



Review article

Current status and future investment potential in renewable energy in Jordan: An overview

Ghaida Abu-Rumman^{a, **}, Adnan I. Khdair^{b, c, *}, Sawsan I. Khdair^d^a Department of Civil Engineering, Isra Private University, Amman 11622, Jordan^b Jordan University of Science and Technology, Mech. Eng. Dep., P.O.Box: 3030, Irbid 2011, Jordan^c King Abdulaziz University, Mech. Eng. Dep., P.O.Box: 80204, Jeddah 21589, Saudi Arabia^d Faculty of Pharmacy, Al-Zaytoonah Private University of Jordan, Amman 11733, Jordan

ARTICLE INFO

Keywords:

Energy
 Energy economics
 Renewable energy resources
 Energy sustainability
 Energy use in building
 Renewable energy
 Wind energy
 Solar energy
 Investments
 Jordan

ABSTRACT

Jordan imports 94% of its oil and gas (fossil fuels) to meet its energy needs, leaving it vulnerable to variations in fuel price. Jordan's demand for energy is growing at a rate of 3% annually. In response, the government set a target of obtaining 10% of its energy needs from renewable energy resources by increasing electricity generation share from the present 1.13 GW–1.8 GW by 2020. The sources of generation include abundant solar, wind, and biomass resources, which also enhance economic growth and reduce pollution. This article analyzed the current energy situation in Jordan and assessed the available renewable energy resources potential for direct investments. The actual contribution of clean energy is still moderate at roughly 7% of total energy demand, despite the efforts placed on the development of alternative energy resources. The national electricity supply and demand are presented, and the government initiatives, financial incentives, and tax exemptions to encourage investments in clean energy are also discussed. The renewable energy policy generates future opportunities for investors with an ambitious \$20 billion energy plans as does its strategy to improve energy efficiency. This article will benefit interested clean energy investors and developers and plans for 2,000 MW investments in wind and solar energy are ready for bidders. Such an endeavor and model will also benefit neighboring countries in the region.

1. Introduction

Energy is necessary for economic growth, social development, and improved quality of life worldwide [1]. Energy consumption grows roughly at a rate of 1% and 5% per year in developed countries and developing countries, respectively [2]. Fluctuating oil prices put pressure on the world's economy, making the search for alternative clean energy sources a priority for many developed nations. Shifting those countries' current environmental and energy policies towards the development and implementation of environmentally friendly renewable energy technologies at affordable prices [3]. In 2015, renewable energy accounted for 19% of global total energy demand [4, 5]. This transition to renewable energy worldwide came from a critical international turning point concerning climate change with the adoption of The Kyoto Protocol in December 1997. A landmark agreement was reached in Paris in 2016 to combat climate change within the United Nations Framework of climate change (UNFCCC). The long-term objective of the Paris Agreement's is to

keep the global temperature increases well below 2 °C by accelerating and intensifying the actions and investments needed for a sustainable low carbon future. As of November 2019, 195 members of UNFCCC have signed the agreement [6].

In 2018, Jordan imported 94% of its energy needs, which constitute nearly 10% of the country's gross domestic product (GDP) [6], leaving it vulnerable to variations in fuel prices. Jordan's power demand is also growing in part due to the flux of 750,000 Syrian refugees entering the country over the last seven years. As such, Jordan's government set a target of 10% of energy needs are to be met from renewable energy resources, mainly by increasing renewables electricity generation share from the present 1.13 GW–1.8 GW by 2020 [6,7,8]. These renewable sources include solar, wind, and biomass, which supports the 10% target while promoting economic growth and reducing air pollution [9, 10, 11, 12, 13].

The adoption of clean energy technology in Jordan has been tremendously successful due in part to generous financial incentives,

* Corresponding author.

** Corresponding author.

E-mail addresses: ghaida.rumman@iu.edu.jo (G. Abu-Rumman), akhdair@just.edu.jo, akhdair@kau.edu.sa (A.I. Khdair).

taxes and customs exemptions, and technical and financial assistance from foreign aids and international agencies. Jordan's political and economic stability also establishes it as a potential clean energy hub in the Middle East, with the country boasting several success stories in executing renewable energy projects, which will be discussed in this study.

Jordan has capitalized on the cumulative scientific knowledge and technical experience concerning renewable energies to increase awareness among the population. Providing the country with the qualifications to lead, with confidence, the adoption of renewable energy technologies through joint ventures between local partners and foreign investors. The present paper analyzes the current energy situation in Jordan and reviews available renewable energy resources for potential investment in light of government initiatives to increase renewable energy share in the national energy matrix. This paper also reflects on successful stories in renewable energy implementation and development in Jordan and how government policy, tax exemption, and financial incentives promote a clean energy transition.

2. Energy situations in Jordan

Jordan's power demand is growing from two perspectives, economic growth in several sectors and the increasing number of refugees from neighboring countries fleeing regional instability. In 2015, the national energy cost accounted for 20% of the country's budget but was reduced to 10% in 2018 due to the adaption of energy efficiency measures and increasing the contribution of renewable energy to the national power mix [6]. Jordan adopted its National Energy Efficiency Action Plans (NEEAPs) in 2012 and plans to reach a 20% cut of main energy consumption by 2020 [14].

2.1. Energy data

Jordan faces two significant challenges in its energy sector, the rising energy demand, and limited domestic resources to meet the country's needs. For example, in 2018, the local energy production was 790 ktoe, mainly from natural gas, renewable energy, and to a lesser extent crude oil (this represent 7.8% of 9,712 ktoe of the national energy need) [6]. The primary energy sources for Jordan in 2018 are shown in Figure 1. Imported oil and natural gas comprise the largest share at 87% of the total energy need (9,712 ktoe), while domestic resources account for 7.8% of energy supply, including the 7% obtained from renewable energy [6].

