

Emissions Reduction Resulting from Renewable Energy Projects in Jordan

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Abstract

This paper aims to present energy supply, demand and policy reforms, in Jordan, that had helped in transforming renewable energy schemes into bankable projects. The current study focuses on implemented and planned renewable projects and its investment as a case study aiming to identify impacts on economy and environment, with emphasis on the power sector. In order to attract private sector participation in the development of such projects, the government developed and enacted a new system of direct proposals as well as needed regulations. This resulted in the construction of more than 1000 MWe of renewable energy and awarding about 1500 MWe to be completed until end of 2024.

According to the adopted methodology, in this study, the calculated avoided GHG emissions resulting from the completion of these projects, during the study period from 2016 and up to 2025, are significant. The net anticipated accumulated reduction of GHG emission over this period exceeded 16 million ton of CO₂ eq. The solar PV sharing ratio being the highest, i.e. 45% of total accumulated reduction, followed by wind, about 24%, and direct applications of renewables by 28%. Such figure may increase in the future depending on the completed capacity and would touch 20 million ton by 2025, when all planned projects are completed.

Keywords Solar, Wind, Biogas, Emissions, GHG, Power Generation, Water-Energy Nexus

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1. Introduction

Jordan is in the eye of Arab cyclone, however, remained stable until now while surrounded by extremely complex situation in Syria, Iraq and the West Bank. Unfortunately, unlike other Arab neighboring countries, it is a non-fossil fuel producing country with limited natural resources and minerals. However, there are vast proven reserves of oil shale of more than 70 billion tons, within an average content of shale oil, i.e. liquid fuel, yield between 5-8 billion ton [1,2]. In addition, Jordan has abundant supplies of RE sources: high average daily solar radiation of between 5-7 kWh m⁻² day, and acceptable wind speed (6-8 m/s) to generate electricity [3]. But the high wind regime is limited to certain districts. The estimated potential of solar energy is unlimited for different applications, more than 1000 GWh/yr of wind power in selected sites and about 350 GWh/yr of municipal waste and biomass [4]. There is also limited potential for small hydropower schemes, in addition to the good potential of the Red-Dead seas project. The latter when constructed would involve building a hydropower plant with a capacity of between 400-800 MW [5,6]. However, until recently, these untapped energy sources could satisfy Jordan needs if utilized wisely.

Jordan is considered as an upper middle-income country with a population of more than 10 million, in 2018, with about 3 million refugees and foreign residents, and average per-capita gross domestic product (GDP) was about USD 4500, in 2018 [7]. Approximately 60% of the population is young and under 20 years of age, being mostly students or trainees, i.e. not productive. The country has limited natural resources. Potash and phosphate are its main export commodities, limited agricultural land, and water is especially scarce; Jordan is among the world's five poorest countries in terms of available water resources [8]. Services account for more than 70% of GDP and absorb more than 75% of jobs. As one of the most open economies of the region, Jordan is well integrated with its neighbors through trade, remittances, foreign direct investment, and tourism, and has especially strong links to the Arab Gulf states. As a result of its open economy and high degree of regional integration, Jordan is vulnerable to the political, economic and social volatility of the region. The costs and impacts of Syrian refugees are very high and caused serious difficulties for concerned authorities and hosting communities. The government (GoJ) is suffering from lack of available resources and international aid. Hosting increasing number of Syrian refugees are being mitigated by the National Resilience Plan 2014-2016 and Jordan Response Plan 2016-2018 which includes priority responses to mitigate the impact of the Syrian crisis on Jordan and on host communities [8].

This research paper is aimed to discuss the impact of policy reforms that had helped in transforming renewable energy (RE) investment projects into bankable projects, allowing these projects an easier access to financing.

Moreover, an assessment of economic and environmental benefits was conducted, with focus on reductions of greenhouse gas emissions (GHG) considering forecasted future energy mix in Jordan.

