality index reflects a country or region with a high seasonal variability in electricity production through photovoltaic modules. Low values of the seasonality index are desirable for stable solar energy exploitation. The values of selected indicators for Jordan are shown in Table 1 along with the world ranking of Jordan for each indicator.

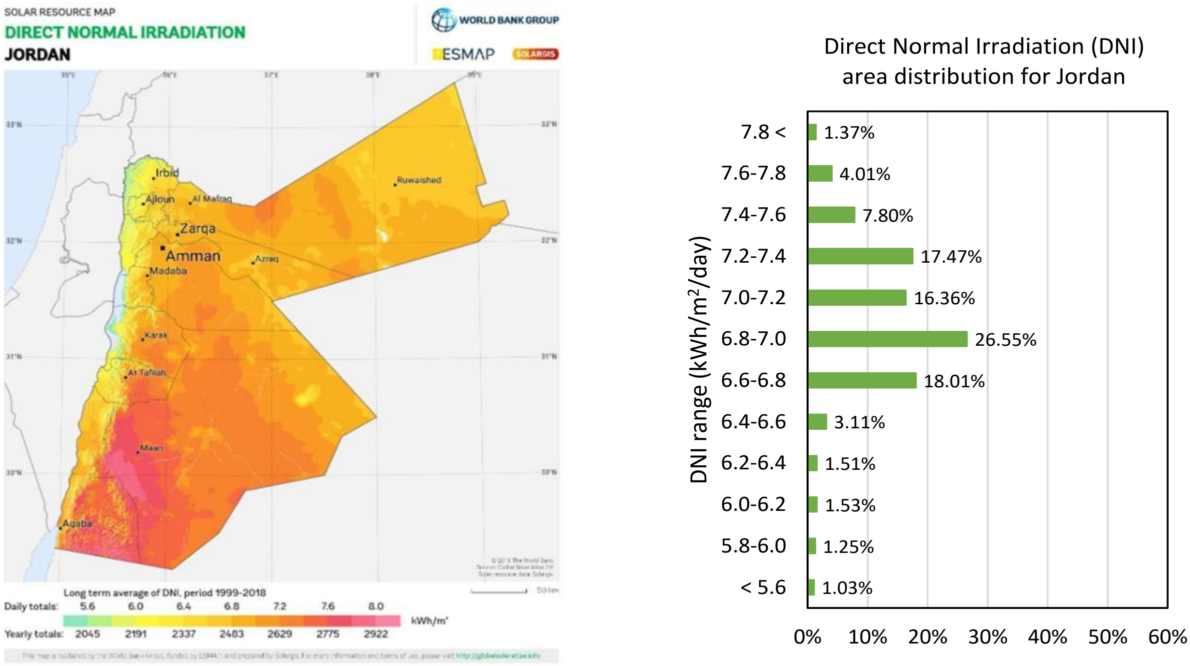
Table 1. Jordan world rankings in terms of GHI, specific PV_{OUT}, and seasonality index [33].

Indicator	World (209 countries)		Lowest	Jordan's world rank
	Highest	Lowest		
GHI ($kWh/m^2/day$)	6.47	2.53	6.02	19
PV_{OUT} (kWh/kWp/day)	5.38	2.51	5.32	3
Seasonality Index (-)	14.97	1.15	1.41	110

According to Table 1, Jordan ranks 19th among 209 countries in the world, with a GHI of 6.02 $kWh/m^2/day$, the highest being 6.47 $kWh/m^2/day$ for the Republic of Yemen and the lowest being 2.53 $kWh/m^2/day$ for Ireland [33]. However, Jordan ranks third in terms of PV_{OUT} with a value of 5.32 kWh/kWp/day, following Chile (5.36 kWh/kWp/day) and Namibia (5.38 kWh/kWp/day). The lowest value is that of Ireland (2.51 kWh/kWp/day). Although the seasonality index ranks Jordan in the 110th place, its value is 1.41, which is relatively low, considering that the lowest seasonality index is 1.15 (Haiti) and the highest is 14.97 (Norway). This indicates that the photovoltaic potential in Jordan varies by approximately 40% around the year.

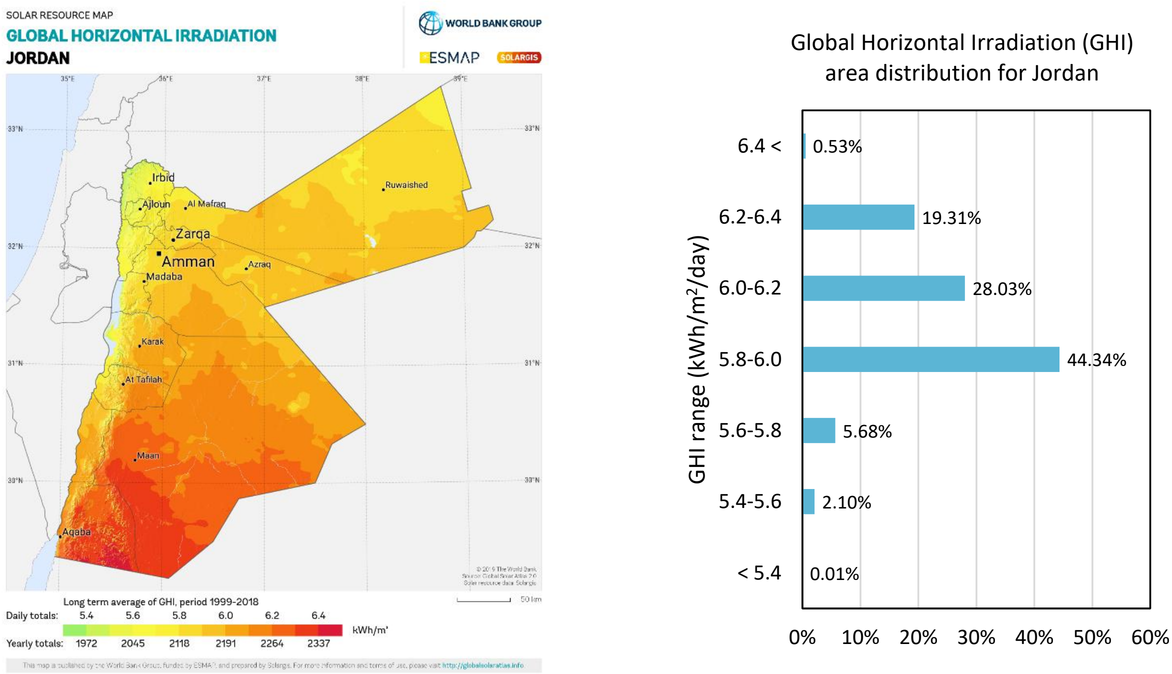
Moreover, Jordan boasts ample solar radiation, averaging between 5 and 7 kWh per square meter per day, with approximately 300 sunny days annually. Prime locations like Ma'an and Aqaba are particularly suitable for solar PV and CSP installations. The country currently hosts several large-scale solar projects, including the Baynouna Solar Project with a capacity of 200 MW and the Quweira Solar Plant generating 103 MW. Additionally, small-scale rooftop PV systems, backed by programs like Jordan Renewable Energy and Energy Efficiency Fund (JREEEF), make a significant contribution to the national grid.