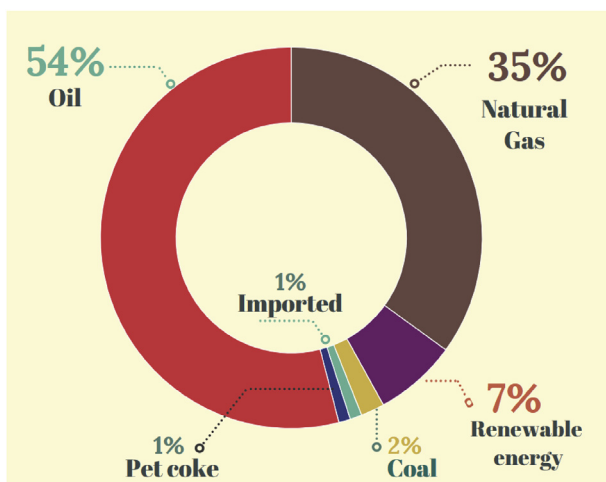


Figure 1. Structure of primary energy sources in Jordan in 2018 (9,712 ktoe) [6].

Jordan's electricity demands are rising fast and paving the road to attract overseas investments, providing the capital and additional capacity to meet the growing demand. In 2018, electricity generation was 5,236.4 MW and is anticipated to reach 5,770 MW by 2020, thus the introduction of reliable and clean energy alternatives is essential for the country's socio-economic development [6].

2.2. Energy consumption

The shares of energy consumption by major sectors are shown in Figure 2. Transportation consumed 49% of the national energy demands, followed by residential needs at 21.5% (lighting, cooling, and heating), the industrial sector consumed 14%, and the remaining 15.5%, which includes agriculture and forestry. The government gradually eliminated all fuel subsidies by 2012 [15], and the electricity subsidies were eliminated in 2017 [14,15].

2.3. Energy import

The country's limited national resources forced Jordan to import 8,922 ktoe of energy to meet its domestic demands in 2018, which cost 10% of the national GDP [6]. Egypt was the leading supplier of natural gas with its competitive prices. Unfortunately, this supply has been disrupted, which caused severe energy security threats in Jordan. As a result, Jordan started seeking secure alternatives to energies due to the unstable political situation in the region. This will provide the country with financial leverage for obtaining an affordable gas supply from multiple sources, however the political price is still unclear.

3. Renewable energy resources in Jordan

High refugee influx, growing commercial and industrial sectors, and increasing imported fuel costs and the associated GHG emissions have made a clean, sustainable, and affordable energy supply a priority for the country's decision-makers. Implementation of energy efficiency measures and tracking renewable energy advancements has become the government's main focus. In 2012, the government approved the Renewable Energy (RE) and Energy Efficiency (EE) Law (REEL) No. 13 to meet its renewable energy plans [16, 17]. The law includes energy management and efficiency measures in the services and industrial sectors - the major energy consumers. The government is also taking extra measures to facilitate the licensing of renewable energy projects by establishing a "one-stop-shop" office at Jordan Investment Commission [18] to attract new investments.

Energy security and the increasing cost of imported energy pushed the government to draft a National Energy Strategy Plan for the years 2007–2020. Renewable energy became the main concern under this plan, with the government seeking an ambitious \$ 20 billion investment in energy development by 2020 [18]. The initiatives consist of oil shale use, renewable energy, and nuclear power plants, though nuclear energy recently ceased following public pressure and financial shortages [19].

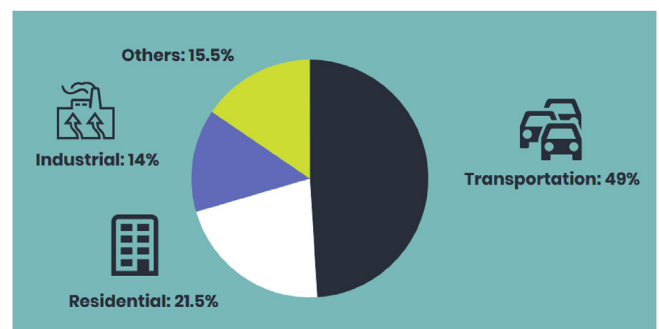


Figure 2. Jordan's national energy consumption by sector in 2018 [6].

Under this strategy, the power supply from renewable energy sources will increase from current measures of 7% in 2018 up to 10% by 2020.

The National Energy Strategy Plan seeks to produce 2,000 MW from direct investment in wind and solar energy by 2020. As a result, a wind plant began operating in Al-Tafileh (starting in 2015) with a capacity of 117 MW, and a 200 MW solar plant in Ma'an completed in 2016 [6]. Wind and solar energy are promising renewable energy resources for electricity generation in the country [8, 10, 12, 20].

As a result, Jordan has ranked first in the Middle East and North Africa (MENA) region in renewable energy adoption and clean energy growth and ranked third globally, according to a Bloomberg report in 2017 [21]. The report, which was based on growth in the market of renewable and clean energy in Jordan and included policies and legislation related to investment. It also analyzed the achieved and expected volume of investment in the country and the impact of these investments on greenhouse gas and mitigation carbon emissions. Continuous tracking of technical advances in renewable industries and the implementation of pilot and demonstration plants have been Jordan's trademark while pursuing clean energy utilization.

Further, to promote the investment in renewable energy projects and secure investors, the electricity regulatory commission published with full transparency, the "Reference Price List" The investors now can evaluate their project's feasibility and future revenue with minimum risk, which promote the investments in RE. The "Reference Price List" shows the suggested prices (Tariff) for generated power from different renewable energy sources, as shown in Table 1.