2. Energy Supply and Demand

Energy demand, in Jordan, was doubled during the last twenty years, and expected to continue but at a lower rate. Hence, all energy forecast scenarios showed that national consumption might double, the current rate, between 2025 and 2030 [10]. Such rapid increasing demand is due to high growth ratio of population, expansion in economic activities at various sectors and increasing dependence on electricity, which is the most flexible and clean source of energy from customers' point of view. Jordan is an energy importing country; about 94% of its needs supplied from abroad as natural gas, crude oil and refined products. It is therefore unlikely that any future energy scenario for Jordan will not include a significant proportion from renewable sources. In 2018, the total energy demand was around 9.71 million toe, compared with about 7.35 million toe in 2010. The indigenous sources covered only a small fraction, i.e. Jordan produced 0.136 million toe of natural gas and less than 0.0012 million toe of crude oil. In 2018, the situation is even worse: local production of oil and gas was less than 50% of the rate in 2010. This is clearly illustrating that Jordan is heavily dependent on imported fossil fuels to fulfill its domestic energy needs in the transport, industrial, domestic heating, and power sectors. Table 1 shows primary energy consumption during the last six years [2].

Table 1 Primary energy consumption (000 toe)

Year	Oil & Coal Products	Pet Coke	Natural Gas	Renewable Energy	Imported Electricity	Total
2010	4774	-	2289	141	168	7357
2011	6141	-	873	130	313	7457
2012	6992	226	659	140	188	8205
2013	6689	204	907	145	96	8157
2014	7479	332	301	152	109	8461
2015	6331	161	1944	160	183	8944
2016	5326	220	3390	412	84	9615
2017	5671	165	3510	515	13	10009
2018	5225	205	3438	753	47	9712

It is clear that the country is still dependent on imported oil (55%) and gas (35%), while renewable sources contributed by only 7.8%, in 2018. In the near future, Jordan will remain a net importer of oil and natural gas from the Arab Gulf countries, and electricity from Egypt to meet peak-load and sometimes part of baseload, even with on-going renewable energy projects in the country. This is mainly due to the fact that transport sector consuming petroleum products, i.e. diesel and gasoline, and most of power generation is based on oil products and/or natural gas. Thus, the current situation presents an ideal environment for development of renewables sources whose financial and technical demands can be met by private sector. Such approach will lead also to the enhancement of security of energy supply into the country, which hardly threatened the national economy and even all activities several times during the past 25 years, i.e. in 1990, 2003 and 2010. The interruption in energy supplies made the country vulnerable to supply shocks and higher oil prices in the international market.

Electricity generation in Jordan has greatly increased over the past few decades in response to rapidly rising demand. In 2004, total electricity generation sold by the National Electric Power Company (NEPCO), the sector off-taker, to the country's distribution companies and wholesale consumers stood at approximately 8,447 GWh. In 2010, just six years later, this amount had grown to nearly 14,258.7 GWh. In 2018 it reached 18963 GWh compared with 18,911 GWh in 2015. Almost 91% of the generated electricity came from burning natural gas in combined cycle power plants. While electricity produced from renewable sources was less than 1%, in 2015, but jumped in following years to reach more than 10.5%, in 2018. This is due to the completion of 18 renewable energy projects: 700 MW solar PV, 280 MW wind, hydro 12 MW and 3.5 MW [11,12]. The high growth rate of electricity consumption is attributed to the need to respond to the increased demand resulting primarily from

Jordan's population growth rate and increasing economic activity, including industrial production, commercial activities, tourism, and construction activities as well as the increasing number of Syrian refugees.

The mix of power plants is summarized in Table 2. In 2015, the GoJ has approved several decisions related to the energy sector. These are:

- The construction of oil shale direct combustion power plant (2x235 MW) in Attarat by a consortium led by Esti Energia and expected to be commissioned in 2019.
- The construction of a combined cycle power plant by ACWA as IPP 5 (in the site of Hussain Thermal Power Station) with an installed capacity of 480 MW firing natural gas as primary fuel and diesel as a substitute fuel, which is expected to be completed by the end of 2018 and become operational in 2019.
- IPP 4, owned by the US firm AES and Japanese Mitsue, has started the construction of a 100 MW PV plant in its site, east Amman.
- The construction and a nuclear plant in the eastern desert, however, this project was cancelled, and the state owned Nuclear Electric Power Company shutdown in early 2019.

