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Greenhouse Gas Emissions Reduction Potential of Jordan's Utility Scale Wind and Solar Projects

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Abstract

Jordan's high reliance on foreign energy sources forced the country to reconsider its energy consumption policies and address the issue of reliance on international energy markets for direct imports. Moreover, renewable energy sources offer important environmental, social and economic benefits. Wind and Solar energy, in particular, carries a very good potential in solving the energy problem in Jordan, diversify its energy supplies and reduces greenhouse gas emissions. This paper focuses on the Green House Gas (GHG) emission reduction associated with the implementation of Jordan energy strategy's solar and wind projects. Four different scenarios were investigated based on the replaced traditional fuel type used for electricity generation that the proposed project will replace. The study shows that the proposed solar and wind project will result in a significant reduction of the country's projected greenhouse gas (GHG) emissions of 1.93 – 3.21 mega tons of CO2e annually.

Keywords: *PV, WIND, JORDAN, EMISSION REDUCTION, GHG, CO2.*

1. Introduction

As the world is moving toward more environmentally friendly economies, mainly by depending on cleaner sources of energy associated with fewer negative environmental impacts, renewable energy is attracting a tremendous attention. During the past few years, the cost of the renewable energy has witnessed significant drop and consequently became more competitive. Renewable energy viewed as a significant part of the solution to Jordan complicated energy problems.

Energy considered the major setback to achieving Jordan's goals in terms of social and economic sustainable development. It consumes about 20% of the country's GDP in a country that is currently importing about 96% of its energy needs [1]. Energy price dramatic hike in 2007 was the main drive for energy importing countries, like Jordan, to develop ambitious strategies aiming at securing local sources of energy.

Beside its direct economic benefits and energy security, local renewable energy offers several benefits such as mitigating environmental pollution, providing public health benefits, and creating significant job opportunities that lead to a strong economic growth rate. However, some adverse environmental impacts are associated with the adaptation of renewable energy choices such as land usage and visual distraction of rooftop PV system installation. Environmental benefits can be amplified by increasing the share of local clean energy specially in countries like Jordan that are blessed with plenty of sunshine of high solar radiation of 5-7 kWh/m^2 per day with over 300 sunny days per year [2]. Etier et al. analyzed the solar radiation in Jordan and found that the majority of Jordan areas receive global radiation of 2080 kW-h/m² and more [3]. Figure 1 shows the Global Horizontal Irradiation (GHI) received by Jordan where most of the country receives over 2000 kW-h/m² [4]. Jordan also has a good potential for wind energy, with a wind speed ranging between 7.5 to 11.5 m/s in several areas [2]. Such forms of alternative sources of energy help in reducing harmful gaseous emissions associated with energy consumption.

2. Jordan's Renewable Energy Sector

Jordan's energy strategy originally targeted an increase of the renewable energy share in its energy mix to a 1000 MW wind projects and a 600 MW solar generation capacity by the year 2020[1]. In light of the overwhelming progress in implementing the strategy, the county raised its target for solar energy. The Jordanian Minister of Energy has recently announced that the country is expected to commission about 1,800 MW of wind and solar power capacity by 2018, raising the target for solar capacity to 1,000MW by 2020 [5].

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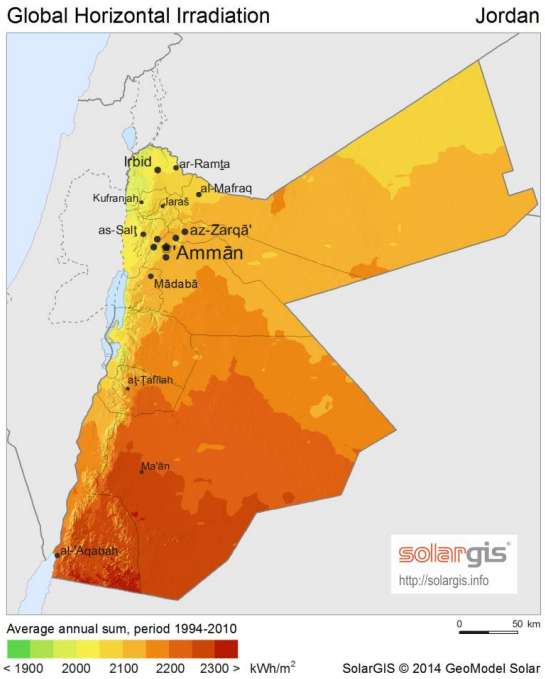

Figure 1: Global Horizontal Irradiation (GHI) for Jordan[4]

Consequently, the country currently targets 1000 MW wind projects and a 1000 MW solar generation capacity by the year 2020. Table 1 summarizes the ongoing wind and solar energy projects in Jordan as per the Ministry of Energy and Mineral Resources. These projects are expected to be commissioned and connected to the grid by 2018 [6].