Investors can use the "Reference Price List" as the Feed-in Tariff to evaluate their proposal investment in the RE sources. The developers can bid under this upper limit, considering that there is an extra 15% tariff that will be awarded if the winning bidder installs a fully local renewable energy supply. This will encourage technology transfer and boost the renewable energy industries in the country.

The National Electricity Power Company (NEPCO), as a representative of the Jordanian Government, signed twelve Power Purchase Agreements (PPAs) with developers to provide 200 MW of solar power energy to the national grid under direct proposal submission [6]. Phase II of direct proposal submission has been issued by the Ministry of Energy and Mineral Resources (MEMR) to promote foreign investments in renewable resources to generate an additional 650 MW of wind and solar energy. In the second phase, thirteen investors will be selected to produce 50 MW for each developer. Initially, financial proposals from twenty-three companies were submitted to the MEMR for evaluation and negotiation. A summary of available renewable energy resources and their potential for further development and direct investment in the country are presented in the next sections (3.1, 3.2, 3.3, 3.4, 3.5).

3.1. Wind energy

Jordan possesses several locations suitable for wind power generation [10, 11, 20]. The first commercial plant started in 1996 in Hofa, located in the northern part of the country and funded by the German Eldorado program, has a generation capacity of 1.125 MW. The second wind energy plant was constructed in 1998 in Ibrahimyya, close to Hofa. This plant was a pilot project, supported by a Dutch corporation, and boasts a capacity of 320 kW. In 2017, the electricity generated by both plants reached 3 GWh [15]. Many regions in the northwestern and southern

parts of the country are suitable for electricity generation with wind speed ranging from 7 m/s to 11 m/s. Thanks to Danish RISO research center, a Wind Atlas, which has been available since 1989 [23], is updated regularly with support from Jordanian agencies to provide the most recent data measurement.

Wind-generated energy is projected to compromise a significant share of the country's electricity generation. This transition started in 2013 with the finalization of an agreement between international companies and a Jordanian consortium to build a windmill (117 MW) in Tafila, south of the country. The project was commissioned in the second half of 2015 and expected to increase the country's power generation by 4% [6]. Another contract has been signed with the Spanish company Elecnor based on an EPC (Engineering, Procurement, and Construction) basis. This wind farm located in Ma'an, a city in the southeast of Jordan, produces 66 MW and was connected to the national grid in 2016 [6]. Along with Masdar's 117 MW Tafila wind farm, the plant will advance Jordan's target of producing 15% of its domestic electricity needs from renewable sources. Combined, the two projects will account for nearly 18% of the 1.8 GW of renewable, or 20% of the energy mix, that Jordan plans to reach by 2020. Currently, four wind projects are finalizing their Power Purchase Agreements (PPAs) with a combined capacity of 230 MW. Jordan is expected to generate 600–1000 MW from windmills between 2019–2021 [6]. This include the Al-Rajef project (82 MW), Shobak project (45 MW), Al-Fajeej Project (89 MW), Mas project (100 MW), Daihan project (51 MW), El-Abour project (51 MW) and an additional 100 MW from a third round of direct offers 2020–2021 [6].

3.2. Solar energy

Jordan is blessed with a 5 to 7 kWh/m² direct solar radiation intensity and averages 310 sunny days annually [22]. The annual daily average of global solar irradiance on a horizontal surface is around 5.6 kWh/m² day and the total annual irradiance is between 1800–2700 kWh/m². The government plans to obtain 800 MW from solar energy by 2020. After the issuing of the Renewable Energy Law in 2012, an estimated of 236.4 MW PV has been generated in the country [6]. Currently, there are more than 300 registered installation companies in the country, with approximately 20 companies active in the market. Twelve direct PPAs proposals were signed in 2015 to construct and produce 200 MW, all located within Ma'an Development Area. Another 75–100 MW PV plant under assessment in the Quweirah region (Aqaba) is funded by the Gulf Corporation Council Fund (GCCF) [6].

Electricity generation capacity from stand-alone PV systems has a peak capacity of 1000 kW in remote villages and rural and desert areas, where PV is used to pump water, light homes, and support other community activities. Around 20% of all households have their solar water heating systems on their roofs [22]. According to the Energy Master Plan, it is expected that 30 % of all households will install a solar water heating system by 2020 [22]. The first concentrated solar power (CSP) plant and first solar desalination plant will be installed in Aqaba soon with a capacity of 300–600 MW consisting of hybrid systems of CSP and PV in 2020 according to the national strategy plan [22].

The company, First Solar, signed a PPA with Jordan's electrical company for 20 years to manage 52.5 MW Shams Ma'an PV solar plants starting from 2016 [22]. Additional 400 MW plants (2 × 200 MW tender rounds) are under assessment [22]. In October 2016, Masdar, a UAE based company, signed a PPA to build Jordan's largest solar power plant (200 MW) to date. It is estimated that the plant, called Baynouna, will supply 110,000 households in the south of the country with their annual electricity needs by the end of 2018 [22].

Approximately 1.40 km² of solar water heaters panels were installed on building roofs and 150 kWh of installed PV [24]. Most of these panels are fabricated locally by 25 smalls solar water heaters enterprises, which assemble around 4500 solar water heaters every year [24]. Approximately 30% of residential buildings are equipped with solar water heating systems.

Table 1. Reference price list (Tariff) from renewable energy sources [22].

Resource	Cents/kWh
Thermal Solar Energy (CSP)	20
PV	15
Biomass	13
Wind Energy	11
Biogas	9

Future plans consist of hybrid CSPs with a total capacity of 100–250 MW and three windmills with a capacity of 125–150 MW. Sixty percent of the wind turbine parts are expected to be fabricated by local wind turbine manufacturers [24]. At the same time, many investors are looking to manufacture photovoltaic and CSP parts in Jordan, thanks to generous taxes and customs exemptions, and solid industrial infrastructure, such domestic production is possible. All combined, this makes Jordan a regional hub for renewable energy resources training, capacity building, and technology transfer.

