Economic and Social Commission for Western Asia

UNITED NATIONS

الاسكوا

ESCWA

United Nations Development Account project on promoting renewable energy investments for climate change mitigation and sustainable development

Case Study on Policy Reforms to Promote Renewable Energy in Lebanon

E/ESCWA/SDPD/2017/CP.7

Economic and Social Commission for Western Asia

United Nations Development Account project on promoting renewable energy investments for climate change mitigation and sustainable development

Case Study on Policy Reforms to Promote Renewable Energy in Lebanon

UNITED NATIONS
Beirut

United Nations publication issued by ESCWA, United Nations House,
Riad El Solh Square, P.O. Box: 11-8575, Beirut, Lebanon.

Website: www.unescwa.org.

Cover photo credits:

Solar panel, by stevanovicigor
Wind energy, by Satura
Beirut sea rock in Lebanon, by Wissam Santina

Preface

This case study report was prepared for the Energy Section of the Economic and Social Commission for Western Asia (UN ESCWA) Sustainable Development Policies Division within the framework of the United Nations Development Account (UNDA) project on Promoting Renewable Energy (RE) Investments for Climate Change Mitigation and Sustainable Development. The project focused on capacity building for policymakers and project developers in order to promote investments in RE projects. The project was led by the UN Social Commission for Western Asia (UN ESCWA) and implemented in partnership with the United Nations Economic Commission for Europe (UNECE).

The UNDA project included case studies on the experience of RE policy reforms in selected countries from each of the two Regional Commissions (RCs). A total of eight countries were targeted (four from each RC): Jordan, Lebanon, Morocco and UAE from the UN ESCWA Member states, and Serbia, Ukraine, Kazakhstan and Georgia from UN-ECE Member States.

The present report covers the case study for Lebanon and was prepared by Mr. Joseph Al Assad (PhD), Associate Professor at the USEK University, Lebanon, he is currently serving at the ministry of energy and water as a senior advisor in renewable energy and energy efficiency. He has been leading a number of related initiatives, including the preparation of the Lebanese Renewable Energy Strategy, the National Renewable Energy Action Plan and the Lebanese Energy Statistics Review. The following experts helped review and finalize the document: Mr, Mazen Halawi, Head of Subsidized Loans and Financing Programs Divisions at the Banque Du Liban, Lebanon, and member of the UNDA advisory board; Radia Sedaoui, Chief, Energy Section and Mongi Bida, First Economic Affairs Officer (SDPD/UN ESCWA in Beirut).

Executive summary

In cooperation with the United Nations Economic Commission for Europe (UNECE), the United Nations Economic and Social Commission for Western Asia (ESCWA) is implementing a United Nations Development Account Project Promoting Renewable Energy Investments for Climate Change Mitigation and Sustainable Development.

The objective of the project is to assist the two UN regional commissions to strengthen capacities of their Member States to attract investments in renewable energy projects in the context of climate change mitigation and sustainable development.

The report presents one of the four case studies on the experience of policy reforms in selected ESCWA Member countries. Its main purpose document is to present a comprehensive study of the impact of the implementation of the National Renewable Energy Action Plan (NREAP) on the Lebanese energy market in general.

The energy sector in Lebanon has been suffering since the beginning of the 1990s because of the lack of a clear policy setting goals for the development of the sector. No investments have been made in any power plants since the mid-1990s, leading to a decline in their generating capacities, and enlarging the deficit thereby with increasing demand.

Several plans and policies were developed in order to improve the situation. The most comprehensive plan was prepared by Gebran Bassil and adopted by the Lebanese Government in 2010. For political reasons, however, the application of the plan was delayed several times.

Since the beginning of the conflict in Syrian Arab Republic, the problem has been amplified even more by the influx of Syrian refugees, increasing the Lebanese population and thereby the demand for electricity, and widening the gap between generation and demand to approximately 5,524 GWh in 2014.

Renewable energies presented an opportunity in Lebanon, offering a developing market in the electricity sector, especially in terms of decentralized installations that were adopted essentially as a solution for electricity back-up instead of diesel generators.

Renewable energies have not reached their optimal potential in Lebanon, however, and still lack a legal framework that will allow them to flourish on the national level in a manner that will allow the integration of large-scale renewable energy projects.