In Figures 4–7, the geographical distribution of solar energy indicators is presented for Jordan. The DNI shown in Figure 4 ranges from 5.66 to 7.89 $kWh/m^2/day$ with an average of 7 $kWh/m^2/day$ [34]. More than half of the area presents DNI values between 6.8 and 7.4 $kWh/m^2/day$. Figure 5 shows the long-term averages of daily and yearly totals of GHI ($kWh/m^2/day$ or year). This indicator varies within the range 5.5–6.4 $kWh/m^2/day$ with an average value of 6.02 $kWh/m^2/day$. Approximately 70% of the area has a GHI value between 5.8 and 6.2 $kWh/m^2/day$. As seen in Figure 7, the optimum tilt angle (OPTA) for PV modules in Jordan ranges between 27° and 33°, with an average of 30°. This alignment is critical for maximizing yearly energy harvest. The practical potential for solar energy is best represented by the PV_{OUT} distribution, shown in Figure 6; nearly half of Jordan's land area offers a PV_{OUT} between 5.2 and 5.4 kWh/kWp/day. This translates to an expected annual yield of approximately 1898–1971 MWh per installed MW of capacity. Such high specific yields are a primary driver of Jordan's competitive levelized cost of electricity (LCOE), which has seen direct proposal bids as low as 0.03 USD/kWh—significantly lower than the average cost of electricity purchased by NEPCO (0.114 USD/kWh). From a strategic perspective, the regions in the south and east (e.g., Ma'an and Aqaba) that fall within the highest PV_{OUT} brackets are optimal for utility-scale deployment due to land availability and high yield. Conversely, the western highlands remain ideal for decentralized rooftop systems due to their proximity to major population centers like Amman, reducing transmission losses across an already strained and debt-laden national grid.



(a) (b)

Figure 4. (a) Long-term averages of daily and yearly totals of DNI in kWh/m^2 for Jordan [35]; (b) Area distribution of DNI (daily totals) for Jordan. Source [36].



(a) (b)

Figure 5. (a) Long-term averages of daily and yearly totals of GHI in kWh/m2 for Jordan [35]; (b) Area distribution of GHI (daily totals) for Jordan. Source [36].

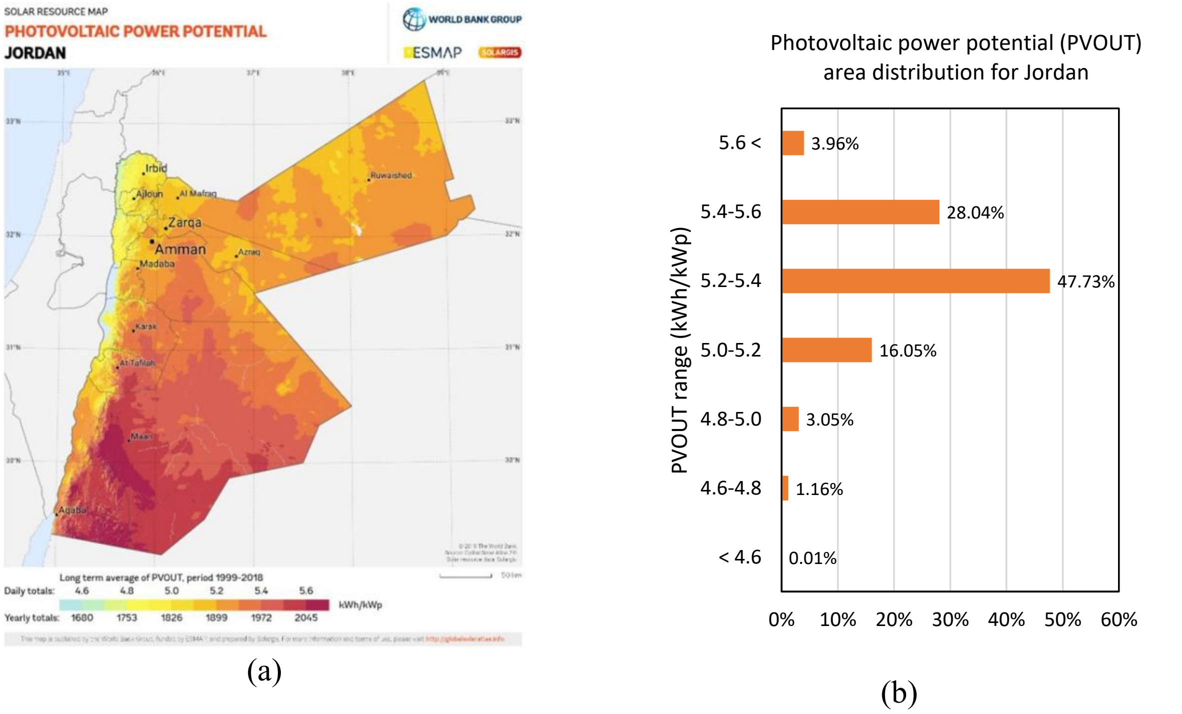


Figure 6. (a) Long-term averages of daily and yearly totals of photovoltaic power output (PV_{OUT}) in kWh/kWp/day for Jordan [35]; (b) Area distribution of PV_{OUT} (daily totals) for Jordan. Source [36].