3.3. Hydropower

Jordan lacks flowing water bodies suitable for the construction of large-scale hydro-electric power plants. Only two small scale hydro plants are operational, with one plant having a capacity of 5 MW (King Talal Dam). The second hydro-electric power plant uses a turbine to take advantage of the waters drawn from the Gulf of Aqaba for cooling a thermal power plant. In 2018, the two plants generated 60 GWh of electricity accounting for 0.4% of the electricity generated in Jordan [6]. In the near future, the Red-Dead sea canal (400–800 MW) will be started after signing a final peace agreement in the region, which requires an estimated three billion dollars investment [6, 24].

3.4. Biogas and biomass

With the assistance of the United Nations Development Program (UNDP), a plant has been built at Amman municipal dump site to capture and utilize the methane gas produced as a result of organic waste decomposition using a 1-MW electricity generator. The facility is run by a joint venture between Jordan Biogas Company and the Greater Amman Municipality. Since 2000, the plant generates 5 GWh of electricity annually [25]. Some researchers recommended further development and promotion of biogas systems in rural areas especially for poultry and livestock farms in Jordan [26, 27].

Biomass energy from agriculture waste, animal manure, urban wastes, and organic industrial wastes (e.g., olive mill pomace) shows substantial promise. The rapid scientific and technological progress in waste handling and management makes this waste-to-energy principle attractive. Unfortunately, due to the semi-arid climate, vegetation covers less than 5% of the land; this limits the potential use of horticulture biomass in energy generation on an economical scale. Vegetable biomass, mainly from trees pruning and olive oil pressing industries, is used for cooking and heating in the countryside by direct combustion. On the other hand, huge energy potential can be obtained from household garbage, which has an organic matter content of 60% [25, 27]. Based on daily waste generation estimates of 0.35–0.95 kg per capita, municipal solid waste is expected to total 1.1 million tons annually. Projections place municipal solid waste and cattle/poultry farming energy potential at up to 60 MW, in addition to small scale heating/cooling systems [25].

3.5. Geothermal energy

Geothermal resources in Jordan are located along the east bank of Jordan River in the Dead Sea rift valley and to the east of Madaba as hot mineral water. These locations provide low temperatures of hot water (below 100 °C), though too small to be used for electricity generation, the hot mineral water is used recreationally for physical therapy and heating swimming pools [24].

4. Electricity

4.1. Generation capacity

In 2018, Jordan's installed power station capacity increased to 5,236.4 MW from 3,312 MW in 2012 [15]. The generation capacity from different generation sources (2012–2018) are listed in Table 2.

Most of the country's power stations are state-owned; however, large industrial enterprises, such as potassium, phosphate, and cement companies generate their electricity via company-owned power plants. The amount of generated electricity is insufficient to meet Jordan's demands, and additional energy needs were previously supplied by Syria and Egypt. Unfortunately, due to the political unrest in the region, supply from Syria ceased in 2012 and has been heavily reduced from Egypt [6, 14].

Figure 3 shows electric power generation according to source in 2018. Natural gas share was 55% of the energy input in power plants, 11% from Heavy Fuel Oil (HFO), 15% from Diesel Fuel (DF), and the renewable energy representing its largest share for the first time at 19%. The generation of electricity from steam power plants at Al-Hussein Thermal Power Plant in Zarqa decreased over the past few years and stopped recently due to the end of its operational life.

4.2. Major stakeholders in the energy sector

The long terms objectives and political framework initiatives for energy market expansion are set by state authorities represented by the Ministry of Energy and Mineral Resources (MEMR). Its mission is to ensure adequate energy supply to assist in the country's continual development at a high standard and promote economic growth [6]. The MEMR faces a dilemma to catch up with cutting edge technology while minimizing spending. As such, the ministry welcomes foreign investors interested in power generation and development from locally available resources including, renewable resources, shale oil, and gas and oil search.

The total generation capacity of the Jordanian power system for 2018 was 5,236 MW, up from 4,143 MW in 2015, with an annual growth rate of 3.5%. Eight major players in the electricity generators sector are active in Jordan and generated 19,753 GWh in 2018 [15], these players are:

- 1 The Central Electricity Generating Company (CEGCO), which generated 1,833 GWh, around 9.28% of the electricity generated in 2018.
- 2 The Samra Electric Power Generation Company (SEPGCO) (mainly from natural gas at Al-Risha), contributed by 7,710 GWh or 39.03% of the electricity generated in 2018.
- 3 Independent Power Producers (IPP1) (AES Jordan), which generated 2,794 GWh (14.27%)
- 4 IPP2 Al-Qatraneh Power Generation Company (QEPCO), which generated 2,754 GWh (14.07%) [13].
- 5 IPP4 AES Levant contributed 764.5 GWh (3.87%). IPP1, IPP2, and IPP4 each have an annual capacity of 380 MW [15]. All plants are in the Amman eastern area.
- 6 IPP3 Amman Asia East Generation Company in (Al-Manakher) area (AAEPCO) contributed 499.3 GWh (2.53%),
- 7 Zarqa Power Station (ACWA) contributed by 1,218 GWh (6.17%).
- 8 Solar Energy generated 1440 GWh (7.29%).

The renewable energy sector contributed 19% of the total production capacity, which exceeded the target set by the government of 7% for 2018. Table 3 (below) summarizes the amount of energy (GWh) generated and in Jordan from 2016 to 2018.