During the 2009 Conference of the Parties (COP) meeting in Copenhagen, the Lebanese Government launched a commitment to have 12% of renewable energy in 2020. This commitment was more of a political commitment and lacked a clear definition of the energy mix based on which the 12% target is set.

In 2010, the Lebanese Ministry of Energy and Water (MEW) strengthened and clarified this vision in their Policy Paper for the Electricity Sector by stating that the target was to reach “12% of the electric and thermal supply”.

This policy paper did not, however, set a clear path towards the 12% and did not set shares for each renewable energy technology. All this was completed in the The National Renewable Energy Action Plan for the Republic of Lebanon, in which a clear path was set towards the 2020 target of 767 kton of oil equivalent (ktoe) of renewable energy (equivalent to 12%). Moreover, NREAP proposed a

Shares of renewable energy within the national 12% target

Technology	Generated energy (ktoe)	Share of the 12% target (%)
Wind	595.7	17%
PV, CPV	240	7%
Distributed PV	160	4%
SWH	685.5	19%
CSP	170.6	5%
Hydro	961.9	27%
Geothermal	6	<1%
Biomass	771.5	21%

Source: El Assad, J. and P. El Khoury (2016)

clear distribution of the 2020 among the different resources as shown in the table below.
Having a clear vision, combined with the detailed targets, presents a significant motivation for investors in renewable energies to identify their opportunities and hence help develop the sector even further through the integration of the private sector.

The impact of the implementation of NREAP was studied in this report on Lebanese society from various points of view. The total cost of the implementation of NREAP varies between US$ 1,320 million and US$ 3,166 million, whereas the direct cumulative savings for the Lebanese economy is estimated at approximately US$ 319 million.

From another point of view, these renewable energy projects will be providing about 1,890 hours of extra electricity in 2020, reducing blackouts and diesel generators shares. The first to benefit will be the least fortunate section of the Lebanese population by lowering the financial burden of their electricity bills.

On the environmental level, full application of NREAP will induce a reduction of more than 2,206 kilotons of carbon dioxide equivalent per year (ktCO2eq/year) of equivalent GHG emissions, helping lower Lebanon's contribution from 19,603 ktCO2eq/year by some 11.25% to reach 17,397 ktCO2eq/year.

The main barrier to full deployment of NREAP is the lack of components within the institutional and legal frameworks. Completing these frameworks would help initiate a quicker development and utilization of renewable energy resources, attract more investments into the sector and finally create more job opportunities on several levels.

The Lebanese Government did not give any privileges to renewable energies on the legal level and did not distinguish them from traditional resources which remain tied to the current legal framework, giving Electricité du Liban (EDL) a complete monopoly over the electricity generation, transmission and distribution sectors. In 2002, Law 462 established the Electricity Regulatory Authority (ERA) and gave it the ability to grant licenses for independent power producers to generate electricity and feed it to the grid: it was, however, never implemented. This law was followed by several amendments that were proposed to make it more applicable to current Lebanese conditions and to stimulate the spread of renewable resources. In conclusion, the review of the current legal situation in Lebanon shows that this framework still requires many efforts from the regulatory point of view in order to cope with those being carried out on other levels.

Meanwhile, most of the renewable energy projects are limited in size, essentially because of this legal barrier with some deviation from these restrictions by the recently organized wind-farm tender that can constitute a precedent.

Another example of relatively large-scale projects being implemented in Lebanon is the Beirut River Solar Snake (BRSS), where MEW, through the Lebanese Centre for Energy Conservation (LCEC) called for bidding from private-sector participants, with funding available from the Government. In this case, the private sector will design, build and transfer the renewable energy generation plant.

Challenges facing a full deployment of NREAP are not of a legal nature only but also of a financial and economic nature; most of the local financing mechanisms were adapted to small-scale projects and would need several modifications in order to be applied to larger projects. Concerning international financing, both the political instability and the problem of EDL bankability are bound to increase the financial risk of the investment. In fact, when it comes to any investor or lender, EDL is a company in deficit which will be the main customer for all large-scale renewable energy projects. This represents an added factor to be included in the risk study of the whole investment that will affect the final price.

On the market level, main challenges are caused by the lack of a licensing procedure for suppliers of renewable energy projects. This is combined with the fact that most parts of the renewable energy system are imported and, with the high volatility of their prices, most local suppliers do not keep large stocks. This usually induces delays in the shipment of products and components that may reflect badly on the whole value chain.

