Economic, Environmental and Social Impacts of Developing Energy from Sustainable Resources in Jordan

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ABSTRACT

Sustainable development is an evolving policy taking different forms in countries throughout the world. The development of renewable energies from solar, wind, geothermal, hydro and tidal will improve energy security for oil importing countries and promote sustainability. Renewables also create employment and a supply chain of industries that educate, design, finance, procure, manufacture, manage, construct, commission, and maintain the new clean energy technologies.

This article details the status of the development of renewable energy sources in the Middle East and North Africa (MENA) concentrating on the successful efforts in Jordan. The development of Jordan's regulatory system began after the oil crisis in 2008 with renewable energy (RE) and energy efficiency legislation in 2012.

The economic, environmental and social impacts of renewable energy (RE) will be discussed as will the lessons learned from adopting strategies to achieve the renewable energy targets in the energy mix. These lessons can be implemented locally by other oil importing countries to improve energy resilience, energy security, and contribute to global climate change adaptation efforts. This article concentrates on the development of sustainable energies which are naturally available, socially acceptable and economically feasible in the Middle Eastern country of Jordan.

INTRODUCTION

Renewable energies do not consume fossil fuels and they are available free in nature. Since the 1970s, many countries have directed investments towards the development of renewables.

Solar is earth's most readily available energy and the ultimate source of most energy resources. Solar photovoltaic (PV) was first developed by Bell Labs in 1954 as a means of producing electricity. Since then, the efficiencies of solar PV cells have improved and costs have declined while the number of the world's electric consumers has increased.

The latest energy crisis in 2008, which increased oil prices to 147USD/barrel, caused economic problems in the national economies of oil importing countries while oil exporting countries gained huge monetary reserves. The most rapidly developing renewable energy source has been solar PV. The Global Status Report 2015 shows installed PV capacity increasing since 2010.

Hydro power provides the largest amount of renewable electrical energy in the world. New hydro-electric capacity is being added in developing countries.

Generating electricity from wind power is a type of renewable technology that was commercially developed in the 1970s. Since then, the generating capacity of the turbines has continued to increase with longer blade lengths, higher hubs and larger rotor diameters to access greater wind speeds at higher elevations.

Worldwide renewable energy generation capacity is increasing at the rate of approximately 100 GW annually. The renewable energy development in MENA began in the 1990s and within 10 years, Egypt successfully installed over 545 MW of wind powered electrical generation. Currently, Morocco, Tunis, Jordan, the UAE and Lebanon are leading the installation of renewable energy systems.

Energy Status in Jordan

The Ministry of Energy and Mineral Resources (MEMR) Energy Facts and Figures Report 2014 [1] indicates that Jordan imports 97% of its energy requirements with the balance from local production. Jordon's primary energy needs are roughly 8.15 million tons of oil equivalent (TOE). 82% of Jordan's primary energy consumption is from crude oil and refined products, 11% from natural gas, 3% is from coal, 2% from renewable energy, 1% from coke, and 1% is imported electricity.

These energy resources are consumed by the transportation, (51%), household (21%), industrial (17%), and other sectors (11%).

About half of the oil consumed is used to generate electricity. Electricity is used by various sectors: household (43%), industrial (24%), commercial (17%), water pumping (14%) and street lighting (2%). The electricity generated in Jordan equals an average annual electricity intensity of 959 kWh per person annually or 5,180 kWh per family, based on an average family size of 5.4 persons.

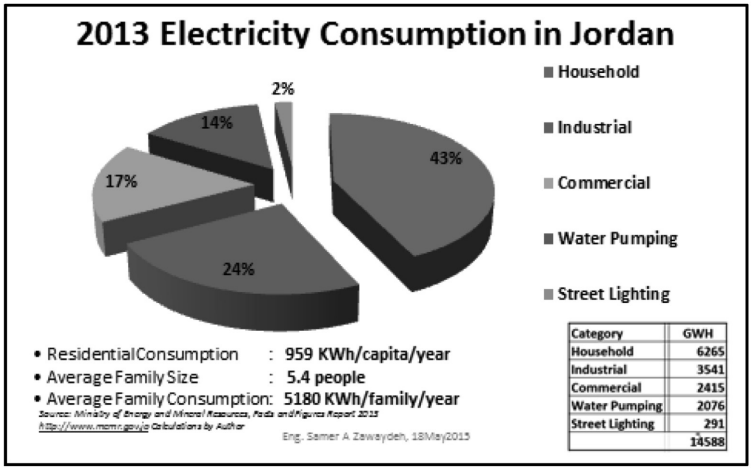

Figure 1. Jordan's electricity consumption by sector [1].

Since 2013, the installation of renewable energy resources was permitted after the renewable energy regulatory framework was enacted and it was agreed that electricity from utility scale projects would be sent to the National Electrical Power Company (NEPCO). Subsequently, these intermittent resources are providing a portion of the needed electricity. Consumers are allowed to install renewable energy systems that provide all their annual energy consumption by using on-grid PV and wind systems.

While energy prices were subsidized in the past, the majority of the subsidies were removed after 2008. Currently, fuel prices follow the international market prices for crude oil and national prices are adjusted monthly. The price of crude oil during the past ten years has varied from a high of roughly 140USD/barrel to a low of 28USD/barrel. Commercial, industrial, hospitality, and other consumers are unable to

frequently adjust their commodity prices. This leads to substantial economic losses particularly when oil prices are high.

Jordan's 2020 Primary Energy and Cost Targets

The national strategy [2] is to reduce imported crude oil and products from 82% to 52-55% by 2020, maintain coal usage at 3-5%, increase the renewable energy share in the energy mix to 10%, increase natural gas to 20%, reduce imported electricity and begin using the oil shale reserves up to 10%.

The cost for Jordan's consumed primary energy is found in NEPCO's annual reports. In 2014, this totaled 4,480 million Jordanian Dinars (JDs), an increase from 2010 when the total equaled 2,603 million JDs.