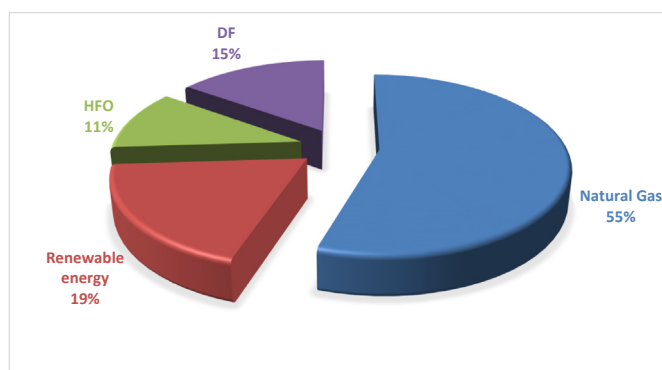
4.3. Other energy projects

4.3.1. Oil shale

The generation of electricity from the direct burning of oil shale is considered the most secure energy project in Jordan, due to its substantial local availability as an energy resource in many regions of the country, with an estimated reserve of 70 billion tons [22]. Based on this availability, many companies have shown interest in investing in the construction of a generation station based on direct shale oil burning technology and selling the generated electricity to the National Electric Power Company (NEPCO).

Table 2. Generation growth (in MW) by source 2012–2018 [15].

Generation Source	2012	2013	2014	2015	2016	2017	2018
Steam	925	787	787	787	605	605	605
Gas turbine (N. Gas)	499	618	618	332	307	228	83
Gas turbine (Diesel)	134	27	27	27	27	-	-
Combined cycle	1,737	1,737	1,614	2,044	2,044	2,044	2,740
Diesel/(HFO + N. Gas)	-	-	814	814	814	814	814
Hydro	12	12	12	12	12	12	12
Wind	1.4	1.44	1.44	118.4	198.4	198.4	280.4
Biogas	3.5	3.5	3.5	3.5	3.5	3.5	3.5
Solar	-	-	-	5	285.5	395.5	698.5
Total	3,312	3,186	3,876.9	4,142.9	4,269.4	4300.4	5,236.4

**Figure 3.** Electrical power generation according to source in 2018 [15].

The Atarat Power Company, on March 16, 2017, reached the financial close for the first project of its kind to exploit the oil shale ore [15]. This project includes constructing an electricity generation station in the Atarat Um Al-Ghodran region in the center of Jordan, with a generating capacity of (470) MW, roughly (9%) of the total electricity generated in Jordan in 2018. The project will be implemented in two stages; the first

stage will start work after 38 months from the financial closure, and the second stage will start after 42 months. The total investment of this project is around 2.1 billion US dollars, of which 10% is shared by the Estonian company and 45% each for the Malaysia Company, YTL, and the Chinese company, UDN.

4.3.2. Nuclear energy

In 2016, three bids were awarded for conducting the necessary technical and financial studies required for implementing a nuclear plant [15]. These studies included:

- A feasibility study for the project.
- An assessment of the national grid capacity to assimilate the energy production from this station, and
- The needs of the local market of the produced electrical energy from the reactor and export potential.

Project construction in Al-Azraq area (Amrah) was expected to begin in 2018, following the completion of the above required studies. If approved, the implementation of the project would have reached the operational stage (the first reactor) in the year 2025, with a generating capacity of (1000) MW. The nuclear energy authority launched an extensive media campaign over the past five years to get public support

Table 3. Generated and imported electrical energy (GWh) in Jordan 2016–2018 [6,15].

	2016	2017	2018	(%)
1. Electricity Sector	19,101.9	20,053.60	19,753.40	(1.60)
GEGCO	4260.40	4332.30	1,833.60	(57.70)
SEPGCO	7194.40	7643.20	7,710.20	0.90
AES Jordan PSC (IPP1)	3163.00	2626.20	2,794.40	6.40
QEPCO (IPP2)	2880.60	3033.20	2,754.50	(9.2)
AAEPCO (IPP3)	262.80	288.10	499.30	73.30
AES Levant (IPP4)	509.00	767.20	764.50	(0.40)
Zarqa Power Station (ACWA)	-	-	1,218.40	-
Wind Energy	387.50	447.60	719.80	60.80
Solar Energy	421.40	894.70	1,440.70	161.03
King Talal Dam	18.70	17.00	14.10	(17.10)
Jordan Biogas Company	4.10	4.10	3.40	(17.10)
2. Industrial Sector	558.60	706.10	748.40	6.00
Potash Co.	222.00	354.10	339.70	(4.10)
Indo-Jord Chemicals Co.	46.30	76.20	86.50	13.50
Refinery	84.10	79.30	8.13	2.50
Fertilizer Co.	51.20	45.30	81.00	78.80
Qatrana Cement Co.	155.00	151.20	160.00	5.80
3. Imported Energy	333.80	51.30	188.30	(267.10)
Energy from Egypt	333.80	51.30	188.30	(267.10)
Total	19,994.30	20,811.00	20,690.20	(0.60)

() Decrease.

for the nuclear reactor but failed to obtain parliament approval under public pressure in addition to financial constraint and technical issues, which stopped the nuclear power plant project [19].

4.3.3. Coal

MEMR signed an agreement to construct a generation station using coal and petroleum coal in Al-Qatrana region with a capacity of 30 MW. This will be the first-generation station fuel by coal in Jordan if the environmental impact assessment studies of the station are approved by the Ministry of Environment (MoE) [22].

4.3.4. Al-Zarqa electric power generating project

The power company (ACWA) is currently working on rehabilitating the Al-Hussein Thermal Power Plant by constructing a new power generation plant to replace the out of service steam power plant, which had reached the end of its operational life. The generating capacity of the new plant is projected to be 485 MW. The plant will be run by natural gas as a base fuel and diesel oil as an alternative fuel. The project was completed by the end of 2017 and generated 1,218.40 GWh in 2018 [15].