Challenges derive also from the technical aspect of renewable energies: they are essentially caused by the lack of a grid code that will allow an effective connection of projects to the electrical grid. The real challenge is that that the Lebanese network itself does not comply with international standards, which imposes a major need to adapt any grid code to the Lebanese situation in terms of operation and dispatching capabilities.

Finally, this study highlights the major impact of the implementation of NREAP on all levels –economic, environmental and social – while predicting also the challenges that would face such an implementation. A series of recommendations was deduced from the study:

- Adopting a clear and transparent custom fee to be applied to all renewable energy products;
- Working on lowering all taxes on renewable energy products with a view to removing them completely at a later date;
- Establishing a clear and transparent financing model for large-scale renewable energy projects;
- Solving the problem of EDL's bankability through the use of another agency related to MEW in Lebanon, which would function as a buffer customer for renewable energy projects;
- Political, security and economical stabilities are very important factors for the development of the renewable energy market;
- Creating a licensing scheme for installers and suppliers in order to be able to monitor and control the quality of components and systems injected into the market, avoiding thereby any negative advertising;
- The development of local manufacture of renewable energy systems, parts or components must be considered as a complementary step for the development of the renewable energy market in Lebanon;
- A serious implementation of energy policies is needed in order to build trust in the field of energy in Lebanon and to send a clear message of commitment thereto.

Table of Content

List of tables

List of figures

List of abbreviations

ADEREE	National Agency for Renewable Energies and Energy Efficiency
AMDI	Agence Marocaine pour le Développement Industriel
AMISOLE	Association Marocaine des Industries Solaires et Eoliennes
ANRE	National Energy Regulatory Authority
AREF	Arab Renewable Energy Framework
BAU	business as usual
BDL	Banque du Liban
BRSS	Beirut River Solar Snake.
CCGT	combined cycle gas turbines
CDER	Renewable Energy Development Centre
CDM	Clean Development Mechanism
CO2	carbon dioxide
CO2eq	carbon dioxide equivalent
COMELEC	Maghreb Electricity Committee
COP	Conference of the Parties (UNFCCC)
CSP	concentrated solar power
DOP	Directorate of Observation and Programming
EDF	Energy Development Fund
EDL	Electricite du Liban
EPC	engineering, procurement and construction
ESCWA	Economic and Social Commission for Western Asia
EUR	euro
FEMIP	Facility for Euro-Mediterranean Investment and Partnership
GDP	gross domestic product
GHG	greenhouse gas
GIZ	Deutsche Gesellschaft für Internationale Zusammenarbeit (German Corporation for International Cooperation)
GME	Maghreb-Europe Gas Pipeline
GW	gigawatt
ha	hectare
HV	high voltage
IEA	International Energy Agency
IFI	international financial instrument
IMA	Morocco-Algeria Interconnection
IME	Morocco-Spain Interconnection
IMF	International Monetary Fund
INDC	Intended Nationally Determined Contribution
IPP	Independent Power Producer
IRENA	International Renewable Energy Agency
IRESEN	Institute for Research into Solar Energy and Renewable Energies
IWP	Integrated Wind Programme
JLEC	JorfLasfar Energy Company
KfW	Kreditanstalt für Wiederaufbau (German development bank)
km	kilometre
kV	kilovolt
kWh	kilowatt hour
LAS	League of Arab States.
LCEC	Lebanese Center for Energy Conservation.
LNG	liquefied natural gas
LPG	liquefied petroleum gas
LV	low voltage
MAD	Moroccan dirham (US$ 1 ≈MAD 9.5)
MASEN	Moroccan Agency for Solar Energy
MEMEE	Ministry of Energy, Mines, Water and Environment
MENA	Middle East and North Africa
MENA-SELECT	Middle East North Africa Sustainable Electricity Trajectories