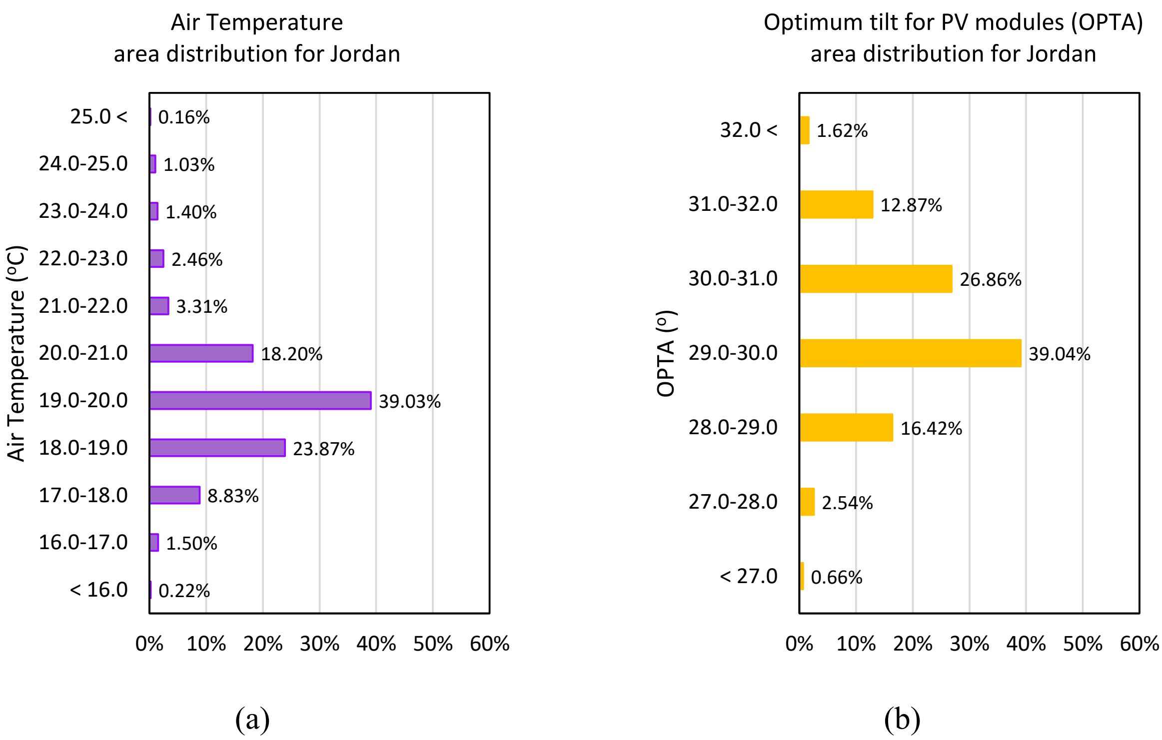


Figure 7. Jordan area distribution of (a) average temperature in °C at 2 m above ground and (b) OPTA for PV modules in degrees. Source [36].

4. Current state of solar energy in Jordan

4.1. Policies and regulations

Jordan is a Middle Eastern country that faces several energy-related challenges, including growing energy demand, dependence on fossil fuels, and the need to develop sustainable energy sources. The Jordanian government has undertaken various initiatives to address these challenges and promote energy sustainability. Jordan's energy strategy prioritizes renewable energy, aiming for 31% renewable power capacity and 14% of total energy from renewables by 2030. Recent commitments target 50% of electricity generation from renewables by 2030. The country has implemented various policies, such as proposal frameworks, net-metering, wheeling mechanisms, and energy auditing support, along with offering significant tax incentives and exemptions on renewable technologies, supported by the Jordan Renewable Energy and Energy Efficiency Fund.

The legal and institutional framework includes several key laws and regulatory bodies:

1. MEMR: MEMR is the main government body responsible for formulating and implementing energy policies. It has worked to promote energy efficiency, diversify energy production, and develop new energy projects. Also, the MEMR guides the Jordanian Solar sector development through strategic policies and planning decisions that shape market behavior and project deployment.

2. Energy Regulatory Authority (ERA): The ERA is the independent regulatory body responsible for monitoring and regulating the energy sector. The ERA plays a crucial role in approving energy tariffs and ensuring transparency and fairness in energy markets.

3. IRENA: IRENA is an intergovernmental organization that supports countries in their transition to a sustainable energy future and serves as the principal platform for international cooperation, a center of excellence, and a repository of policy, technology, resources, and financial knowledge on renewable energy.

The national strategies, laws, and action plans formed in Jordan for the solar sector are as follows:

1. Renewable Energy Law of 2012 [Renewable Energy and Energy Efficiency Law (REEEL)—Law No. 13 for the year (2012)]: This law was an important step toward promoting renewable energy in Jordan. It provided tax incentives, feed-in tariffs, and facilities for investment in renewable energy and in solar and wind energy. In Jordan, the expansion of distributed solar generation under net metering mechanisms led to technical and financial challenges for distribution companies, particularly in areas with high PV penetration. This situation contributed to regulatory revisions and updated interconnection rules aimed at preserving network stability and addressing cost-recovery concerns.

2. Jordan Energy Strategy (JES): JES is the strategic document edited by the MEMR to design the main objectives and strategies to improve the energy program of Jordan for the decade 2020–2030. It was developed and released in June 2020.

3. National Energy Efficiency Action Plan (NEEAP): NEEAP is a document adopted in Jordan in 2014 to promote the optimal use of energy in different economic and non-economic sectors.

4. JREEEF: JREEEF is a public fund created by Bylaw No. 49/2015 that helps farmers, households, industries, hotels, mosques, churches, schools, and communities to optimize their energy consumption and use more renewable energy.

Jordan has set clear energy goals to address energy challenges and promote sustainability:

1. Increasing renewable energy: Jordan has an ambitious goal to increase the share of renewable energy in its overall generation. This includes the implementation of large-scale solar and wind power projects. Moreover, these projects require huge funding, which is a critical issue in Jordan.

2. Reducing dependence on fossil fuels: The country aims to reduce its dependence on fossil fuels through the diversification of energy sources where possible. Moreover, new regulations for importing electric cars have been released to encourage the reduction of fossil fuels.

3. Energy efficiency: Promoting energy efficiency in various sectors, such as industrial, residential, and commercial, is a priority to reduce overall energy consumption. Additionally, many regulations related to building have been issued to encourage the green building culture.