Energy costs were 17.1% of Jordan's total GDP in 2013, reaching a high of 21.1% in 2012 [3] as shown in Figure 2.

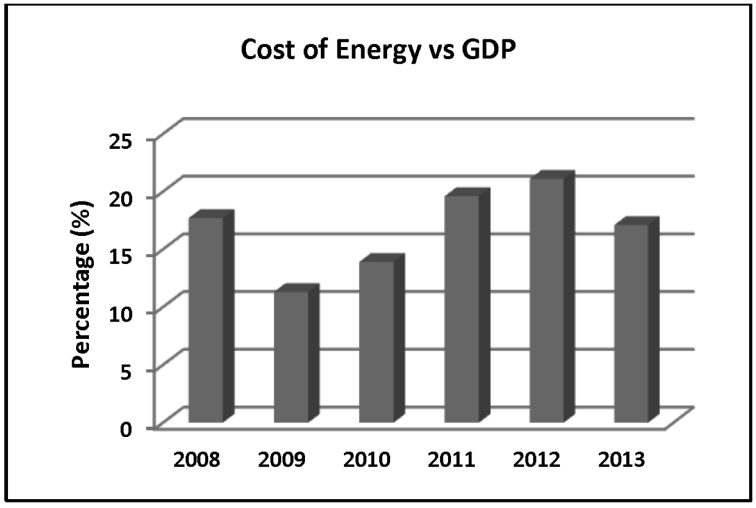

Figure 2. Jordan's cost of energy vs. GDP

The cost per kWh sold in 2013 was 0.145 JD (0.205 USD/kWh) and in 2015 it reached 0.156 JD (0.22 USD/kWh).

Electrical Energy Consumption & Network Losses

The household sector in Jordan consumes 43% of total generated electricity, 24% is consumed by the industrial sector, 17% by the commercial sector, 14% by the water pumping and 2% for street lighting.

The efficiency of the generating stations in Jordan is improving. Currently, the overall efficiency is 41%, which means that the remaining 59% is lost primarily in the form of heat. The national electricity grid has 17% losses. Technical losses are 2.3% in transmission and 6% in distribution, and the remaining losses are unauthorized uses within the network.

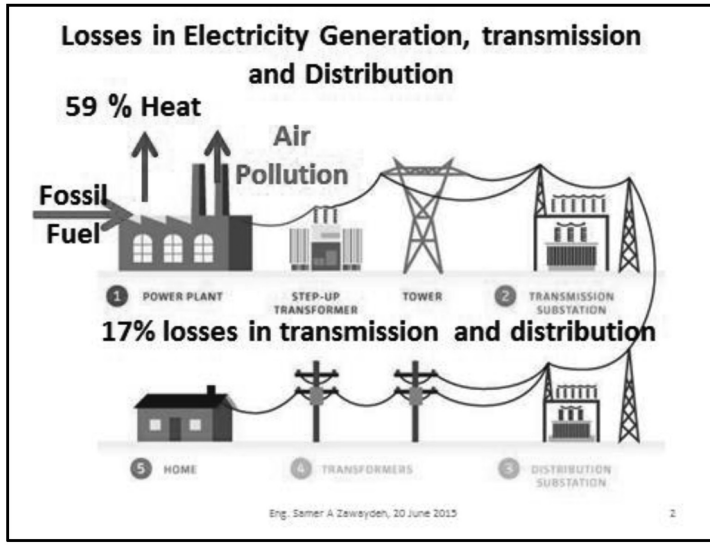

Figure 3. Losses from Jordan's electrical generation network.

Jordan's 2020 Renewable Energy Targets

The national plan that was developed in 2007 called for 7% of the primary energy mix to be RE by 2015 and 10% by 2020. The recent RE targets reported by the MEMR are 1,000 MW of wind (65% of total), 600 MW of solar (32%) and 50 MW using biomass (3%) by 2020.

STAKEHOLDERS

The energy sector directly contributes to all the economic sectors in the country. It is very important to have positive interactions among the various stakeholders to achieve their requirements and expectations. The major stakeholders include representatives from both the public and private sectors.

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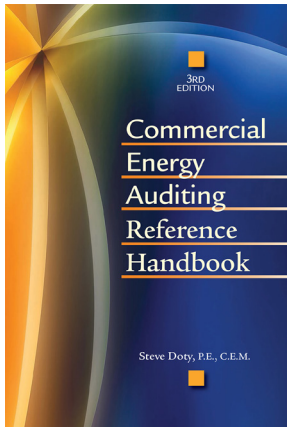

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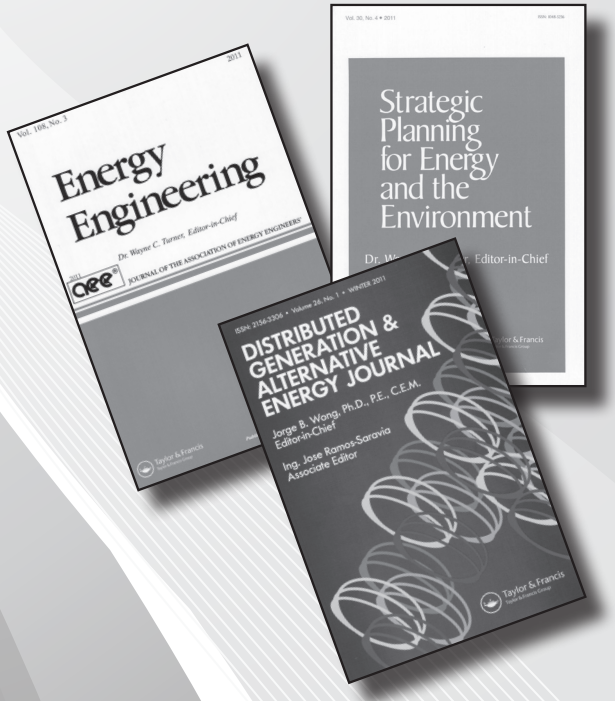

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In the public sector, energy policies are established by the Ministry of Energy and Mineral Resources. The energy sector is regulated by the Energy and Minerals Regulatory Commission (EMRC). Electricity is generated by the different generation stations, transmitted by the National Electrical Power Company (NEPCO), and distributed by the electricity distribution companies. The Jordan National Building Council (JNBC) under the Ministry of Public Works and Housing issues the national technical codes and guides which govern building design and construction. The media updates the various stakeholders. Universities are also key stakeholders as they develop the capabilities of students in the energy sector.