Table 1: Ongoing Wind and Solar Energy Projects in Jordan

Project	Technology	Capacity (MW)
Jordan Wind / Tafilah	Wind	117
Ma'an Wind energy	Wind	80
Wind Energy /first phase of Direct Proposals	Wind	585
Al-Fujej	Wind	90
Total wind projects		**872**
Azraq PV	PV	5.17
First Phase of Direct Proposals (12 projects)	PV	565
Philadelphia / Mafraq	PV	10
Second Phase of Direct Proposals (4 projects) / Mafraq	PV	200
Al Qweirah	PV	103
Total Solar Project		**883.17**

Jordan has a good experience in utilizing thermal solar energy to provide hot water for Jordanian residences and businesses. Photovoltaic (PV) off-grid systems have been used for water pumping and as a power sources in communications equipment in remote areas of the country. In Jordan, there are about one million square meters of solar heating systems installed in residential and commercial buildings [7]. Renewable energy, in Jordan, offers a strong potential for securing a good source of local energy that covers a high proportion the country's energy needs. Among the different types of renewable energy, solar and wind energy received a considerable interest in Jordan.

The main challenge that faces a better utilization of renewable energy in Jordan is the lack of appropriate renewable energy infrastructure that is not robust enough to meet Jordan's current energy demands [8]. Previous experience indicates that in order to make renewable energy program successful, the right policy must be adopted nationally with the right incentives to overcome any resistance to such a new technology [9][10][11].

Technical difficulties are expected to rise initially specially when it comes to the readiness of the existing infrastructure to support new renewable energy generation project specially central utility scale projects due to the variability and uncertainty in the output of renewable energy generation [12]. The technical barrier in the case of Jordan is similar to what other countries with similar conditions faced at the beginning of their adoption of a renewable energy generation. In a recent study focusing on the barriers to renewable energy, the technologies adopted in India have been investigated. In that study, which offers an extensive literature review, twenty eight barriers have been identified and categorized into seven dimensions of barriers, i.e., Economic & Financial; Market; Awareness & Information; Technical; Ecological & Geographical; Cultural & Behavioral; and Political & Government Issues [13]. High initial capital cost, lack of financing mechanism and subsidies, lack of consumer awareness to technology, lack of sufficient market base, and lack of local and national infrastructure are examples of priority barriers that will be applicable to renewable energy market in Jordan.

3. Governmental Effort to Promote Renewable Energy

By November 2012, the government of Jordan completed the legal framework to encourage electricity users to use solar energy by installing Photo Voltaic (PV) solar system and connect it to the national grid. Electricity exchange with the grid is regulated by the net metering system. The government aims to make the solar energy an important contributor to the country's overall energy needs.

Under electricity net metering system, the customer's electric meter keeps track of how much energy is consumed and how much excess energy is generated by the PV system and sent back into the electric utility grid. Therefore, the customer has to pay only for the net amount of electricity used from the utility over and above the amount of electricity generated by their solar system. Furthermore, the net meter accurately captures energy generated and consumed providing customers with annual performance data.

In parallel with introducing the legal framework of grid connected systems, the government of Jordan has introduced a five-year plan to reform the pricing mechanism that gradually eliminates subsidies and ultimately leads to cost recovery by the end of 2017. The electricity pricing mechanisms divides consumers into activity-based segments such as residential, industrial, service, domestic, etc.; each segment is divided into several blocks according to the monthly electricity consumption in kw-h. The economic feasibility of a

potential PV system in Jordan depends mainly on the price of the electricity produced, which in case of net metering system equivalent to the electricity tariff for a cretin segment. Based on a previous study, an increase in electricity price will ultimately raise the interest of consumers to adopt renewable energy solutions, including solar energy [14].

Jordan is currently upgrading its national grid to integrate new mega-size project expected to start operating by 2017. The new grid, being known as the green corridor dedicated for renewable energy project, is expected to be completed by 2017 [1]. During the transitional period, distributed generation scheme can be considered using the existing national grid without the need for major grid upgrades; it also reduces losses due to the distribution over a long distance.

According to the instruction issued by the Electricity Regulatory Commission, the electricity customer can install a PV system that could cover all its average monthly power consumption over a year. Therefore, and in order to decide on the possible and best PV system size, the historical monthly power consumption data are needed.

4. Renewable Energy and Climate Change

With the growing environmental concerns over climate change, clean energy attracted the attention of researchers and policy makers. Traditional fossil fuel consumption is responsible for 56.6% of Green House Gases (GHGs) emissions, widely believed to be the major contributor to global warming [15]. About 28 billion tons of CO_2 are released to the atmosphere annually from burning traditional fossil fuels worldwide [16].

The United Nations (UN) organized Rio de Janereiro's earth summit to address this issue. Few years later, the UN framework Convention on Climate Change was held in Kyoto. Kyoto protocol quantitatively and qualitatively detailed greenhouse gases emission reduction targets. International efforts currently focus on GHG reduction as outlined by the Kyoto Protocol [17].