Table 2 Installed power generation capacity (MWe) [7,12]

Year		2010	2011	2012	2013	2014	2015	2016	2017	2018
Steam Turbines		925	925	925	787	787	787	470	470	470
Gas Turbines	Diesel	149	134	134	27	27	27	-	-	-
	Natural Gas	600	500	500	618	618	332	307	228	83
Combined Cycle		1317	1737	1737	1737	1737	2167	2044	2044	2740
Diesel Engines	HFO & Diesel	-	-	-	-	814	814	814	814	814
Renewables	Wind	1.44	1.44	1.44	1.44	1.44	118.4	198	198	280
	Hydro	12	12	12	12	12	12	12	12	12
	Bio-gas	3.5	3.5	3.5	3.5	3.5	3.5	3.5	3.5	3.5
	Solar	-	-	-	-	-	15	285.5	395.5	698.5
Industrial sector	Steam	85	85	85	85	135	135	135	135	135
	Gas Turbine	7.5	7.5	7.5	7.5	7.5	7.5	7.5	7.5	7.5
	Diesel Engine	46.8	46.8	46.8	46.8	46.8	46.8	46.8	46.8	46.8
Total		3147	3451	3452	3325	4189	4465	4269	4300	5236

As can be understood from this table, there was a shift from steam turbines to higher efficiency combined cycle power plants fired with natural gas. At the same time the capacity of open-cycle gas turbines which have the lowest efficiency in the system was reduced. In addition, many of solar PV and wind power generation projects were completed and come-on-line by 2018. Such approach was important to increase the efficiency of power generation and reducing the cost of unit electricity produced. It is important to note that no energy storage systems, e.g. pumped storage, exist at present or planned in the near future.

There are about 1500 MW of wind and solar under construction: wind 418 MW in 2020 and 50 MW in 2021, PV 400 MW in 2020, 600 MW in 2021 and 100 MW in 2024 [2]. These projects could substantially reduce Jordan's energy dependency and create significant fiscal benefits. These include but not limited to (i) expected to generate about 2,000 GWh annually (ii) create between 2,000 and 3,000 jobs and avoiding more than 1.0 million ton of GHG emissions depending on the fuel mix used in power generation. The Ministry of Energy and Mineral Resources (MEMR) is working in close cooperation with the Ministry of Municipalities and the Great Amman Municipality and investors to convert solid waste into energy and the expected installed capacity estimated at around 60 MW [11]. In addition to these central generation projects, on-grid roof tops PV systems based on net-metering directive witnessed high growth rate during the past five years. The estimated installed capacity exceeded 250 MW as of early 2019 and expected to double within next few years due to the fact that the

government increased electricity prices by an average of 15% per year for the period 2013-2017 for almost all tariff categories except low income households and agriculture sectors.

Final energy consumption can be distributed between four main sectors: transport sector is the major consumer (48%), followed by residential (22%), industry (17%) and others (13%). The latter includes agriculture, commercial and other minor sectors such as government and military consumptions. The rate of energy consumption, especially electricity, was rising rapidly during the past decades due to the high growth rate of population and urbanization. However, recently in the last three years, the rate was slow and thus demand on electricity dropped. The residential sector is ranked 1st (46%), followed by the industrial (22%) sector, then water pumping (16%) and commercial (14%) sectors and finally street lighting (2%). Again, the high rate of electricity consumption in the residential sector can be attributed to the increased population as a result of continuing waves of Syrian refugees into the country. Also it can be seen that consumption of the water pumping sector is increasing at high ratio, because fresh-water is pumped from underground aquifers and Jordan valley up to the high land in the western chain of mountains with difference in elevation exceeding 400-1000 m and from Disi fossil aquifer in the southern desert, near the Saudi border, to the northern region, i.e. Amman, with a distance of 350 km.

3. Energy-Water Nexus

Jordan is considered as an arid-semi-arid climatic region, since more than 80% of its area dry desert, and surface water sources are very limited, since the diversion of River Jordan in early 1960s. In addition to limited agricultural land and absence of new discoveries of oil or gas, the limited natural resources, including fresh water supplies are fundamental problems facing the GoJ. Jordan's primary sources of water are aquifers and basins shared with neighbouring countries. The water budget of Jordan is around 1.0 billion cubic meters per annum, which is considered relatively low when, compared to the social, economic, and environmental needs of the country [13]. It is considered among the world's five poorest countries in terms of available water resources. Thus, water shortage is already happening with clear signs such as streams are drying up and water-table is falling. Thus, a rationing system has been implemented such that citizens get water from public supplies just one to two days per week. With Jordan's population expected to continue to rise at higher rates, due to unexpected influx of refugees from neighbouring countries, the gap between water supply and demand threatens to widen significantly. According to official sources, in 2025, if current trends continue, per capita water supply will fall from the current 100-120 m³/yr to only 90 m³/yr, putting Jordan in the category of having an absolute water shortage [4,14].