The private sector leads the economy and engages the tools for future development in the EE and RE sectors. Private sector initiatives are varied. Private universities provide energy-related educational programs and today, at least ten training centers are offering RE and electrical energy courses.

Developers began planning for RE projects after the expression of interest (EOI#1) was issued in July 2011. A total of 68 companies responded to EOI#1, expressing interest in implementing wind and solar projects. Twelve companies signed power purchase agreements (PPA) with NEPCO in March 2014. Equipment suppliers are offering new products and taking advantage of the 0% customs and 0% sales tax on energy efficiency (EE) and RE systems which are now major industry incentives. Financial institutions are offering green energy loans for EE and RE projects to a maximum 100% of the project value.

The media has been reporting on solar and wind projects in Jordan for the last three years. Energy exhibitions and conferences occur monthly. Such activities facilitate networking and communication among stakeholders and increase the likelihood of progress toward a clean energy economy.

REGULATORY SECTOR

The Renewable Energy and Energy Efficiency Law (REEEL) (13) 2012 was first developed in 2008/2009, issued in preliminary form in 2010, enacted in 2012, revised as REEEL (33) in 2014, and reenacted in 2015. Bylaw (10) providing the customs and tax exemption was also revised and became Bylaw (13) in 2015. Bylaw (73) for energy efficiency

was issued to regulate the sector. Figure 4 summarizes the development of Jordan's recent energy laws and regulations.

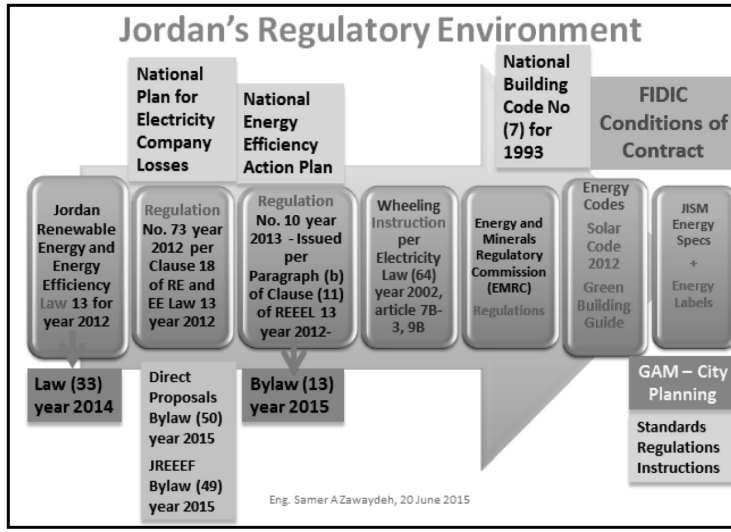


Figure 4. Energy sector regulatory environment [4].

Two bylaws help regulate the development of the RE sector. In 2015, Bylaw (49) supporting the Jordan Renewable Energy and Energy Efficiency Fund was issued along with Bylaw (50) enabling direct proposals.

Wheeling regulations were issued to regulate the generation of RE at locations distant from the points of consumption. The RE Guide was issued by the Energy and Minerals Regulatory Commission (EMRC) when the REEEL was issued. This guide assisted consumers with the process of requesting the installation of RE systems, including review, changes, installation and commissioning.

The Jordan National Building Council (JNBC), part of the Ministry of Public Works and Housing (MoPWH), issued the Solar Code in 2012 which outlines the mandatory requirements for the installation of solar water heaters and solar PV. The Jordan Green Building Guide has a section devoted to the energy and renewable energy point structure providing increases in points available for increased percentages of renewable energy supplied. The Jordan Standards and Metrology Organization (JSMO) prepared energy label regulations for electrical equipment.

The National Energy Efficiency Action Plan (NEEAP) was approved in June 2013 and it calls for several projects to be implemented to achieve the targeted requirements for renewables.

COST OF ELECTRICITY

The cost of electricity began increasing in 2008 after fuel prices subsidies were removed. As fuel prices rose, electric companies began to face losses. The reported losses are roughly one billion JD (1.40 Billion USD) in 2013 and 1.18 Billion JD (1.65 Billion USD) in 2014. A national strategy was developed to increase electricity prices through 2017, implement measures to raise money from large end consumers and develop energy efficiency measures offset the losses. This plan calls specifically for the implementation of RE projects.

Residential and Industrial Sectors

Jordan's residential and industrial sectors have specific electricity tariffs. The residential sector has a stepped tariff with prices increasing since 2008 for consumers with monthly consumption over 600 kWh monthly. There are seven tariff categories for the residential sector. The first four are subsidized and the tariff is fixed for small consumers. To regulate the market and reduce electric company losses, the tariff was fixed for 2014 through 2017 for each category. Tariffs are shown in Table 1.

Table 1. Residential electricity tariff.