MEW	Ministry of Energy and Water
MoF	Ministry of Finance
Mt	million tons
Mtoe	million tons of oil-equivalent
MV	medium voltage
MW	megawatt
NAMA	Nationally Appropriate Mitigation Action
NEEAP	National Energy Efficiency Action Plan
NERL	National Exposure Research Laboratory
NREAP	National Renewable Energy Action Plan
OCP	Sharifian Phosphate office (Office Chérifien des Phosphates)
ONE	National Electricity Agency
ONEE	National Agency for Electricity and Potable Water
ONEP	National Drinking Water Agency
PERG	Global Rural Electrification Programme
PPA	power purchase agreement
PPP	power purchase parity / public–private partnership
PROMASOL	Development Programme of the Moroccan Market for Solar Water Heaters
PSPP	pumped storage power plant
PV	photovoltaic
R&D	research and development
RES	renewable energy supply
SIE	Energy Investment Company
SME	small and medium-sized enterprises
SPC	solar project company
SWHs	Solar water heaters
TFC	total final consumption
Toe	ton of oil-equivalent
TPES	total primary energy supply
TWh	terawatt hour
UNDP	United Nations Development Programme
UNEP	United Nations Environment Programme
UNECE	United Nations Economic Commission for Europe.
UNFCCC	United Nations Framework Convention on Climate Change
UNHCR	United Nations High Commissioner for Refugees
US$	United States dollar
VAT	value-added tax
VHV	very high voltage
W	watt

I. Introduction

The energy sector in Lebanon has been suffering since the beginning of the 1990s from the lack of a clear policy setting long- and short-term goals for its development. No investments have been made in any power plants since the mid-1990s, leading to a decline in their generating capacities.

Several plans and policies were developed in order to improve the situation. The most comprehensive plan was prepared by Gebran Bassil and adopted by the Lebanese Government in 2010 (Bassil, 2010). For political reasons, the application of the plan was delayed several times. Political instabilities associated with the influx of refugees has led to worsening the situation of the electricity sector.

Renewable energies presented an opportunity in Lebanon to develop the market in the electricity sector, especially in terms of decentralized installations that were adopted essentially as a solution for electricity back-up to substitute diesel generators.

On the other hand, UN ESCWA, in cooperation with UNECE, is implementing a UN Development Account Project: Promoting Renewable Energy Investments for Climate Change Mitigation and Sustainable Development. The objective of the project is to assist the two UN regional commissions to strengthen capacities of their Member States to attract investments in renewable energy projects in the context of climate change mitigation and sustainable development. This report presents one of the four case studies on the experience of policy reforms in selected ESCWA Member countries. In fact, the main purpose of this document is to present a comprehensive study on the impact of NREAP on the Lebanese market in general and to show the impacts it will have in reforming and shaping these markets.

The second chapter of this study is an introduction to Lebanon: its geography, demography, economics and specificities affecting the energy sector. The third introduces the energy sector in Lebanon and its characteristics along with some indicators. The fourth chapter covers the existing potential for renewable energy production in Lebanon for both electricity generation or direct use, essentially for heating purposes. Chapter 5 discusses the methodologies used for the assessment of such a potential for the main resources identified. Chapters 6 and 7 present the economic and environmental impacts of the implementation of NREAP, and Chapter 8 presents the main parameters of the design considered in NREAP. Chapter 9 examines the barriers and challenges that are, or may be, facing the implementation of NREAP. Chapter 10 presents the conclusion and recommendations of the case study for Lebanon.

II. Country brief

2.1 Geography

Lebanon has been a sovereign State since 1945, located in Western Asia. It is bordered by the Syrian Arab Republic to the north and east with a border 375 km long and by Palestine in the south along a border of 79 km.

Figure 1: Geography of Lebanon

Source: Map 4282 United Nations, January 2010.

The geography of Lebanon is characterized by a coastline of 225 km along the Mediterranean Sea bordering a narrow coastal plain, only 6.5 km at its widest point, adjacent to the Lebanon Mountains rising up to 3,088 m. The Bekaa Valley separates Lebanon and the Anti-Lebanon Mountains that rise up to 2,814 m. The weather in Lebanon is mediterranean: mild to cool, with wet winters and hot and dry summers (CIA, 2016).

The rivers of Lebanon can be divided into two groups. The first group is made up of the east–west rivers, cut mostly into steep gorges, which drain Mount Lebanon (Figure 1). The second group is that of the two large rivers of the Bekaa: the Litani, which flows south and eventually cuts through to the Mediterranean and the Nahr al Assi, which flows northwards into the Syrian Arab Republic (Walley, 2016).