The political upheaval that swept the Arab region has had a significant impact on Jordan taking the form of economic shocks as well as inspiring domestic demands for stronger citizen voice, greater accountability and improvements in living conditions. The regional political upheaval impacted Jordan economically through two channels: (i) the sharp drop in natural gas supplies from Egypt led to a surge in Jordan's current account and fiscal deficits; and (ii) the Syrian conflict which led to a large influx of refugees is further straining Jordan's difficult fiscal position. Equally important is the instability in the region as a whole.

Lack of energy sources and the deficit in water supplies are considered fundamental problems for consecutive governments. At present there is no simple direct solution for both issues, especially energy demand for pumping water is increasing year after year. There are plans to pump deep saline-water and use it to supply the municipal water network but after being desalinated. Exploiting the elevation difference between the Red and Dead Seas, by allowing seawater flow from the Gulf of Aqaba into the Dead Sea through a canal system at predetermined rates, will produce electrical power from hydropower stations and potable water from seawater desalination plants. While this project is expected to help in establishing new economic activities, such as tourism and agriculture, it will ensure the supply of large amounts of highly needed electricity and water as well as the replenishment of the Dead Sea by replacing the evaporated water. Feasibility reports have shown that it is possible to build hydropower stations with a total capacity of 400–800 MW [15]. But the required capital investment is extremely high due to the long canal, i.e. about 200 km, and necessary infrastructure. In addition, this is a cross-border project and requires special coordination.

The scarcity of both energy and water makes the management of such vital resources very complex from a political, technical, socio-economic and environmental perspective. Moreover, it is evident that water resources in Jordan are very vulnerable to climate change. Previous strategic studies and legal documents (i.e. Jordan's Second Communication Report to UNFCCC (2009) and National Climate Change Policy (2013), and the latest Third National Communication (2014)) all have identified that scarcity of water resources as one of the major

barriers facing sustainable development in Jordan that will be further magnified by climate change [16-18]. Expected reduced precipitation, maximum temperature increase, drought/dry days and evaporation are the main determinants of climate change hazards. The impact of the increased evaporation and decreased rainfall will result in less recharge and therefore less replenishment of surface water and groundwater reserves. In the long term, this impact will extend to cause serious soil degradation that could lead to desertification, exacerbating future conditions and worsening the situation of the agricultural sector due to the lack of sufficient water that will affect the income of the agriculture sectors. As a direct result this will ultimately reduce the ability to the adaptation to climate change with families unable to respond to the pressing needs for replacing traditional water supplies with new methods that require more spending, e.g. private supply. In addition to climate change, the increased demand for water in Jordan during the last decade has contributed significantly to reducing per capita shares. The natural growth of economy and population has been significantly affected by continuous flow of refugees from Syria in particular and thus increase the demand for water. The main conclusion is that limited local water resources are vulnerable to Global Warming and adaptation actions and measures should be taken seriously at all levels. Thus, there is a real need to adapt policies and measures which were proposed in the 3rd communication [18].

4. Carbon Footprint

The GoJ in the National Strategy and Action Plan for Sustainable Consumption and Production (NSAP) for (2016 – 2025) aimed to shift to sustainable patterns, the issues of excessive energy consumption and the associated GHG emissions and their potential effects on the global climate change were addressed [19]. Jordan has signed and adopted almost all the international and regional conventions relating to environmental protections, e.g. the Biological Diversity and Climate Change Convention. According to the recent report of the 3rd National Communication in 2014 [18], the annual CO₂ emissions were estimated in 2006 to be 28,717 Gg of CO₂ eq., i.e. 28.72 million ton of CO₂ equivalent, and expected to be around 38,151 Gg in 2020. Fig. 1 shows that fuels combustion related activities, in both of energy and transport sectors, have the dominant share of GHGs emissions totaling 73%, of about 33 million ton, followed by waste and industrial activities, in 2014. It is obvious that the energy sector and transport are leading emitters of GHGs and predicted to increase in the future based on business as usual scenario, i.e. when no actions and measures adopted by GoJ aiming to enhance efficiency and reduce energy consumption. Therefore, the GoJ should focus its efforts on this sector. Renewable energy power generation projects and resuming natural gas as prime fuel in power stations will significantly reduce national emissions. Equally important is enhancing energy efficiency in various sectors.