Year – Unit Price (1/1,000 USD/kWh)					
2017	2016	2015	2014	QTY (kWh/ month)	Tariff Category (kWh/month)
46.2	46.2	46.2	46.2	160	1 - 160
100.8	10.8	10.,8	100.8	140	161 - 300
120.4	120.4	120.4	120.4	200	301 - 500
159.6	159.6	159.6	159.6	100	501 - 600
263.2	245.0	228.2	212.8	150	601 - 750
313.6	292.6	271.6	253.4	250	751 – 1,000
414.4	399.0	379.4	362.6		above 1,000

Electricity prices in Jordan were low until 2008. Afterwards, the number of tariff categories increased along with the unit rates for high use consumers [5]. Electricity tariffs for consumers using less than 600 kWh monthly will increase until after 2017. Residential consumers using more than 600 kWh monthly will experience annual increases in tariffs of between 5-15% through 2017.

The industrial sector has five different tariff categories:

1) Small—under 10,000 kWh per month;
2) Small—over 10,000 kWh per month;
3) Medium;
4) Large mining; and
5) Large other.

Each of these sectors will experience tariff increases over a 4-year period. Figure 5 shows the current costs of electricity and their expected price increases. Large consumers will experience greater rate increases for electricity than small consumers.

The day rate for large industrial users is 0.27 JD/KWh (0.38USD/kWh) in 2015 and is planned to increase to 0.32 JD/kWh (0.45 USD/kWh) in 2017.

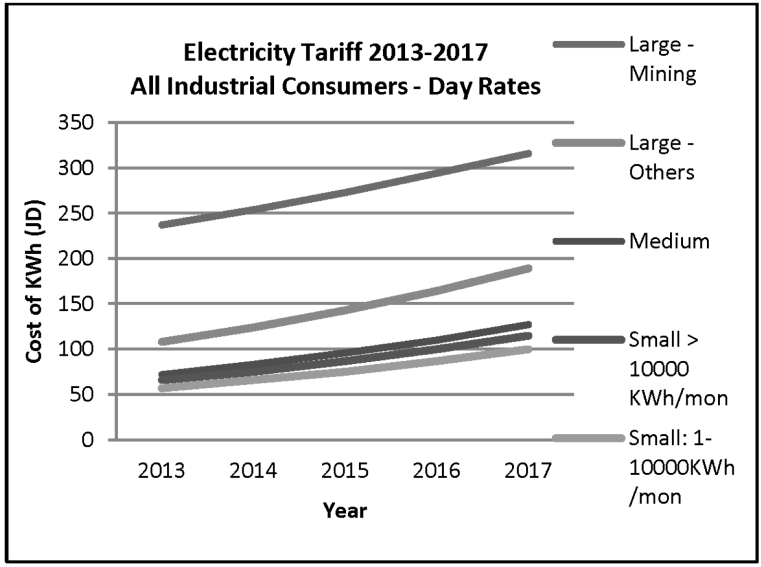


Figure 5. Planned tariff for industrial sector categories.

Adopting renewable energy projects is a good investment strategy for large consumers because they can reduce their levelized cost of energy (LCOE), avoid the impact of price variability and maintain a competitive advantage.

RENEWABLE ENERGY—PHOTOVOLTAIC

The availability of RE resources depends on geographic location and local meteorological conditions. In order to explore the economic feasibility of RE resources, field measurements must be taken for a minimum of twelve months at the locations where utility scale projects are planned. Engineering firms often require that measurements be recorded for three years prior to using data for the design of utility scale projects.

Jordan has over 300 sunny days annually, and the further south the better the solar resources. The German Aerospace Agency (DLR) supported the development of the solar sector in Jordan by installing a solar scientific data measurement station at the Ma'an Development Area. Solar data measured at the industrial park in Ma'an for three years showed an average direct normal irradiance (DNI) of 2,700 kWh / m^2 annually. This is among the highest readings in the world.

Solar Photovoltaic (PV) Installations

As of 2015, there are approximately 747 PV decentralized systems installed in Jordan with a total capacity of 23.6 MW. It is expected that the installations by consumers to completely or partially provide for their annual energy requirements will be over 60 MW by the end of 2015. Utility scale projects being developed with power purchase agreements are expected to provide an additional 200 MW within the next 18 months.

Table 2 shows the solar PV projects currently being developed. This is more than 70% of the 2020 Solar RE targets.

Major Investors—Expression of Interest II

Expression of interest (EOI) requests encourage companies to develop utility scale projects. EOI#2 is underway for selection of four companies to each develop 50 MW solar-electric plants. In 2015, 34 companies submitted their responses to the EOI to develop solar plants.

Table 2. Jordan's solar PV projects.

1	Kawar Consortium	53
2	Catalyst Private Equity	20
3	EJRE Projects	20
4	SunEdison Hellas SA	20
5	Evolution Solar	20
6	Shamsuna Power Company	10
7	Clean Energy Concepts	10
8	Ennera	10
9	Bright Power Group	10
10	Martifer Solar, S.A	10
11	Scatec Solar	10
12	Greenland Alternative Energy	10
13	Philadelphia Solar	10
14	Spanish Grant	3
15	Queira	65
16	Expression of Interest #2	200
17	Installed Decentralized	24
18	In progress	40
	Total Solar	***468***

The financial results of the EOI#2 were announced by MEMR in May 2015 as shown in the Table 3. The average of the lowest four prices was 0.0482 JD/KW (0.068 USD/kWh). Therefore, the second group of utility scale renewable energy solar PV projects will sell roughly 400 GWH per year at the average price of 0.068 USD/kWh for the next 20 years.

PV ECONOMIC DEVELOPMENT

Investment

One of the economic goals for developing countries is to increase foreign direct investment (FDI). The RE sector in Jordan, like those of other countries, has attracted major companies. Over 100 different international companies have competed for RE projects in Jordan since 2012.

Utility scale RE projects initially require large capital investments. The Central Bank of Jordan (CBJ) started EE and RE low interest loans (2.3%) up to 10 Million JD (14 Million USD) for use of clean energy technologies.

Table 3. Results of Expression of Interest #2.