Jordan has made significant progress in the development of solar and wind energy. Several key projects have been implemented in these areas. The 2012 Renewable Energy Law established feed-in tariffs for solar and wind energy, incentivizing investment in these sectors. It is worth mentioning that several bylaws and regulations have been released for the implementation of the REEEL:

1. Bylaw No. 50 of 2015 and its amendment in 2016 (conditions and procedures of the renewable energy direct proposal submission and connection to the grid).

2. Instructions for costs of connecting renewable energy sources to the distribution system in the cases of competitive bidding and direct proposals related to Article 9/B of the REEEL.

3. Instructions for the sale of electrical energy generated from renewable energy systems related to Article 10/B of the REEEL (net metering system).

4. Instructions governing electricity wheeling for energy generated from renewable energy sources, for consumption purposes and not for sale to others (electricity wheeling), and for wheeling charges (costs of the electricity wheeling).

5. Bylaw No. 49/2015 (JREEEF) defines the legal, financial, and administrative structure of JREEEF and the implementation mechanism for financing renewable energy and energy efficiency programs.

6. Bylaw No. 10 of 2013, amended in 2015, 2017, and 2018 (tax exemptions for renewable energy and energy efficiency systems and equipment).

7. Intermittent renewable resources distribution connection code at medium voltage.

8. Guidelines for interconnection of renewable energy sources on distribution and transmission grids, as well as on electric meters for net-metering applied to both distribution and transmission grids.

The Renewable Energy and Energy Efficiency Law of 2012 played an important role in accelerating the development of renewable energy in Jordan by enabling mechanisms such as direct proposals, net-metering schemes, and investment incentives. However, the rapid expansion of solar PV capacity has also exposed several structural challenges within the electricity sector. In some cases, renewable generation has grown faster than the technical and financial capacity of the national grid to absorb it, leading to curtailment measures and additional operational pressure on the NEPCO. These developments indicate that while the policy framework was successful in attracting investment and expanding the renewable energy market, its long-term effectiveness depends on parallel improvements in grid infrastructure, energy storage integration, and electricity market design. Another major challenge facing NEPCO is the increase in peak electricity demand while total annual electricity consumption remains relatively stable or grows only slowly. This imbalance places additional financial pressure on the utility, as it must maintain sufficient generation and grid capacity to meet peak demand despite limited growth in overall electricity sales. To address this issue, the electricity distribution companies have begun deploying smart meters to support the implementation of time-of-use tariffs, which aim to encourage consumers to shift electricity consumption away from peak periods and improve overall system efficiency.

As a result, recent regulatory updates and strategic initiatives have increasingly focused on aligning renewable energy expansion with grid stability and the financial sustainability of the electricity sector. One example is the updated renewable energy regulation introduced in the summer of 2024, which replaced the net-metering mechanism with a net-billing system. This change significantly increased the payback period for residential PV systems—from approximately three years to around seven years—thereby reducing the financial attractiveness of rooftop solar installations for households. In addition, the EMRC introduced monthly capacity fees based on the installed PV capacity (per kWp), a decision that has generated considerable public concern among homeowners who had already invested in solar systems. While these measures have been controversial, they were primarily intended to slow the rapid expansion of distributed PV and reduce pressure on the national electricity grid.

The Jordanian government has actively promoted energy efficiency across multiple sectors through awareness programs, financial incentives, and regulatory reforms aimed at improving energy management practices. In parallel, Jordan has collaborated with international organizations and development partners to secure funding and technical assistance for renewable energy and sustainability initiatives. While these partnerships have accelerated renewable energy deployment, they also reflect the country's continued reliance on external financing and expertise to support its energy transition. These partnerships have played a significant role in achieving the country's energy goals. It should be noted that the Middle East region faces unique challenges, including political tensions and instability. These factors can affect energy planning and energy supply security. Furthermore, the Middle East region's political tensions and economic instability introduce additional uncertainty into long-term energy planning and investment security. While Jordan's regulatory framework has created a relatively attractive environment for renewable energy investment, sustaining this progress requires addressing systemic constraints related to grid management, financial sustainability, and regional geopolitical risks. The energy regulations and policies adopted have created a favorable environment for investment in the energy sector, particularly in solar and wind energy. However, regional instability and other ongoing challenges require careful management to ensure a reliable and sustainable energy supply. Collaboration with international organizations has played a significant role in achieving the country's energy goals.

The status of renewable energy investments and development projects in Jordan as of 2020 has been previously documented; however, a deeper evaluation of the structural and regulatory factors shaping these investments remains necessary to fully understand their long-term sustainability [28,29]. In the year 2020, Jordan imported approximately 94% of the total fossil fuels from other countries for the internal national energy demand. This weakness exposed the national economy to fuel price variations, impacting different sectors of the economy. The national energy demand had been growing at an average rate of 3% per year (in alignment with countries with similar economies), which led the national government to set the goal of covering 10% of the energy demand from RERs. The main RERs in Jordan are solar, wind, and biomass energy, and they found that the contribution of clean energy in 2020 was not enough (7% of total energy demand).

Moreover, other similarly conducted analyses pointed out that the structural vulnerability and conflicts of the geographical and political region challenge the stability of the energy market and production means [37,38]. These studies concluded that Jordan's institutions and authorities must work to design new and advanced strategies toward a more sustainable energy sector in the next few years.

Additional research underscored that reducing reliance on energy imports is a critical strategic priority for minimizing Jordan's exposure to regional political volatility [39,40]. In this context, redefining the national energy mix through expanded deployment of renewable energy resources (RERs), particularly solar energy, is not merely an environmental objective but a strategic measure to enhance energy security. It was also concluded that the negative consequences of a regional conflict would have a reduced impact in the medium to long term if a rational and sustainable policy is adopted by the Jordan government.

In a recent publication, it was outlined that the Jordanian government is working on an energy policy aimed toward the attainment of sustainable development goals (SDGs) by leveraging technology to promote economic growth while preserving the environment [41]. However, while the expansion of renewable energy improves diversification, without parallel reforms in grid management, storage integration, and market design, energy security gains may remain structurally constrained. However, the current national discourse remains largely shaped by short-term economic concerns, particularly rising electricity costs and operational safety issues in conventional power generation facilities [42]. In addition, strategic analyses have proposed comprehensive action plans for renewable energy development in Jordan, offering structured pathways for implementation and coordination among stakeholders [43]. Nevertheless, the effectiveness of such plans ultimately depends on their integration with institutional reform, grid modernization, and long-term market restructuring. Without aligning technological advancement with market reform and inclusive governance, renewable energy expansion may remain technically successful but institutionally fragile [44].