2.2 Demographics

Throughout its whole history, Lebanon has hosted a range of civilizations. This is still reflected in its ethnic mix which includes Arabs, Phoenician descendants and Armenians. According to the CIA World Factbook, the Lebanese population in July 2014 was approximately 5,882,562 (CIA, 2016). Moreover, Lebanon hosts a large number of Palestinian refugees in refugee camps and continues, by far, to host the greatest number of Syrian refugees (in proportion to the population). According to the United Nations High Commissioner for Refugees (UNHCR), , the number of registered Syrian refugees on 31 January 2016 was 1.1 million, representing 24.5% of the total Lebanese population (Harake & Le Borgne, 2016).

2.3 Economics

Lebanon has a long tradition of domestic free trade and investment policies, with free market pricing for most goods and services, an unrestricted exchange and trade system and extensive links with the developed world in virtually all economic activities. The Government has maintained a generally non-interventionist stance towards private investment and public ownership has generally been limited to infrastructure and utilities.

The Lebanese economy has historically relied on the services sector and has always been directed to initiatives in the private sector. This has led to an economy whose major sectors are banking, tourism, construction and real estate.

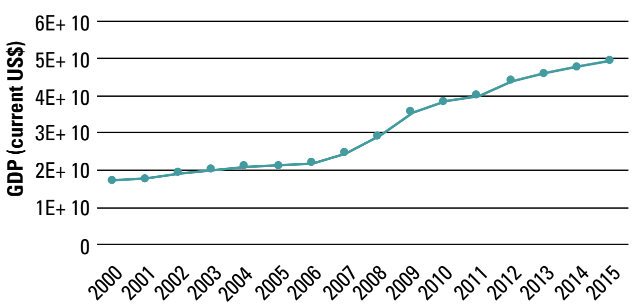
Lebanon's gross domestic product (GDP) was estimated by the World Bank as US$ 47.103 billion with an estimated increase of 1.5% in 2015 (World Bank, 2016).

Looking at the trend during the last 15 years, it can be seen in Figure 2 that GDP at current prices increased from US$ 17.26 billion in 2010 to its current value in 2015.

This increasing trend can be better observed from the annual GDP growth rate for the same period in Figure 3, when it increased from 1.34% in 2000 to a maximum of 10.3% in 2009, falling back to 1.51% in 2015.

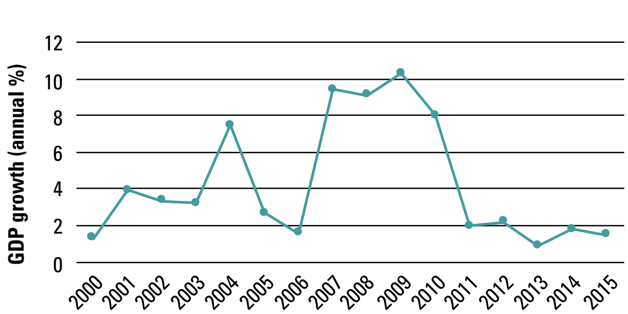
Lebanon's GDP per capita (Figure 4) shows a more or less stable trend before and after the 2006 war.

Figure 2: Lebanon's GDP at current US$ million



Source: World Bank, 2016.

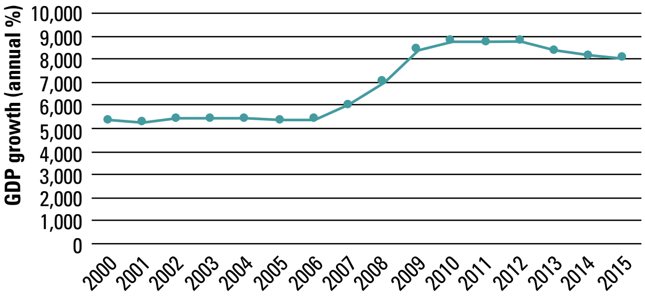
Figure 3: Lebanon's GDP annual growth rate (%)



Source: World Bank, 2016.

Lebanon is situated at the nexus of regional conflicts which have often shaken its economy. While security conditions have improved markedly since the start of 2015, anxiety over regional conditions and potential spillovers persist. Despite all these problems, Lebanon's GDP has continued to increase, but it is still much lower than its potential.

Figure 4: Lebanon's GDP per capita (current US$)



Source: World Bank, 2016.