Partnership/bidder	Bid in JOD cents/kWh	Bid in US$/kWh
GI Karnomourakis SunRise PV Systems (Greece)	4.34	0.0613
Saudi Oger (Saudi Arabia)	4.60	0.0649
Fotowatio/ALJ (Spain)	4.89	0.0691
Hareon Swiss Holding (Switzerland)	5.43	0.0767
Evolution Solar/AMP	5.59	0.0789
Philadelphia Solar (Jordan)	5.60	0.0791
SolaireDirect (France)	5.68	0.0802
Neoen (France)	5.74	0.0810
Linuo Group (China)	5.86	0.0827
Activ Solar (Austria)	6.00	0.0847
Mainstream (Ireland)	6.15	0.0868
Kawar-First Solar (Jordan)	6.23	0.0880
Alten Renewable Energy Developments (Netherlands)	6.28	0.0886
Al Salad for RE (JoSolors)	6.36	0.0889
SkyPower-FAS (US)	6.36	0.0898
SunEdison (US)	6.40	0.0904
Elecnor (Spain)	6.41	0.0905
ACWA (Saudi Arabia)	6.58	0.0929
SECI (Italy)	6.60	0.0932
ELF-ENEL (Jordan)	6.6	0.0932
Scatec (Norway)	6.70	0.0946
Hanergy (China)	7.00	0.0988
Spectrum International for Investment (Jordan)	7.30	0.1031
Suncore PV Technology (France)	9.40	0.1327

International banks, the World Bank and other major banks in developed countries are eager to provide long term loans at low interest rates because they consider these investments to be secure and use proven technologies. Local banks now offer low fixed interest rates for renewable energy projects for a period of 10 years.

Bylaw (50) under the REEEL (13) year 2012 was issued in 2015 to regulate investments in RE projects. This supports the RE sector and enhances the transition to clean energy.

Manufacturing and Commercial Development

Renewable energy manufacturing opportunities exist for those with manufacturing experience. The first solar module assembly plant in the Middle East was opened in Jordan in 2008.

Philadelphia Solar began production prior to the issuance of the REEEL. Their Jordanian solar modules were exported to Europe and North Africa. The company expanded production to include mounting structures in 2015. Today, they have a fully automated structure fabrication line to meet the anticipate demand for utility scale PV projects.

Starting in 2014, electric cable manufacturers developed capabilities to produce PV cables and direct current (DC) cables.

Commercial sector PV developed gradually. It was linked to the issuance of the REEEL in 2012. Then there were 40 companies operating in the commercial PV sector in Jordan. Today, there are over 500 such companies that directly and indirectly employ over 10,000 people.

University Initiatives

The RE sector needs qualified workers to lead and manage the sector. Job opportunities across the supply chain for the PV sector include sales, estimation, education, design, training, manufacturing, procurement, construction, commissioning, quality control and maintenance.

To supply such needs, several major universities incorporated the required undergraduate and graduate RE university degrees. These universities include:

University of Jordan
Jordan University of Science and Technology
German Jordanian University
Hashemite University
Hussein Bin Talal University
Zaytouneh University
Middle East University

The universities are cooperating with international universities in Europe and the U.S. to develop their training capabilities and their cur-

riculums. The education systems will continuously produce qualified and trained workers for the clean technology sectors in Jordan.

Universities are also investing in utility scale projects. These will support education, help cover their annual energy demand and avoid paying higher electricity costs, presently about 0.38USD/kWh. The projects that are being developed include:

Hashemite University (5 MW)
Jordan University of Science and Technology (5 MW)
Hussein Bin Talal University (4 MW)
Yarmouk University (3 MW)
Taffila University (1 MW)
Petra University (1.5 MW
Zaytouneh University (1.5 MW)
Applied Science University (0.5 MW)
Hussein Bin Talal University (50 MW)
Al Beit University (85 MW)
University of Jordan (40 MW)

RE Development Initiatives

National electricity grids are often not designed to accommodate renewable energy. The flow of electricity during the last 60 years was from the generation station to the demand center. Now Jordan's national grid must carry electricity bi-directionally since consumers are now generating entities as well. The decentralized RE project owners (commercial and residential) are required to study the electricity grid near the project prior to site development. To accommodate the new RE projects, this often requires upgrades to the grid infrastructure.

Utility scale RE projects are planned for development in locations with the best resources. The Ma'an Development Area (MDA) was dedicated to the purpose of accommodating developers selected for EOI#1. The MDA is the targeted location for 190 MW of solar PV between 2015 and 2017. The MDA also is developing another area (5,000,000 m^2) to develop future Phase III RE projects.

The REEEL (13) year 2012 established an upper limit to RE development of 500 MW. This limit can be increased depending on the future capabilities of the national grid. This important subject was addressed by international consulting companies from the U.S. and Japan.

The Green Corridor concept will reinforce Jordan's high voltage electricity network, enabling the integration of more renewable genera-

tion capacity and improving supply reliability. It consists of two new transmission lines (400 kV/150 km and 132 kV/51 km), upgrading three existing lines (132 kV/100 km) and construction of one new 400/132 kV, 1,200 MVA substation. Construction is anticipated by 2017. A third stage is being considered in southern Jordan between Qatraneh and Aqaba and will be constructed when projects in Aqaba are operational.

Jordan Renewable Energy and Energy Efficiency Fund (JREEEF)

This fund is managed by the MEMR. Bylaw (49) under the REEEL (13) year 2012 was enacted to regulate the development and implementation of monies to support EE and RE projects. The projects implemented by the fund use a revolving loan program. The first project purchased roughly 5,000 solar water heaters (SWHs) and distributed them to 70 community based organizations (CBOs) [6]. These organizations will distribute the SWHs to families that will reimburse installation costs from savings on their electricity bills. Once the consumer repays the CBO the full cost of their SWH system, then another consumer will use the revolving funds to purchase a new SWH.

BENEFITS OF RENEWABLE

The renewable energy sources developed within Jordan are determined by the owners. Imported fossil fuel energy resources are less attractive than RE systems that provide locally available energy. Energy from RE systems reduces imported energy expenditures from purchasing fossil fuels.