4.4. Consumption

Overall consumption in Jordan has increased steadily by 4–5% annually over the past few years across all sectors (see Table 4). Electricity consumption in 2018 reached 17,439 GWh with a peak load of 3,100 GWh [15]. In 2018, the domestic share was 45.12%, followed by industry at 22.07% and commercial and water pumping accounting for 15% (see Figure 4).

4.5. Electricity demand and generation forecast

Jordan's forecasted electricity demand, up to 2040, is detailed in Table 5 (below). The demand for electricity increased steadily by 3% over the years due to urban and industrial development, domestic population growth, and the influx of refugees from neighboring countries. The maximum demand growth is expected to be around 3% with projected electrical generated growth of also approximately 3% [15], which is tentatively projected to meet the country's growing demands in the coming years.

4.6. Grid

Electricity generated from power stations is transmitted by the national grid to various regions in the country via distribution and transformer substations using 132-kV and 400-kV high voltage power lines. The grid follows a south-north axis from Aqaba in the south to Irbid in the north, near the Syrian border. The national grid is linked to the Syrian grid by 230–400-kV power lines in the north and to Egyptian grid in the south via a 400-kV power line. The total length of the high voltage power lines was approximately 3,511 km in 2016, with a grid capacity of 4,000 MW. To meet the growing demand for electricity and to support the current electric grid, a new transmission grid was planned to be installed by 2015 to reinforce the overstressed electric grid. However, due to

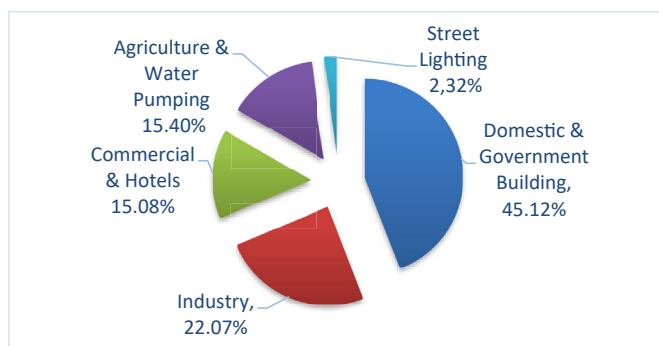


Figure 4. Electrical power consumption (GWh) by sector in 2018 [6,15].

financial issues (approx. the US \$ 500 million), it was delayed until 2019 by the National Electric Power Company (NEPCO) [15].

4.7. Electricity cost

The country's electricity prices account for the financial capacities of consumers as well as their social aspects. In 2018, electricity prices ranged from \$ 0.45 per kWh for small consumers (170 kWh per month) to a maximum of \$ 0.40 per kWh for banks. The production and distribution costs were \$ 0.25 per kWh in 2015, while the average selling price was \$ 0.20 per kWh [15]. The difference in prices was subsidized by the government, thus generating a deficit of \$ 1.22 billion that year. To alleviate the deficit, electricity tariffs were adjusted in 2016 to reduce government subsidies. All fuel subsidies were gradually eliminated by 2012 [16], and the electricity subsidies were gradually removed by 2017, which enabled NEPCO to cover its cost by the end of 2017 [15].

5. Energy policy

5.1. General information

As mention earlier, 94% of energy resources are imported at high market prices, so it is crucial to search for cheaper energy alternatives to secure the electricity supply and support economic growth. Alternative energy sources from shale oil and nuclear energy need many years of investigation, bidding, and negotiation before starting [22]. A growing population, fluxes of refugees fleeing battle zones, and economic growth increase Jordan's energy consumption, which requires several options that can rapidly generate additional electricity capacities needed to meet the growing demand.

5.2. Renewable energy policy

A summary of the Jordanian Renewable Energy (RE) market was initiated by Jordan's renewable energy country commission in 2012 [16]. It provided investors with RE market capacity, long term targets, flexible regulations, and future investments needed in the country. It also gives a short analysis of Jordanian Energy Efficiency goals, measures, and regulations. This includes plans for 2,000 MW investments in wind and solar

Table 4. Consumption of electricity by sector (in GWh) 2009–2017 [15].

Sector	2009	2010	2011	2012	2013	2014	2015	2016	2017
Domestic	4,888	5,225	5,667	6,126	6,265	6,583	7,228	7,515	7,999
Industrial	3,006	3,262	3,486	3,461	3,517	3,878	3,823	3,983	3,910
Commercial/Hotels	1,980	2,187	2,173	2,427	2,414	2,358	2,376	2,416	2,510
Agriculture & Pumping	1,772	1,868	1,899	1,955	2,076	2,284	2,412	2,552	2,683
Street Lighting	310	315	310	305	291	316	339	378	402
Total	11,956	12,857	13,535	14,277	14,563	15,419	16,178	16,844	17,504

Table 5. Electricity demand and generation forecasts in the interconnected system [15].

Year	Maximum Demand (summer loads)		Electrical Energy needed	
	MW	Growth (%)	GWh	Growth (%)
2019	3,057	1.9	20,143	2.6
2020	3,146	2.9	20,744	3.0
2022	3,341	3.1	22,063	3.2
2025	3,645	2.9	24,250	3.2
2030	4,186	2.8	28,230	3.1
2040	5,528	2.8	38,261	3.1

energy plants by 2020. The approval of the REEL Law No. 13 boosted investments in renewable energy sources by simplifying the investment procedures [16]. The REEL initiatives allow Independent Power Producers (IPPs) to sell electricity generated from renewable energy resources directly to state-owned National Electric Power Company (NEPCO).