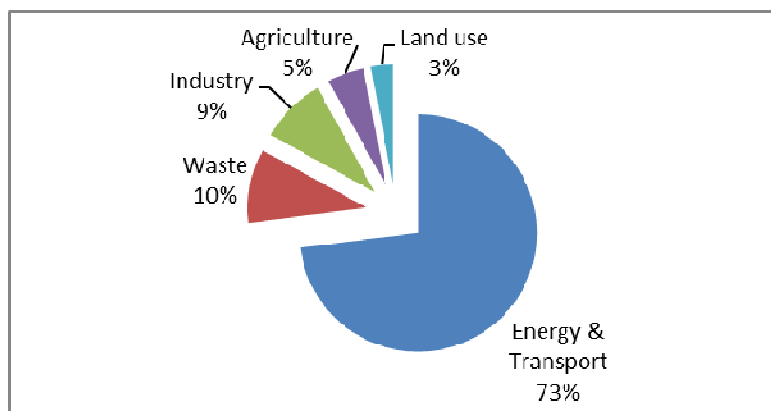


Fig. 1 Distribution of GHG emissions in Jordan (2014)

The Country's bulk share of GHGs represents less than 0.06% of global total according to a global GHGs analysis conducted in 2014. Although this is a small contribution of the world's annual CO₂ emissions, its intensity is considerably high: according to the World Bank, per capita emission is about 3.4 ton of CO₂. Such rate is much higher than that incurred in most European countries, and almost similar to those of oil producing Arab countries. This implies that there is room for energy efficiency improvement and emissions reduction in all

sectors by employing RE systems. The GoJ has developed a targeted program aiming to reduce the national GHGs emissions by 1.5 % by 2030 compared to a business as usual scenario levels. It was submitted as Intended Nationally Determined Contribution (INDC) to reduce GHG emissions. The conditional outcome target is aiming at reducing Jordan's GHGs emissions by 12.5 % by 2030. The two targets will be achieved based on implementing at least 70 projects (43 sectoral projects resulted from the mitigation scenario assessment articulated in the 2014 Third National Communication Report to UNFCCC and another around 27 sectoral priority projects proposed concurrently or newly planned and not listed in the TNC Report). The latter group of projects was disseminated to INDC document by involved stakeholder line ministries and organizations in response to INDC formulation process [20]. These 70 projects represent 14% of INDC of Jordan, of which many projects are now under execution by relevant institutions and will be implemented under the guidance of the overarching national Climate Change Policy of the Hashemite Kingdom of Jordan 2013-2020 [17]. The climate change policy of Jordan is a holistic nation-wide policy encompassed strategic objectives and measures for mitigation and adaptation. It is considered the first of its kind in the Arab Region and, in terms of sectoral coverage, in the Middle East, covering the pre-2020 period, which was developed voluntarily as a demonstration of the self-commitment of a small yet an ambitious country. The Policy itself as well will be extended at the end of its term to 2030 to concurrently go in line with and serve as an overarching umbrella guiding and monitoring the implementation of the 70 project and 14% GHGs emission reduction pathway of activities until 2030.

5. Assessment Methodology

Jordan has a long tradition in energy efficiency and renewable energy and could be considered pioneer in the MENA region in terms of having formulated and implemented strategies as early as 1985. The institutional and legal framework for renewable energy and development of domestic resources are well established. The Renewable Energy & Energy Efficiency Law (REEEL) was approved and enacted in 2012, with needed Bylaws and regulations.