In 2020, Jordan launched the Jordan Energy Strategy (JES) for the decade 2020–2030 [45]. This ambitious plan aims to ensure energy security, affordability, and sustainability, along with increased use of domestic energy resources and improvements to the energy mix in a relatively short time. While considering various scenarios for 2030, the plan has been conceived to promote the energy independence of the country and to reach the broader strategic objectives of diversifying the energy sources, boosting the use of domestic energy resources, increasing energy efficiency, reducing energy costs throughout the national economy, and continuing to develop the Jordanian energy system. One of the main goals is to increase energy production by renewable resources up to 31% of power generation share by 2030.

4.2. Installed capacity

Up to 2023, the total installed capacity of projects using renewable energy to produce electric power exceeded 2681 MW. Figure 8 shows the increased capacity over the years 2015–2023, while Figure 9 shows the main renewable energy projects that were established between 2015 and 2023; the vast majority of these projects are solar energy or wind energy projects.

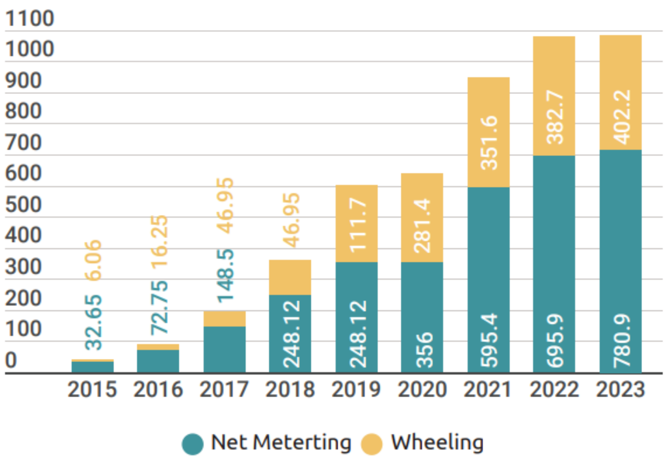


Figure 8. Added capacity for renewable energy systems with the purpose of covering the consumption of subscribers in Jordan during 2015–2023. Source [20].

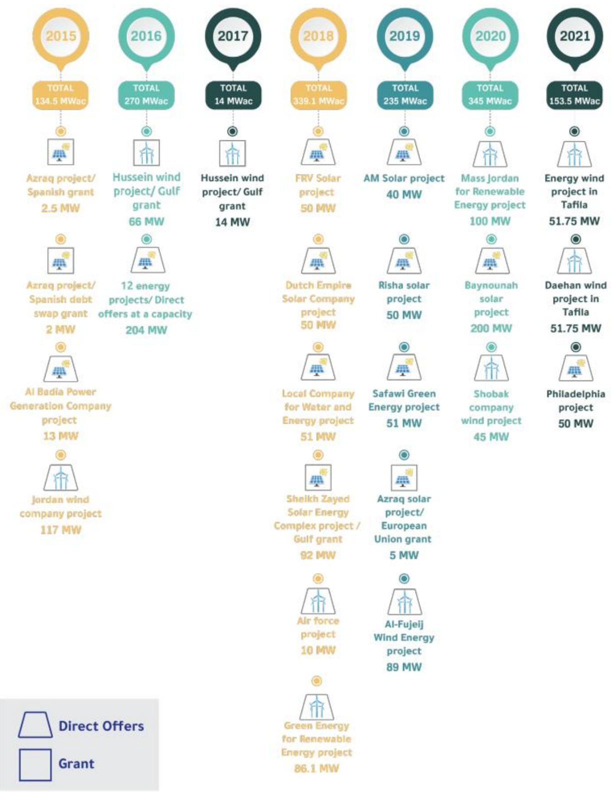


Figure 9. Electricity generation projects using renewable energy established in Jordan during the period 2015–2023. Source [20].

4.3. Investment and funding

Government support for solar energy in Jordan

Increase in solar energy capacity: Jordan has increased its renewable energy capacity to almost 2.7 GW as of 2023. This significant expansion is part of the country's strategy to reduce its reliance on imported fossil fuels [46].

1. JREEEF: The Jordanian Ministry of Energy's Renewable Energy Encouragement and Energy Efficiency Fund has completed the second phase of its support program for solar cell systems in households. This initiative indicates the government's commitment to promoting solar energy at the 12-household level, although the subsidy program was suspended after reaching the target number of beneficiaries and exhausting the allocated budget.

2. Investment in sustainable energy in public buildings: The government is also focusing on sustainable energy investment in public buildings, with national plans supporting this initiative.

3. Policies and International Agreements: Jordan has signed agreements with international organizations and foreign governments, such as a 2018 agreement with the IFC to support the development of a 200 MW solar project.

4. Large-scale and small-scale solar projects: The growth in solar energy in Jordan is supported by the development of utility-scale PV projects and grid-connected private investment. Jordan's recent large projects include the 200 MW Baynouna Solar Park (east of Amman) and the Risha PV IPP (~50 MW) in the Risha area [46]. In parallel, there is significant potential for small-scale solar installations such as rooftop systems; some reports suggest rooftop PV could contribute up to ~1.4 GW by 2030.

Private sector investment in solar energy in Jordan

Private sector investment in solar energy in Jordan has been significant and is a vital component of the country's shift toward renewable energy. Some of the more significant running initiatives are as follows:

1. Baynouna Solar Energy Project: The Baynouna Solar Energy Company, a joint venture between Abu Dhabi's clean energy company Masdar and Finnish investment and asset management group Taaleri, operates Jordan's largest clean energy project with 200 MW capacity. The Baynouna Solar Park, developed through a power purchase agreement between Masdar and NEPCO, Jordan's state electricity provider, produces over 560 GWh of power annually. This project plays a crucial role in contributing to Jordan's climate targets, providing clean energy access, creating jobs, and promoting economic growth [45].