5.3. Energy efficiency strategy

The master plan for energy saving (2007–2020) contains many recommendations related to energy saving and efficiency [17]. These measures include broad public awareness campaigns on energy-saving rational, thermal insulation of buildings, and tax and customs exemptions for energy-saving equipment. A National Energy Efficiency Action Plan (NEEAP) has been drafted in Jordan, which is in the process of final revision, to facilitate this strategy's implementation.

6. Investments in clean energy

Jordan is highly receptive to international companies interested in investing in renewable energy in Jordan and neighboring countries, once peace prevails. Huge demands for solar power units, wind energy equipment, and waste-to-energy plants exist, which draws interest from investors and technology providers.

6.1. Government initiatives

- The government has taken many initiatives to make investments in the renewable energy sector appealing. A new energy fund has been established to support renewable energy facilities' infrastructure development. Tax incentives and customs exemptions are also provided to eliminate any barriers to the extensive use of renewable technologies and energy efficiency measures in all aspects.
- Tax incentives policies were enhanced by passing the "Renewable Energy Law" by including 100% tax exemption for ten years when investing in renewable energy construction in certain areas where socio-economic developments are needed.
- Investors with renewable energy projects can negotiate directly with the Energy Ministry. Accelerating the rate of investments in the renewable energy sector and the legislation allows local and international firms to negotiate directly with the ministry, avoiding long competitive bidding processes. In addition to the law, all electricity generated from renewable energy sources will be sold directly to the National Electric Power Company (NEPCO). Citizens are also allowed to sell electricity generated by solar power or wind turbines back to their electricity provider.

6.2. Opportunities

Several opportunities are available for overseas companies to invest in the renewable energy sector in Jordan. They can supply extensive services, including technology transfer, equipment supply, technical advice, and consultancy. Updates on tender interests and status can be

found on the Ministry's and NEPCO's Websites. Jordan is a rapidly developing stable country with a skilled labor force and well-established banking sector, which makes it an attractive environment for investment and business development.

6.3. Challenges

Jordan imports most of its energy needs, and the high cost of imported oil created challenges for Jordan's economic growth and social development. The replacement of hydrocarbon fuel by renewable energy sources such as wind, solar, and biomass will reduce environmental pollution while also supporting economic growth and sustainable development. The development of alternative energy sources is a national priority; their actual contribution to the energy demand was acceptable and accounts for roughly 19% of Jordan's total electricity generation capacity in 2018.

Longer-term government initiatives to meet future energy demand, include increased renewable energy share, improved energy efficiency, development of alternative energy supplies, financial incentives and tax exemption, which combined will promote clean energy supplying most of Jordan's growing energy demands. To achieve these goals, various challenges must be overcome, including distorted tariffs and a lack of grid capacity to handle generation expansion.

The current grid is overstressed and will be incapable of handling electricity generated from new renewable energy projects in the near future. Therefore, the government should push ahead with the new grid installation, called the "green corridor". The country hopes to leverage the advantages of its national energy strategy plan (2007–2020), which calls for (14–18 \$) billion in capital investments. This plan includes oil shale exploration, crude oil, and natural gas search, renewable resources development, and the expansion of the current transmission and distribution network, as shown in Figure 5. Jordan's untapped potential for generating energy through solar, wind, and biomass resources is open to private sector investment and international developers to take advantage

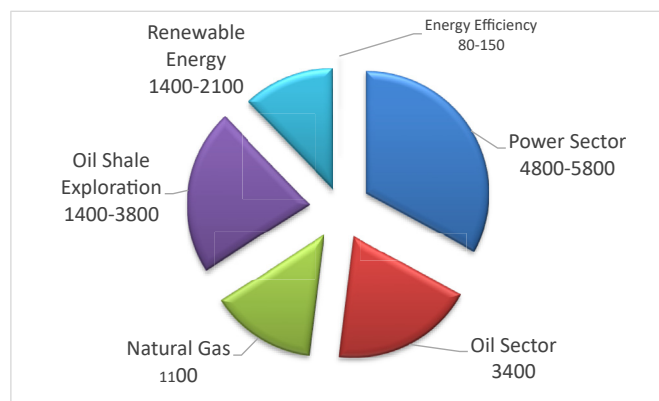


Figure 5. Potential investments (in million \$) in the energy sector according to the energy strategy plan (2007–2020) (14–18 \$ billion) [6].

of available reliable data to support their financial and investment decision.

7. Conclusion

There has been tremendous progress in the implementation of clean energy programs in Jordan, thanks to generous financial incentives and promotion from the government attracting overseas investments and the technical and financial assistance from foreign aids and international donors. In the last two decades, the country's efforts to increase renewable energy resources contributed 7% of the total energy supply (9,712 ktoe) in 2018. This transition provides the country with substantial scientific and technical experience, firmly placing Jordan on the world's renewable energy map. The country is qualified to take the lead with full confidence in adopting up to date renewable energy systems and innovation through joint ventures between foreign investors and local partners. Jordan has the means to become a regional energy and technology hub in the MENA region, due to its political and economic stability. In addition to the many successes' stories in operating projects in renewable energy via joint ventures between local enterprises and international developers. Interested developers should take advantage of the government's ambitious plan to invest (14–18 \$ billion) in the energy sector per the national energy strategy plan 2007–2020. By collaborating with Jordan interest international investors and developers will improve their chances of entering neighboring countries energy markets after the reconstruction of these devastated countries. To further support this booming growth, the government should speed up the installation of a new national grid 'Green Corridor' to increase the current grid capacity to meet the growing demand for electricity supply and generation by 3% annually.