In order to scale up utilizing renewable energy market, the GoJ adopted an ambitious strategy (2007-2020) and important public efforts were made to implement this strategy into actions based on direct participation of the private sector. The updated National Energy Strategy (NES) called for a contribution of 10% of RE sources in the energy mix in 2020, but the NES, approved in 2016, expecting double this ratio: 20% of the installed capacity and 9% of total power generation in that year [21]. In the current study, the assessment methodology of renewable energy potential was completed based on committed RE projects, which represent a fraction of the economic and market potential, and the adopted energy mix in the NES. So existing and future RE capacities were taken as reported by MEMR, however, the potential is much higher. The following Table 3 summarize the installed RE power generation systems and the future committed expansion. This represents a conservative scenario for employing RE in power generation and it is expected that more will be installed as rooftops and after the completion of the green corridor, PV systems on wheeling basis. The Concentrated Solar Power (CSP) technology still will not be deployed since it is too expensive and lack of professional expertise in Jordan. At present, there are only two systems in Jordan used for an industrial application. A low-pressure saturated steam is produced by a Liner Fresnel System to supply a pharmaceutical industry and the other one for tobacco factory. The final costs are very high and economics still not attractive.

Hydro power systems are assumed to remain the same unless the Red-Dead project is approved to be financed by international donors. Other small hydro unites are not expected to see the light within next few years. On the other hand, waste-to-energy project of about 40 MW may become operational in 2020 if the Ministry of Municipalities and the Great Amman Municipality and investors sign needed agreements, including the Power Purchase Agreement with NEPCO. Other applications are assumed to have a contribution ratio of between 1.5-2.0% of the total primary energy consumption due to many reasons. Other RE applications that are not considered in this study due to different reasons, include:

- RE in transport
- Biomass in agriculture and farming
- Solar space heating and cooling
- Geothermal space heating and cooling
- Desalination using RE technologies

However, the total potential of these applications within the time frame of this study (2017-2025) will not be significant, with a sharing ratio of not more than 1.0%-2.0% of the national energy mix. Thus, such applications

are not considered in this study.

Table 3 Renewable energy power plants (2015-2025)

Technology	Installed Capacity (MW)									
	2016	2017	2018	2019	2020	2021	2022	2023	2024	2025
PV	175	405	435	570	800	830	860	900	950	985
Wind	118.4	310.4	410.4	410.4	410.4	410.4	410.4	410.4	410.4	410.4
Hydro	12	12	12	12	12	12	12	12	12	12
Biomass	3.5	3.5	3.5	3.5	40	40	40	40	60	60
Total	308.9	730.9	860.9	995.9	1262.4	1292.4	1322.4	1362.4	1432.4	1467.4

In this case, the cumulated fuels potential saving during the period from the base year and the year of observation n (i.e. 2020) is calculated as following:

$$F = RE_{\text{prod}} (\text{SFC})$$

Where,

F: avoided fuel consumption (ton/yr)

RE_{prod} : energy produced by RE systems (kWh/yr)

SFC: specific fuel consumption for conventional power generation systems (kg/kW-h)

Based on the energy mix of the industry sector consumption, it is possible then to estimate the GHG emission reductions by using the emission factor of its energy product.

6. Results and Discussion

Based on the adopted methodology, official energy forecasts up to 2025 and implemented RE projects and those in the pipeline as reported by MEMR, the expected power generation is shown in Fig. 2. While the estimated energy saving and avoided GHG emissions due to utilizing RE sources in different applications are presented in Fig. 3.