2.4 Particular geopolitical conditions affecting the energy sector

The Lebanese energy sector has been suffering since the mid-1990s from a lack of investments, which caused a sharp deterioration of the sector's infrastructure and Electricité du Liban (EDL) was not able to satisfy the demand for electricity from the Lebanese community. This led to the development of smaller, private diesel generators that created an electricity market parallel to the official market.

All this has been intensified on the one side by the reduction of the generation capacities of EDL because of the lack of appropriate maintenance and by the increase of demand on the other side. Since the beginning of the Syrian conflict, this problem has been further exacerbated by the influx of Syrian refugees which increased the population and thereby the demand for electricity and widened the gap between generation and demand to 5,524 GWh in 2014 (Bouri & El Assad, 2016).

III. Energy-sector characteristics

3.1 Primary energy supply

Before 1975, more than 70% of Lebanon's electricity was produced from hydroelectric plants. Since the civil war, however, Lebanon has relied on energy imports for the majority of its needs.
Lebanon imports energy in the form of six major components:

- Liquid petroleum gas
- Gasoline
- Gas oil
- Kerosene
- Fuel oil
- Asphalt

These are combined with electricity imports from Egypt and the Syrian Arab Republic, depending on their availability and the security status of the region. The only forms of energy produced within the Lebanese territory come from renewable energy, more precisely from solar water heaters (SWHs) and hydroelectric power plants.

Figure 5 shows the primary energy mix for Lebanon in 2010, where the total primary energy consumed in Lebanon was approximately 6,069 ktoe (El Assad & El Khoury, 2016).

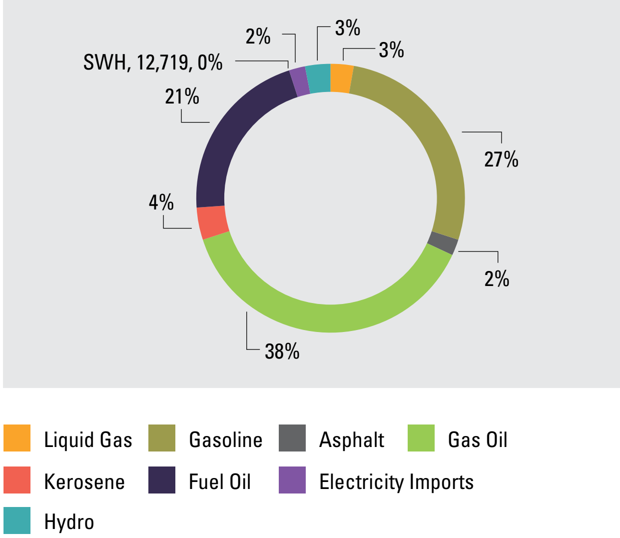
In 2010 also, imports represented approximately 96.8%, whereas only 3.2% was locally produced from hydroelectric power plants and SWHs. The share of primary-energy imports did not change significantly between 2010 and 2015.

During 2009, one of the northern power plants was supplied for a short time by natural gas being imported from Egypt through the Syrian Arab Republic. The energy crisis and political situation, however, did not allow for this important resource to continue supplying the power plant which had to revert to operating with fuel oil.

Combining these figures with the definition by the International Energy Agenca (IEA) of energy security as "the uninterrupted availability of energy sources at an affordable price", shows that the situation of energy security in Lebanon is not favourable. A high dependence on imports of oil products increases the vulnerability of the Lebanese economy to the fluctuation of oil prices. The last few years also showed the intermittence of electricity imports from Egypt and the Syrian Arab Republic because of the political situation.

It can be seen from Figure 5 that the three dominating resources are gasoline, fuel oil and gas oil. As for gasoline, it is mostly used by cars in the transport sector. Fuel oil is essentially consumed by EDL for electricity generation with a share by large industries for private electricity generation. The case of gas oil is more complicated: one part is used by EDL for electricity generation, another is used to fuel private generators, a third is used in houses for heating, and a fourth part is used in the transportation sector, especially for large vehicles. Liquid gas represents a smaller share of the general mix that is essentially consumed for heating in small heaters or for cooking. Kerosene is more or less used solely in the transport sector to fuel the airplane fleet, whereas asphalt is essentially used in industries or to pave roads.