2. International support: The project has garnered support from various international financial institutions, including the International Finance Corporation (IFC), the OPEC Fund for International Development, the KfW Group's DEG, and the Japan International Cooperation Agency. Masdar is active in more than 40 countries and has committed to investing in projects worth over $30 billion to expand its renewable energy capacity to at least 100 GW by 2030. Additionally, Masdar signed a preliminary agreement with the Jordanian MEMR to explore the development of a further 2 GW of renewable energy projects in Jordan [47].

3. Largest private-to-private solar project: The Climate Investment Funds (CIF), the European Bank for Reconstruction and Development (EBRD), and several multi-sector partners have financed Jordan's largest private-to-private solar facility. This facility is expected to produce 70 GWh of energy annually and reduce carbon emissions by 41,500 tons every year. Jordan's solar power capacity has seen a remarkable rise, jumping from around 20 MW in 2012 to over 1000 MW, with an additional 1.2 GW under construction or development [48].

4. Public-private partnerships (PPPs): Jordan has a history of using PPPs in the MENA region, financing key infrastructure, including renewable energy projects, through these partnerships. These

PPPs are an essential part of Jordan's Economic Modernization Vision 2023–2033, which aims to attract a total capital investment of 41.4 billion JD ($58.3 billion) and achieve annual economic growth of 5.6%. The government is aiming to catalyze new PPPS worth 10 billion JD, with the private sector expected to contribute 73% of the funds [49].

5. Institutional support and investment environment: To address challenges in PPPs, Jordan established the Project Preparation Development Facility with the help of the IFC. This facility aims to build government capacity for more informed decisions about PPPs and develop a pipeline of bankable projects. Additionally, in 2021, Jordan established a dedicated Ministry of Investment and introduced the Investment Environment Law.

4.4. Main challenges and barriers

Jordan's solar energy sector, while making significant strides, is confronted with several challenges and barriers:

1. High project costs and regulatory challenges:

The primary challenges in the development of renewable energy projects in Jordan include high project costs, primarily due to high taxes and extensive regulatory procedures required for new projects. These factors can deter investment and slow down the development of new renewable energy initiatives.

Jordan has largely eliminated import duties and VAT on renewable energy equipment by law [50]. As of late 2010s, customs and sales taxes on all solar panels, inverters, and related components were waived [50]. In the current regime, residual fees (such as grid "capacity" charges) effectively act like taxes on projects. An example is the commercial-sector grid fee of 13 JOD/kW-mo (~$18/kW-mo) [51], a cost that can add significant ongoing charges to large systems' economics.

Studies show that Jordan's licensing is slow and fragmented. In a 2025 survey, 68% of solar stakeholders cited "overlapping jurisdictions and inconsistent permitting" as major obstacles [52]. The same report notes that licensing approvals average ~6–9 months [52], reflecting coordination between MEMR, EMRC, and utilities. For smaller installations, anecdotal accounts report even longer delays (one industry source noted residential PV permits sometimes took up to ~18 months before reforms) [53].

Energy surplus and storage: One of the major challenges Jordan faces is managing an energy surplus generated from renewable sources, including solar. This issue underscores the need for high-technology storage solutions to effectively store energy produced from solar and wind sources. Without adequate storage capabilities, the sector cannot fully realize its potential. Figure 10 presents the demand electricity curve in Jordan for a typical day in spring (April 4, 2023). As seen from the figure, the maximum demand for electricity value at noon is less than 1500 MW, while the installed capacity of solar photovoltaic systems is more than 2000 MW. The share of renewable energy in the total energy mix is usually less than 50%, and this surplus of generated electricity from renewable energy forced EMRC to request solar energy power plants to disconnect their plants from the grid for several weeks in spring and autumn.

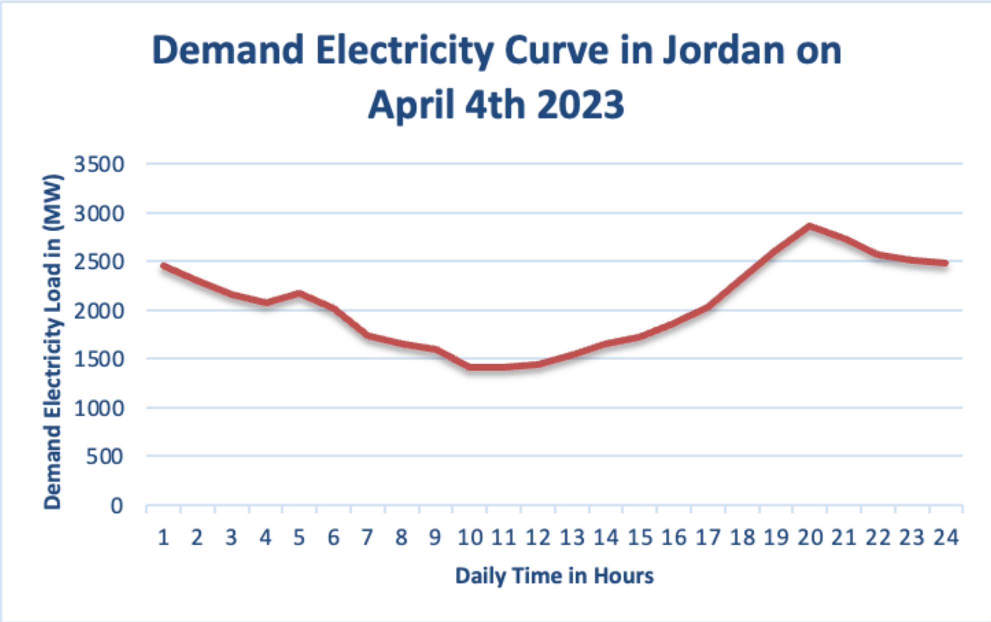


Figure 10. Demand electricity curve in Jordan for a typical day in spring.

2. Grid capacity and expansion struggles:

The Jordanian renewable energy network is facing struggles in its expansion due to several factors. In response to these challenges, Jordan has turned its focus toward private sector development. The private sector is expected to play a crucial role in delivering new projects across various domains, including renewable energy. This shift is part of the country's broader strategy to address energy needs amidst challenges like rapid population growth, water scarcity, and the impact of regional instability and major supply disruptions.

3. Limited technical capacity:

A final challenge that we will mention in this paper is the limited technical capacity in the country. While there are a number of experienced solar energy companies operating in Jordan, there is still a shortage of skilled professionals and technicians who can design, install, and maintain solar energy systems.