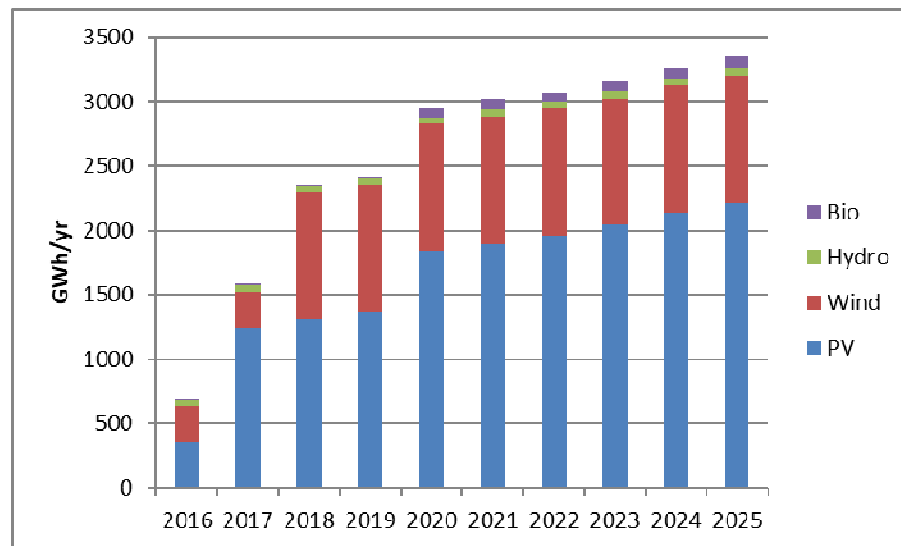


Fig. 2 Expected power generation by RE sources

As can be seen in Fig. 2 that PV central and small systems will contribute slightly more than half of power generated by RE systems in 2016, while wind share is about 40% and the remaining, i.e. 8.5%, fraction by hydro

and bio sources. But in the coming years, it is expected that PV contribution will increase due to the fact that most of projects through direct proposals to MEMR are based on PV, as discussed previously. Main reasons behind this trend are: (i) lower cost, (ii) short period for project development since no need for specific measurements as in the case of wind, (iii) quick implementation time and (iv) no need for highly skilled workforce as in wind turbines.

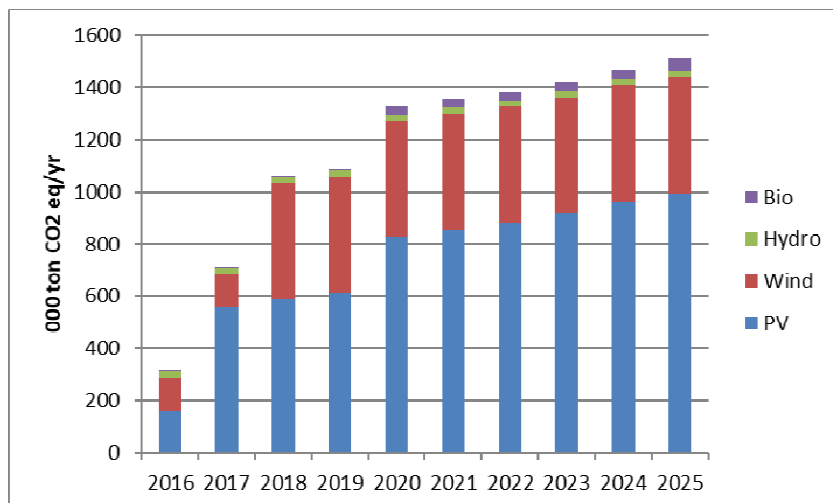


Fig. 3 Predicted annual rate of reduction of GHG emissions

The contribution of bio-energy and hydro-power will remain constant in the coming years because of limited resources. The jump in bio-sources would occur in 2020 when the waste-to-energy project is completed by Amman Municipality. In terms of anticipated reduction in GHG emissions, same scenario applies and there is an increasing trend due to more power being generated using RE sources – see Fig.3. In the year 2020, the expected total reduction of GHG emissions, as a result of RE for power generation and direct application would be about 1.85 million ton of CO₂ eq., which is about 4.5% of the predicted emissions in that year as reported in Jordan INDC report. The estimated accumulated reduction, shown in Fig. 4, as result of power generation, during the study period (2016-2025) would be around 16 million ton of CO₂ eq and approximately 4.5 million ton of CO₂ eq due to using RE sources in direct applications, such as water and space heating. As explained earlier other applications of RE in Jordan will take more time to be implemented on the ground. Main reasons behind the delay in of implementing RE systems for direct applications are related to lack of awareness and know how about RE technologies and still perceived as uncertain and risky investment especially by the local banking sector [22,23]. Equally important is the lack of local financial schemes to RE projects, although Jordan Renewable Energy & Energy Efficiency Fund (JREEEF) announced some initiatives for the industrial and residential sectors.