Figure 5: Lebanese primary energy mix in 2010



Source: El Assad & El Khoury, 2016.

3.2 Characteristics of the electricity sector

The power sector in Lebanon has suffered from lack of investments that influenced not only its generation capacities but also its transmission and distribution sectors.

Since 1990, at the end of the civil war that lasted for about 15 years, the power crisis in Lebanon has worsened due to a shortage of the power supply from EDL, which has a monopoly on power generation, transportation and distribution.

This shortfall in the generation of electricity was increased by the absence of investments in new power plants since 1996 (the year of commissioning the Deir Amar power plant) and the increased demand on power which was estimated at 7% per year (Mortada, El Khoury, & El Assad, 2016).

These electricity shortages have created an alternative solution represented by small local generators, as well as a social dilemma regarding the importance of electricity in the daily lives of Lebanese citizens. Furthermore, different vital sectors were affected, such as the tourism and industrial sectors, where each institution had to provide its own electricity source.

The power crisis in Lebanon has many aspects and causes, some of them are technical and others are financial or political. EDL is struggling to meet the demand for power but is not succeeding for the moment because of the lack of investment and the dependency on imported fossil fuel. During the period 2001–2010, EDL was importing electricity from Egypt and the Syrian Arab Republic (around 1.1 GWh in 2009) but this import has not been stable since 2010 because of the situation in the two countries, which aggravated the situation for EDL even further.

In addition, EDL is selling electricity at a price lower than its production cost, increasing its financial losses. This financial loss is exacerbated by the fact that the customer in Lebanon ends up paying two electricity bills: one for EDL and one for the local generators.

In 2009, the Ministry of Energy and Water launched a policy paper for the restructuring of the electrical network in Lebanon. Although it was approved by the Government of Lebanon, its application has been delayed several times for essentially political reasons. EDL relies on four types of power-generation plants:

- Heavy fuel-oil-fired steam turbines at Zouk, Jieh and Hraycheh;
- Diesel.fired combined cycle gas turbines (CCGTs) at Beddawi and Zahrani;
- Diesel-fired open cycle gas turbines (OCGTs) at Sour and Baalbek;

- Hydroelectric plants at Litani, Nahr Ibrahim and Bared

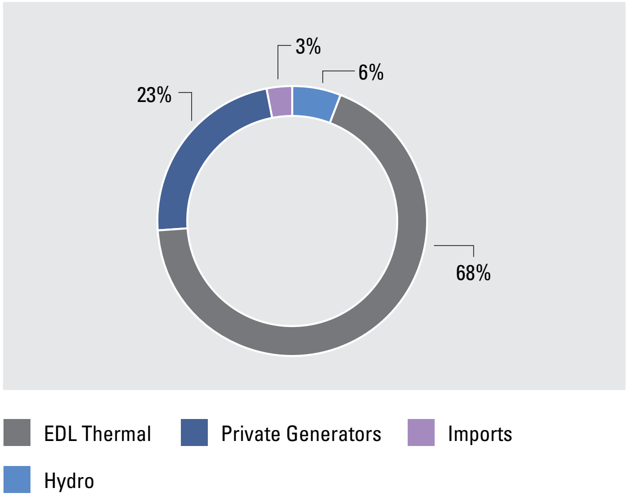
The installed capacity of thermal power plants is 2,038 MW but the actual capacity is 1,685 MW. Thermal capacity represents 86.5% of the installed capacity and 88.7% of the effective capacity whereas the namely installed capacity in the case of hydroelectric power plants is 274 where in 2010 it was effectively 192 MW (Bassil, 2010).

Moreover, in 2010 EDL imported electricity from both Syria and Egypt in the amount of 107.4 GWh (Bassil, 2010).

Finally, the demand was estimated in 2010 to be 15,934 GWh, while EDL supplied only 12,089 GWh. This generation deficit was worsened by private diesel generators, leaving an unsatisfied electricity demand in 2010 of approximately 895 GWh.