It is expected that the effects of climate change will be a driver to adopt more of these projects. Several projects in Jordan, including three solar energy projects, are registered under the Carbon Development Mechanism (CDM) and are benefiting economically from the emission reductions.

Attractive Financial Incentives

The return on investment for RE projects depends on the cost of electricity for the consumer or the investor. Large consumers will have higher electricity tariffs and the payback period is estimated to be 30-36 months. Consumers with lower electricity tariffs will have much longer payback periods on their investments. To assist consumers, the electric distribution companies have a program that allows customers

to pay off their investments in new solar PV systems by deducting costs from their monthly electricity bills. This provides a solution for owners, enabling them to own the PV systems a few years after installation.

The Central Bank of Jordan, through the local commercial banks is providing low interest loans for RE and EE projects. This makes the investment in such projects more attractive. In addition, international banks are funding these projects at lower interest rates than other types of investments.

The Ministry of Energy and Mineral Resources has programs that support RE and EE. The MEMR recently announced a plan to support solar PV systems for 6,000 mosques covering 20% of the cost.

Investors in EOI#1 had a fixed feed-in tariff of 0.12JD/kWh (0.17USD/kWh) for 20 years. This is a very attractive price compared to the current prices (0.068$/kWh).

RE systems are also exempt from taxes according to bylaw (10) year 2012 and bylaw (13) year 2015. This provides a competitive advantage to suppliers and owners who purchase RE systems.

Project Life

RE systems operate for 20-30 years, providing predicable energy for an extended period of time. Using PV module manufacturers' equipment degradation information, predicted PV performance can be integrated into the electric grid requirements.

In Jordan, these systems must be cleaned every 2-3 weeks depending on environmental and seasonal conditions. The operations and maintenance (O&M) requirements are minimal but provide opportunities for service providers.

Reduction in Fuel Losses in Generation, Transmission and Distribution

Presently, the overall efficiency of all generating stations in Jordan is 41%. This means that 59% of the imported fuel purchased is lost in the form of heat to the atmosphere. RE systems eliminate this wasted fuel. This saves money throughout the expected life of the project.

The aggregated loss in the national electricity grid's transmission and distribution networks is approximately 17%. The advantages of on-site RE generation include eliminating these losses and their associated costs.

Fixed Fuel Costs

Jordan's government has issued requests for 400 MW of solar energy. This will allow the prices of electricity to be fixed for the expected life of the projects in accordance with prices in the PPAs. The feed-in tariff for the first 200 MW is 0.12 JD/kWh (0.17USD/kWh) with the second 200 kWh having a lower rate.

Large consumers in Jordan (e.g., banking, telecommunication, universities, large industries, etc.) will have the opportunity to install RE systems to handle 100% of their electricity needs. They will be able to avoid fluctuations in electrical energy prices that result from fossil fuel price variability, improving their competitiveness internationally.

SOLAR ENERGY PROJECT DEVELOPMENT

Residential, Industrial and Commercial PV Systems

Residential systems are relatively small, rated typically less than 200 kWp. The systems can be installed within 2-3 months after the application to the EMRC has been approved.

Jordanian industries vary in size. Large industries consume about 10% of total electricity. These industries need to adopt renewable energy resources to help offset increasing fossil fuel costs.

The largest grid-connected commercial solar PV installation is the 1 MW ground mount system installed in May 2014 at the Ma'an Development Area.

Refugee Camps

Several hundreds of the housing units in a refugee camp that were supplied at the beginning of the war in Syria in 2011/2012 were equipped with off-grid PV systems. These consisted of 0.5 kWp modules with battery storage.

The camp grew afterwards and there is now a project to install 6 MW of PV in phases to provide for the complete needs of the camp (about 12 GWh annually).

Two Axis Tracking Pilot Projects

Tracking technologies increase the electricity produced by PV systems. The Hashemite University was one of the first in Jordan to install pilot projects using different types of solar PV modules and designs.

The expected increase in the annual energy yield for the two axis systems ranges from 15% to 45%.

Figure 6. Two axis tracking system (Hashemite University).

Water Pumping

PV off-grid and on-grid systems are also used for water pumping applications. Consumers with agricultural tariffs pay the subsidized rate of 0.06JD/kWh (0.084USD/kWh) and often do not view solar PV systems as an attractive investment. However, water pumping applications are often feasible alternatives for other consumers.

Transportation

Fifty-one percent of the final energy consumption in Jordan is consumed by the transportation sector [1]. Pilot projects have been initiated to investigate the use of electric vehicles in Jordan.

An electric charging station was installed at the Royal Scientific Society in 2009. The PV station generates electricity that is stored in batteries which supply energy required for electric automobiles.

In 2015, the Greater Amman Municipality announced that they will install ten charging stations. Large suppliers also made electric cars available in Jordan for high end consumers such as owners of BMWs.

Solar Water Heaters

The use of solar water heaters started in Jordan in the late 1970s. Currently, over 1.12 million m^2 of collector area have been installed [8].

This installed capacity reduced the country's primary energy demand by 145,000 tons of oil equivalent (TOE) annually [1]. The SWHs are directly contributing to 1.8% of the 2020 RE target. Most of these systems are single family domestic hot water heating systems.

Jordan's engineering, manufacturing, operation and maintenance capabilities for solar hot water heating systems have not advanced rapidly enough to meet the growth of consumer demand. The solar hot water technologies for multi-family, commercial, industrial, and for combined cooling and heating systems need to be further developed to catch up with the development of these systems in countries like Spain and Greece.

While there are roughly 50 small equipment suppliers, there are just a few large manufacturers to cover market demand. Engineering of larger systems will continue to be important for progress, enabling SWHs to make a greater contribution to Jordan's 2020 RE targets.