Declarations

Author contribution statement

Ghaida Abu-Rumman, Adnan I. Khair & Sawsan I. Khair: Conceived and designed the experiments; Performed the experiments; Analyzed and interpreted the data; Contributed reagents, materials, analysis tools or data; Wrote the paper.

Funding statement

This research did not receive any specific grant from funding agencies in the public, commercial, or not-for-profit sectors.

Competing interest statement

The authors declare no conflict of interest.

Additional information

No additional information is available for this paper.

References

- [1] C. Acikgoz, Renewable energy education in Turkey, *Renew. Energy* 36 (2011) 608–611.
- [2] T. Muneer, M. Asif, S. Munawwar, Sustainable production of solar electricity with particular reference to the Indian economy, *Renew. Sustain. Energy Rev.* 9 (2005) 444–473.
- [3] D. Gielen, F. Boshell, D. Saygin, M.D. Bazilian, N. Wagner, R. Gorini, The role of renewable energy in the global energy transformation, *Energy Strateg. Rev.* 11 (2019) 38–50.
- [4] IRENA and International Energy Agency (IEA), Perspectives for the Energy Transition - Investment Needs for a Low-Carbon Energy System, IRENA & Paris: IEA, Abu Dhabi, 2017. http://www.irena.org/DocumentDownloads/Publications/Perspectives_for_the_Energy_Transition_2017.pdf.
- [5] IEA & the World Bank, Sustainable Energy for All - Progress toward Sustainable Energy, the World Bank & Paris: OECD/IEA, Washington, DC, 2017.
- [6] Ministry of Energy and Mineral Resources (MEMR), Annual Reports, Amman, Jordan, Page30 [accessed Oct 2019], <https://www.memr.gov.jo/echobusv3.0/SystemAssets/56dcb683-2146-4dfd-8a15-b0ce6904f501.pdf>, 2018.
- [7] M. Saidan, Sustainable Energy Mix and Policy Framework for Jordan, Friedrich-Ebert-Stiftung, Amman, Jordan, 2011.
- [8] S. Kiwan, E. Al-Gharibeh, Jordan toward a 100% renewable electricity system, *Renew. Energy* 147 (2020) 423–436.
- [9] E.S. Hrayshat, Analysis of the renewable energy situation in Jordan, *Renew. Sustain. Energy Rev.* 11 (2007) 1873–1887.
- [10] A. Yaser, B. Ahmad, Renewable energy assessment in Jordan, *Renew. Sustain. Energy Rev.* 15 (2007) 2232–2239.
- [11] Z.E. Fawwaz, M.A. Nazih, The role of financial incentives in promoting renewable energy in Jordan, *Renew. Sustain. Energy Rev.* 57 (2013) 620–625.
- [12] J. Jaber, E. Fawwaz, A. Amil, K. Anagnostopoulos, Employment of renewable energy in Jordan: current status, SWOT and problem analysis, *Renew. Sustain. Energy Rev.* 49 (2015) 490–499.
- [13] M. Al Zou'bi, Renewable energy potential and characteristics in Jordan, *J. Mech. Ind. Eng. Res.* 4 (1) (2010) 45–48.
- [14] T. Khammash, Energy sector report, Jordan investment trust P.L.C [accessed September 2018], <http://jordinvest.com.jo/uploads/documents/energy-sector-report-12-12-2012.pdf>, 2012.
- [15] National Electric Power company (NEPCO), Annual reports, Amman, Jordan [accessed Oct 2019], http://www.nepco.com.jo/store/docs/web/2018_en.pdf, 2018.
- [16] Ministry of Energy and Mineral Resources (MEMR), Annual reports, Amman, Jordan [accessed July 2017], <http://www.memr.gov.jo/LinkClick.aspx?fileticket=j2Hm9pn0Osw%3d&tabid=111>, 2013.
- [17] Ministry of Energy and Mineral Resources (MEMR), Updated master strategy of energy sector in Jordan for the period (2007–2020), Amman, Jordan [accessed November 2017], <http://www.memr.gov.jo/Portals/0/energystrategy.pdf>, 2007.
- [18] Jordan Investment Commission Reports 2018 - 2021, Amman, Jordan, 2018.
- [19] B.M. Wardam, Five reasons for Jordanian nuclear program failure. Amman, Jordan [accessed August 2019], <https://www.7iber.com/2014/jo-nuclear-program/>, 2014.
- [20] A.M. Baniyounes, Renewable energy potential in Jordan, *Int. J. Appl. Eng. Res.* 12 (19) (2017) 8323–8331.
- [21] Bloomberg Report in 2017. <https://www.bloomberg.com/middleeast>.
- [22] Ministry of Energy and Mineral Resources (MEMR), Annual Reports, Amman, Jordan, 2014.
- [23] Danish RISO research center, Wind Atlas for Jordan, Amman, Jordan, 1989.
- [24] GIZ, Enabling PV in the MENA Region. The Emerging PV Market in Jordan, Amman, Jordan, 2014.
- [25] Z. Al-Hamamre, M. Saidan, M. Hararah, K. Rawajfeh, H.E. Alkhasawneh, M. Al-Shannag, Wastes and biomass materials as sustainable-renewable energy resources for Jordan, *Renew. Sustain. Energy Rev.* 67 (2017) 295–314.
- [26] M. Al-Samairan, S. Al-Harashsheh, H. Al-Khazaleh, Biomass energy utilization in northeast Badia of Jordan, *Res. J. Appl. Sci. Eng. Technol.* 10 (11) (2015) 1322–1329.
- [27] Z. Al-Hamamre, A. Al-mater, F. Sweiz, K. Rawajfeh, Assessment of the status and outlook of biomass energy in Jordan, *Energy Convers. Manag.* 77 (2014) 183–192.