Jordan ratified the protocol and committed itself to GHG emissions reduction. Recently, during the Paris 2015 UN Climate Change Conference, Jordan's Minister of Environment noted that Jordan was the first country in the region to produce a National Climate Change Policy, under which the Kingdom targets a 14% GHG emissions reduction by 2030 below the Business As Usual (BAU) scenario. The country plans to meet its commitment by implementing 70 projects, mainly in the energy and transportation sectors [18].

5. Green House Gases (GHG) Emission Reduction

Cleaner options of utility scale electricity generation offers environmental benefits that can be evaluated in terms of avoided emissions of GHG compared to business as usual situation. Although several types of gases are emitted to the atmosphere, the equivalent amount of CO_2 is used to evaluate the environmental impact of each mode of electricity generation per kw-h produced (g CO_2e/kw-h).

Currently, oil, diesel and natural gas are the most important feedstock used to generate electricity in Jordan. According to the most recent annual statistical bulletin of 2014 issued by Jordan's energy and minerals regulatory commission, 7442, 7177, 3276 GW-h of electricity were generated using oil, diesel, and natural gas, respectively [23]. Therefore, any added capacity coming from a clean source of energy will result in an avoidance of GHG emission compared to the current situation. Three scenarios will be considered where the planned solar and wind utility scale power plant is replacing oil, diesel, or natural gas power plants.

Table 2: Lifecycle GHG emissions for the different electricity generation technology

Technology	Greenhouse gas emission (gCO_2e/kw-h)	Average (gCO_2e/kw-h)
Oil	733 [19]	733
Natural Gas	499 [19] 469 [20] 400 [15]	456
Diesel	715 [15]	715
Photovoltaic (PV)	85 [19] 60.1 [21] 39 [20]	61
Nuclear	29 [19] 66 [22]	48
Wind	26 [19]	26

Wind turbines operating in Jordan are expected to produce 3.42 GW-h annually per 1 MW installed capacity [24]. Photovoltaic (PV) solar systems produce 1.86 GW-h annually per 1 MWp installed capacity [25].

As illustrated in Table 1, the total capacity of the ongoing wind project is 872 MW and expected to generate about 2982 GW-h annually. The ongoing solar projects have a total capacity of 883.17 (MW) and expected to generate 1643 GW-h annually. The combined electricity generated from all solar and wind project will total 4625 GW-h annually. This new generation capacity is replacing a need for new power plants that use traditional feedstock of oil, diesel, or natural gas. This alternative approach of electricity generation will help the country in reducing its projected equivalent CO_2 emissions. On average solar and wind energy emits an equivalent of 61 and 26 g CO_2e/kw-h. For the proposed solar and wind project, the weighted average of 38 g CO_2e/kw-h. As stated earlier, Jordan generates 7442, 7177, 3276 GH-h of electricity using oil, diesel, and natural gas, respectively. Therefore, the current energy mix emits on average 675 g CO_2e/kw-h.

Table 3: GHG emissions reduction for the different electricity generation technology scenarios

Scenario no.	GHG reduction (gCO_2e/kw-h)	GHG reduction (MegaTon CO_2e/yr)
Scenario 1	695	3.21
Scenario 2	677	3.13
Scenario 3	418	1.93
Scenario 4	637	2.95

Three scenarios are investigated based on the replaced traditional feedstock. Scenario 1, 2 and 3 are based on the assumption that the ongoing solar and wind projects are replacing a generation capacity from oil, diesel or natural gas, respectively. The produced electricity by these projects is compensating for electricity that needs to be produced either from oil, diesel or natural gas. A fourth scenario is considered that bases the comparison on the current energy mix in Jordan. In this fourth scenario, the produced electricity by these projects is compensating for electricity that needs to be produced from oil, diesel and natural gas in the same ratio that is used in Jordan for electricity generation. Table 3 summarizes the potential for CO_2e reduction due to the commissioning of proposed solar and wind projects in Jordan.

The annual CO_2e reduction due to the implantation of Jordan plans of building and operating several solar and wind power plant appears to be significant. Based on the current energy mix in Jordan (Scenario 4), the implementation of the plan will prevent 2.95 Mega ton of CO_2e annually.

According to the Department of Horticultural Science at North Carolina State University, on average, a tree can absorb as much as 22 kg of carbon dioxide per year and can sequester 1 ton of carbon dioxide by the time it reaches 40 years old [26]. Therefore, based on the fourth scenario, commissioning the ongoing solar and wind power plant is equivalent to planting and growing a little less than three million tree for 40 years annually.

6. Conclusions

In Jordan's ongoing solar and wind utility scale, twenty three projects were investigated in terms of their role in reducing the country's CO_2e emissions. These projects have a total production capacity of 1755.17 MW. They are expected to be all commissioned and connected to the national grid by 2018. These projects are expected to provide several economic benefits and to have a high potential for creating significant number of good jobs to the country's struggling economy. Moreover, they will help the country meeting its commitment regarding greenhouse gas (GHG) emissions associated with the traditional modes of electricity generation. Four scenarios, based on the replaced traditional feedstock, were analyzed. The analysis shows that upon operation, these projects will prevent 1.93 – 3.21 mega tons of CO2e from being emitted to the atmosphere annually.

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