WIND PROJECT DEVELOPMENT

Wind energy projects have been located at Hofa and Ibrahimieh since 1998. Utility scale projects started in 2010 and the first completed project was at the Fujeij research station (1.65 MW). The results recorded at the research station indicated that the area has substantial potential for wind power.

These projects were followed by the completion of the Taffila wind farm (117 MW) in May 2015 with 38 turbines. These are Vestas 112x3.0 MW turbines with a hub height of 94 meters and blade length of 56 meters. The balance of the project was constructed by a local contractor with 250 workers who completed the excavation, foundation, and road works in 18 months. This required special expertise and equipment from outside Jordan, especially for the heavy lift transporting and cranes. The wind farm will be operated by 40 people for the next 20 years. The expected annual energy yield is 400 MW.

The Ma'an wind energy project (80 MW) and several other projects are pending and are expected to start construction in 2016 (see Table 4).

Further development of 700 MW of wind energy projects by 2020 is needed in order to achieve Jordan's RE targets.

Figure 7. Taffila Wind Farm.

Table 4. Wind energy projects.

#	Project Name	Size	Status
	Hofa	1.125	Old Project
	Ibrahimieh	0.32	Old Project
1	Fujeij Research Station	1.65	On Line
2	Taffila	117	Commissioned
3	Ma'an	80	Under Construction
4	Fujeij	99	Awarded
5	Rajef	83	Study stage
6	Ibrahimiah	6	Study stage
7	Lamsa	100	Study stage

GEOTHERMAL ENERGY PROJECTS

One of the largest geothermal projects in the Middle East is located at the American University of Madaba. It was designed and constructed by a company that specializes in this field. The details of the projects are shown in Figure 8.

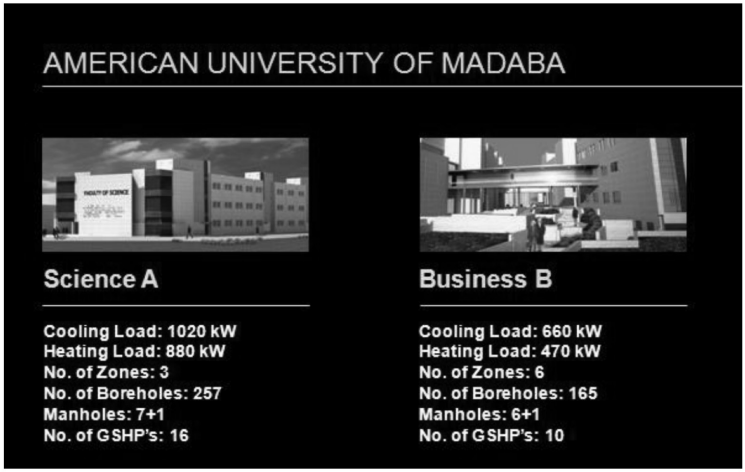


Figure 8. Jordan's geothermal energy project.

While geothermal energy is available, the technology is not yet cost effective, and there are few interested consumers. There are only about ten geothermal residential and commercial projects installed by building owners in Jordan.

REDUCING CARBON EMISSIONS

Combating climate change is a key driver of the world movement to adopt renewable energy. In Jordan, the energy production sector contributes 74% of total greenhouse gas emissions with the industry share being just 8% [9]. The RE systems planned for development in Jordan will reduce future carbon emissions.

The U.S., China and India have agreements to reduce atmospheric CO_2 levels. Jordan has a relatively small population (6.6 million) and average energy intensity. While not a major carbon emitter, the country can play an important leadership role in the Middle East. Jordan's CO_2 emissions are reported annually by the International Energy Agency (IEA). The reported 2011 CO_2 emissions for Jordan total 19.8 million tons.

Average CO_2 emissions per kWh from electricity generation as reported by Jordan to the IEA from 1990 to 2010 [7] peaked in 1992. By 2010, each kWh of electricity generated on average 581 grams CO_2.

The installed SWH capacities in Jordan reduce the emissions of CO_2 by 370,000 tons annually. This is one of Jordan's most important contributions to global sustainability.

Wind energy in Jordan will provide the largest share of renewables with roughly 1,000 MW of electrical capacity installed by 2020. To achieve the 1,000 MW target, the installation rates in the Table 5 were assumed for this assessment. The estimated energy generated includes the Taffila Wind project's design annual energy yield. Table 5 estimates the CO_2 emissions avoided based on the average CO_2 generated from each kWh in Jordan.

Table 5. CO_2 emission reductions from wind energy.

Year	MW	GWH/ year	GWH/ year accumulated	CO_2 tons avoided
2015	117	400	400	232,400
2016	80	274	674	391,306
2017	203	694	1,368	794,530
2018	200	684	2,051	1,191,795
2019	200	684	2,735	1,589,060
2020	200	684	3,419	1,986,325
Total	**1,000**			**6,185,415**

Jordan is planning to install a 50 MW plant to continuously generate electrical energy from biomass using supplies of waste materials. The estimated reductions of CO_2 from the operation of this plant are shown in Table 6.

Table 6. CO_2 Emission reductions from biomass energy.

Year	MW	GWH/ year	GWH/year accumulated	CO_2 tons avoided
2018	50	400	400	232,400
2019	50	400	800	464,800
2020	50	400	1,200	697,200

The large-scale projects (200 MW) will start construction by May 2015. The estimated CO_2 reductions due to renewable energy projects are shown in Table 7.

Table 7. 2020 CO_2 Emission reductions from renewables.

Project Name	Size	Operation Date	CO_2 Emission Reduction (Ton)	No. of Years	Total Reductions (Ton CO_2)
EOI#1	200	2016	200,000	5	1,000,000
EOI#2	200	2018	200,000	3	600,000
Misc.	100	Varies	100,000	2	200,000
SWHs	1.1M M^2	2012	350,000	9	3,150,000
Wind	1,000	2020			6,200,000
Biomass	50				700,000
Total					11,850,000

Using a computer simulation for different types of solar PV modules installed in Amman with identical sizes, tilt angles and orientation, the expected average 25-year life cycle electricity yield is 41,000 kWh per KW_p after accounting for any degradation as specified in manufacturer data sheets. For one sample project, the annual energy yield was calculated for several solar PV suppliers, which translated into the 25-year expected total energy yields as shown Figure 9.