In the Jordanian context, the issue of technical capacity is associated less with the presence of solar service providers and more with the depth of specialized expertise required for advanced system design, grid-compliant integration, and long-term operation and maintenance (O&M). Despite the growth of the local solar market, sector analyses have pointed to constraints related to highly specialized engineering skills, particularly for large-scale projects, hybrid PV–storage configurations, and performance optimization over the system lifecycle. These challenges reflect the broader difficulty of aligning workforce specialization and technical training with the rapid expansion of renewable energy deployment.

The above review, therefore, shows that the expansion of renewable energy, especially solar PV in Jordan, has been supported by an effective policy environment, solar resource potential, and national energy security policies. In addition, this research shows that Jordan has scaled up their renewable energy sector, evidenced by installed capacities and a significant share of renewable energy in electricity generation, thus making it reasonable to argue that it is no longer in the pilot phase.

However, at the same time, the main challenges are no longer related to resource availability; instead, grid absorption capacity, administrative issues like procedures, taxes, and transaction costs, technical issues like technical capacity, and public acceptance for small-scale systems have become pertinent issues in the adoption of renewable energy, including solar PV, in the country.

Regarding grid operations, with increased solar PV, there is a need to ensure timescale flexibility, with issues like forecasting, coordination, sufficient operating reserves, storage, and enhanced practices, as well as sufficient grid infrastructure, becoming pertinent issues in grid operations, especially in high-potential regions. This explains why increased PV capacity does not necessarily mean increased renewable energy supply in the country.

4.5. Contested mega-projects and geopolitical setbacks

Although Jordan has progressed in utility-scale solar energy, its transition is characterized by considerable contentious projects and policy shortcomings that highlight the limitations of technocratic diplomacy. The 2021 UAE–Israel–Jordan Water-for-Energy Deal [54] (also referred to as Blue-Green Prosperity) is a prime example. This agreement involved the construction of a 600 MW solar facility in Jordan, which would export electricity to Israel in exchange for 200 million cubic meters of desalinated water. Despite its technical promise, the agreement unraveled within two years.

According to Abu-Zreig and Hussein (2025) [55], the project's failure shows how vulnerable resource-sharing agreements are when they try to depoliticize unstable environments while neglecting structural inequality and occupation. The agreement was met with strong popular and parliamentary resistance in Jordan since it was seen as strengthening a risky one-sided reliance on Israel for resources necessary for survival. Following the escalation of regional conflict and the subsequent breakdown of diplomatic trust, this domestic pressure, driven by a pro-Palestinian civil society, finally forced a withdrawal from the agreement in late 2023.

4.6. Future outlook of solar energy in Jordan

Table 2 shows the forecast for primary energy demand in Jordan for the period 2020–2030, and Table 3 shows the forecast of electricity generation for the same decade. Figure 11 shows the forecast as a ratio of renewable energy over the total energy and indicates that the renewable energy portion in Jordan will increase from 11% in 2020 to 14% in 2030. Figure 12 concentrates on electricity generation and shows that the generation of electricity from renewable energy sources will increase from 2400 MW in 2020 to 3200 MW in 2030, increasing its contribution in the total electricity generation from 21% to 31% (with the new 50% ambition mentioned previously).

The main assumptions used to predict future numbers are related to the following parameters:

1. The dependency of GDP growth on the current circumstances.
2. The renewable energy projects that are under construction.
3. The National Energy Efficiency Action Plan.
4. The estimated amount of oil that oil shale retorting projects will generate.
5. Increased Risha gas field's output.
6. Technical guidelines for power system operation based on the NEPCO's plans and agreements.

Table 2. Primary energy demand forecast for 2020–2030 in Jordan. Source [10].

Year	Primary energy demand (overall domestic consumption) (toe)
2020	10,039
2021	10,267
2022	10,420
2023	10,595
2024	10,668
2025	10,967
2030	11,760

Table 3. Electricity demand forecast for 2020–2030 in Jordan. Source [10].

Year	Electricity demand (GWh)
2020	17,672
2021	17,831
2022	17,860
2023	17,950
2024	17,958
2025	18,686
2030	19,701

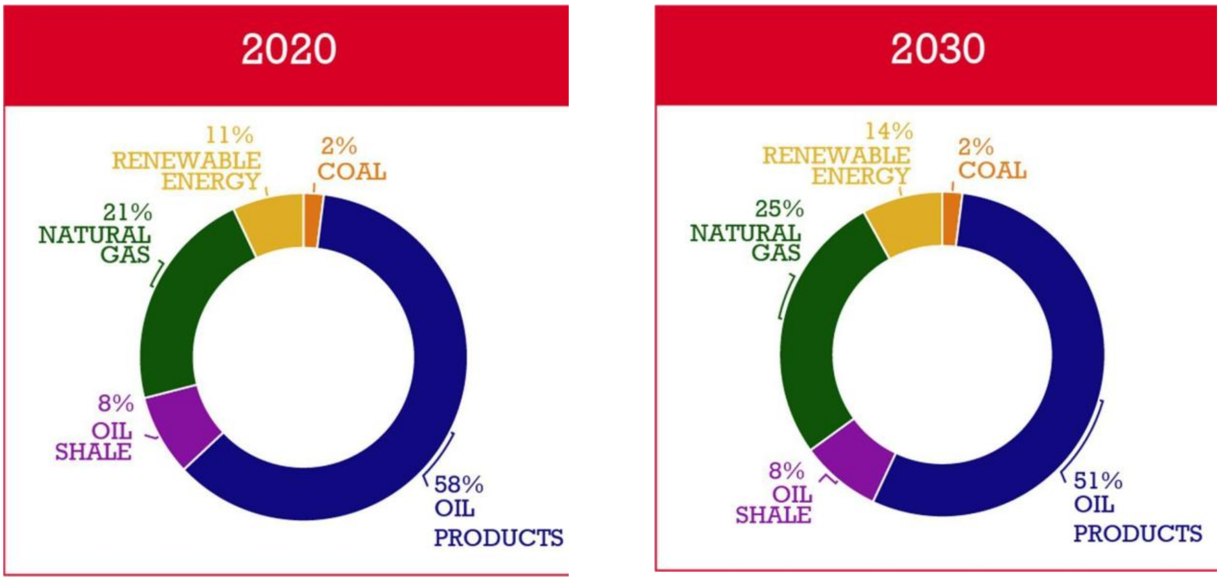


Figure 11. Ratio of fuel contribution to the total primary energy mix (2020–2030). Source [10].