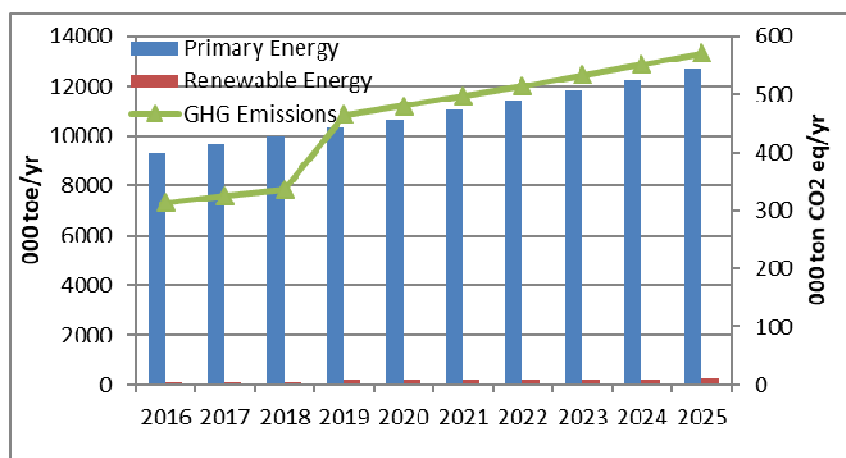


Fig. 4 Annual contribution of RE sources in direct applications and associated reduction of GHG

The distribution of contribution of different sources in such reduction is illustrated in Fig. 5. It is obvious that RE for power generation contributes most of the expected accumulated reduction in GHG emissions, during the study period from 2016 and up to 2025. With solar PV sharing ratio being the highest, i.e. 45% of total accumulated GHG reduction, followed by wind, about 24%, and direct applications of RE by 28%.

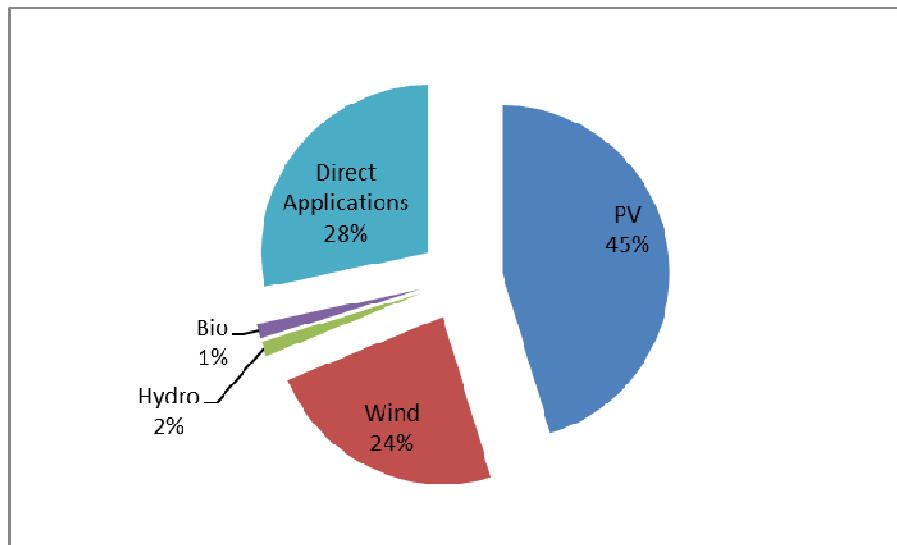


Fig. 5 distribution of accumulated reduction of GHG emissions during (2016-2025)

7. Conclusions

RE is not a luxury or a fantasy for Jordan; it is a life saver for a very critical energy situation in a country that does not have sufficient conventional energy resources. Therefore, it is the way forward for Jordan in the energy domain to face the shortage of energy resources against the increased demand. Government, public organizations and the private sector stakeholders are partners and are collectively responsible for the promotion of RE out of necessity and dire need.

At present, Jordan is considered as leading country in the region in terms of needed basic RE legislation and regulation. The Renewable Energy and Energy Efficiency Law, which provided the legal mandate for the GoJ is enacted since 2012 and a regulatory framework for RE and EE was developed and issued as bylaws, directives and instructions to encourage private-sector investment in RE for power generation and other applications. As a result, long list of RE projects, in southern and northern parts of the country were developed and commissioned and others in the pipeline and will be connected in the near future. In this paper, all future committed RE projects, based on PV and wind, are considered in calculating savings and avoided emissions. Such projects are deemed to reach 20% of the installed capacity in 2025 and produce more than 10% of total power generation, thereby avoiding the release of millions of tons of accumulated GHG emissions to the environment. It is found that the accumulated reduction in GHG emissions during (2016-2025) would be around more than 16 million ton of CO₂ eq as a result of RE in power generation and approximately 4.5 million ton of CO₂ eq due to using RE sources in water and space heating.

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