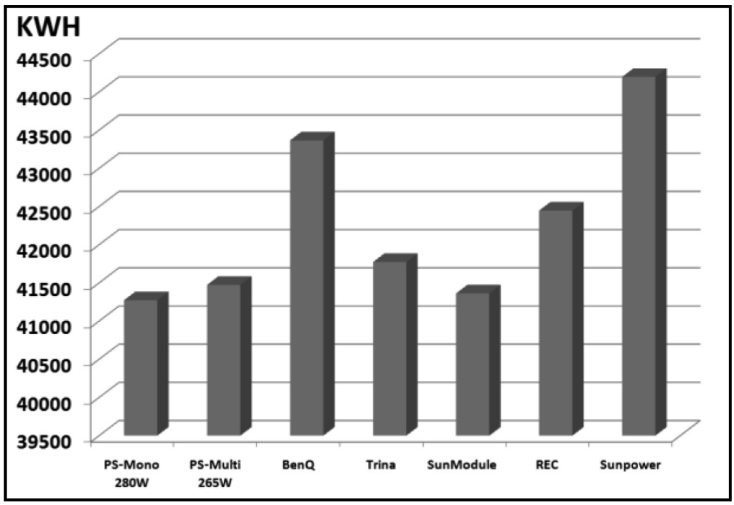
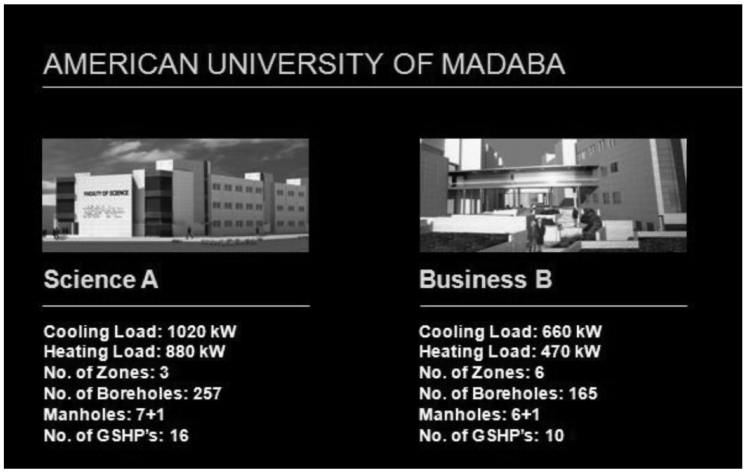


Figure 9. 25-year PV modules total energy yield (kWh/KW_p).

Using the average CO_2 emissions in Jordan (580g of CO_2/kWh), the approximate reduction in CO_2 per kW_p is estimated to be 24 metric tons during the expected project life of 25 years. Based on the national plan to install 600 MW by 2020, and calculating the CO_2 emissions saved during the following 20 years, the expected emission reductions would equal 14 million metric tons of CO_2.

Table 8. 2020 CO_2 Emission reductions due to 600 MW of solar installed for 20 years.



SOCIAL IMPACTS

Energy directly impacts the lives of people. Consumers are more severely affected by increases in energy prices, directly impacting all other economic sectors. Some sectors are more resilient than others. For example, the commercial sector simply increases the price of their products as energy prices increase. The manufacturing sector is unable to readily increase the prices of their goods since products from exporting countries such as China and Saudi Arabia may be more competitive. This is why many industries that heavily depend on electricity have closed their businesses in Jordan.

The many stakeholders in the renewable energy sector must be fully integrated within the economy to successfully implement their

projects. This process begins with the education of engineers, technicians and labor.

The stakeholders working in the energy sector need to upgrade their skills to work with renewables. A vocational education center in Ma'an started a year-long training program for 30 technicians in 2014. The program will help them gain skills for employment on utility scale solar PV projects. Several Jordanian universities are developing curriculums to accommodate RE education. As the market in solar and wind energy systems matures, more specialization will eventually develop into a multi-tier career map [10].

The RE technologies available will impact the projects being planned and developed to achieve the 2020 targets and beyond. Knowledge of RE technologies and grid capacities will enable stakeholders to develop an accurate means of developing system capacities. This will lead to social and environmental benefits including new employment, education, regional competitiveness, and greater availability of financing to develop such projects.

SUMMARY AND CONCLUSIONS

Sustainable development suggests that our proposed solutions be economically feasible, environmental friendly, socially acceptable, and have long term impacts. The RE sector is achieving these requirements. RE a sustainable energy solution which improves a country's mix of energy resources.

RE technologies are commercially available and can be competitive with fossil fuel systems. Clean renewable energy technologies will continue to improve and further reduce the cost of energy.

The regulatory framework is the key in any country for the development of RE. Continuous improvement based on favorable public and private stakeholder experiences will continue to evolve. As stakeholders become more aware, they will be able to make more informed decisions.

Technical knowledge and workforce development is the most important factor in the development of solar PV.

There are many economic and environmental advantages for using RE systems. These include job creation, energy security, reduction in losses, access to electricity, and reductions in greenhouse gas emis-

sions. RE systems will be among the alternative solutions adopted by countries rather than continuing to use fossil fuels and contributing to atmospheric pollution and climate change. RE systems must be adopted to avoid the instability associated with international fuel price variability.

Developing frameworks and incentives for consumers, industries and governments to use renewable energy is necessary to maintain steady and predictable growth. Since energy is integrated within the different economic sectors and some businesses are unable to quickly respond to flu ctuations in fossil fuel costs, they are forced out of business. The regional development of the RE sector will help ensure the availability of skilled employees.

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