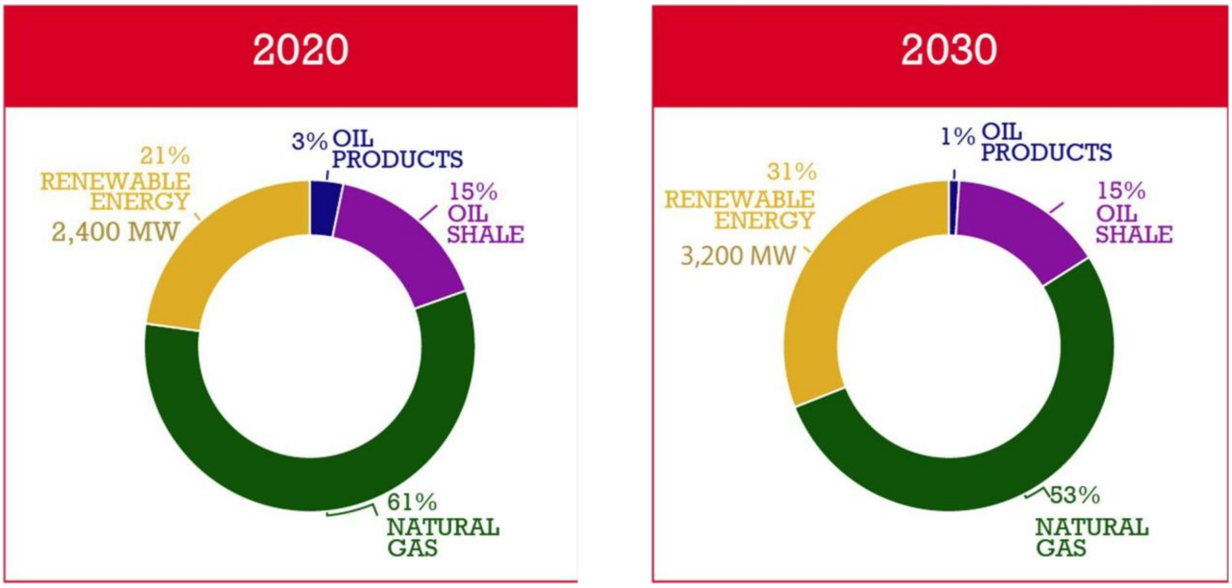


Figure 12. Ratio of fuel contribution to electricity generation (2020–2030). Source [10].

5. Conclusions

Currently, electricity generation relies heavily on fossil fuels, particularly natural gas. Only a quarter of the electricity generation mix is covered by renewable sources. Since the imported energy cost is high, it is important to further increase the renewable energy penetration in Jordan to achieve energy security and economic benefits. The geographic location and climate of Jordan place the country in third place worldwide in mean photovoltaic power potential and 19th in terms of GHI, with a favorable seasonal variability.

Jordan has set clear energy goals to address energy challenges and promote sustainability; namely, increase the share of renewables in energy generation, reduce fossil fuel dependence, and increase energy efficiency. The main challenges toward these goals are high renewable energy project costs, primarily due to high taxes and extensive regulatory procedures, managing the energy surplus generated from renewable sources, including solar, the grid's limited capacity to absorb renewable energy, the inherent intermittent nature of renewable energy sources, and challenges related to the storage of generated electricity.

To face these challenges, Jordan has turned its focus toward private sector development. The private sector is expected to play a crucial role in delivering new projects across various domains, including renewable energy. The 2012 Renewable Energy and Efficiency Law, along with its amendment in 2015, marked a significant shift in the development of renewables. In addition, a wide range of PPP modules and investment incentives have attracted international developers, leading to landmark projects such as the Baynouna Solar Park and other large-scale solar and wind initiatives. However, to do so, more investments are required, some policies need to be modified, and challenges must be addressed.

Notably, the JREEEF has played a key role in expanding solar energy use at the household level. However, continued funding will be essential to maintain and build on this progress.

Jordan's revised renewable energy targets aim to raise the share of electricity generated from renewables from 21% in 2020 to 31% by 2030, with some projections reaching as high as 50%. This growth is driven by ongoing projects, national energy efficiency programs, and technical plans developed by NEPCO.

Raising public awareness and strengthening technical skills remain critical, particularly as gaps in qualified labor and limited social acceptance continue to pose challenges for wider adoption. With the right mix of forward-looking policies, strong international partnerships, and increased investment in research and innovation, Jordan is well-placed to establish itself as a regional leader in the renewable energy sector.

Use of AI tools declaration

The authors declare they have not used Artificial Intelligence (AI) tools in the creation of this article.

Acknowledgments

This paper was supported by European Union's ERASMUS-2022 program for education, training, youth and sport, Project Number 101092041, project INNOMED (Boosting Innovative Solar Energy Technologies and Applications in Mediterranean Countries Education). INNOMED is a Project based on virtual classrooms, which aims at promote innovative technologies and applications of solar energy in MENA Countries. INNOMED is an Erasmus Plus Project funded by the European Union which brings together the University of Jordan, Cyprus, Morocco, Austria, Italy and Greece. The synergistic collaboration between the Project Partners is scheduled with a precise to do list of frequent online meetings and periodic face-to-face meetings which involve, every time, all the Countries that are part on the project.

Conflict of interest

All authors declare no conflicts of interest in this paper.

Author contributions

A. Al-Salaymeh: Conceptualization, Formal analysis, Investigation, Data Curation, Design and Implementation, Visualization, Writing—Original Draft, Writing—Review & Editing; in addition, Distribution the tasks between the co-authors.

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S. Qutishat: Formal analysis, Investigation, Visualization, Writing—Original Draft, Writing—Review & Editing.

N. Komninos: Conceptualization, Formal analysis, Investigation, Data Curation, Visualization, Writing—Original Draft, Writing—Review & Editing.

M. Hauer, G. Colangelo, A. A. Ardebili, A. Longo, M. P. Romano: Investigation, Writing—Original Draft, Writing—Review & Editing.

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