Figure 6 summarizes the electricity-supply profile in 2010 based on (El Assad & El Khoury, 2016):

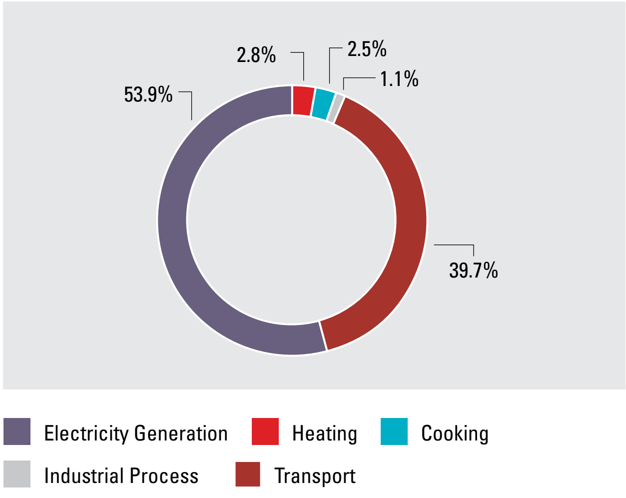
Figure 6: Electricity generation profile in 2010



Source: El Assad & El Khoury, 2016.

The electricity reform paper (Bassil, 2010), estimated an increase of generation capacity to more than 4,000 MW in a first phase to reach as much as 5,000 MW in a second phase. The estimated budget for the first phase is estimated at around US$ 4,870 million, out of which the Government of Lebanon will provide US$ 1,550 million, the private sector will provide US$ 2,320 million and US$ 1,000 million will come from international donors. The required budget for the second phase was estimated at US$ 1,650 million.

Figure 7: Primary energy consumption per sector in 2010



Source: El Assad & el khoury, 2016.

3.3 Energy-demand characteristics

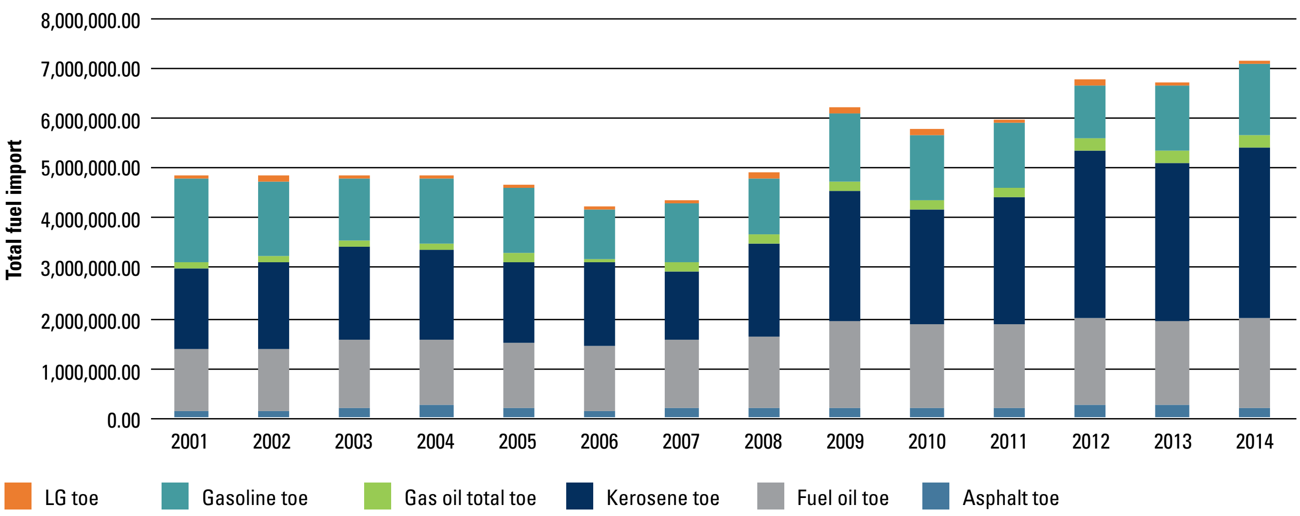
The first and only relatively complete set of energy consumption data was published in both the second NEEAP and the NREAP for Lebanon (Mortada, El Khoury, & El Assad, 2016) and (El Assad & El Khoury, 2016). In both documents, estimations were made in order to evaluate the final energy consumption as shown in Figure 7.

Figure 7 shows the energy consumed in each of the heating, cooking and transport sectors and in industrial processes for non-energy use in most cases. Some 54% of the primary energy is transformed into electricity, however, and it is difficult to know in which sectors this electricity is consumed.

It is difficult to assess the evolution of primary energy in Lebanon because the only available data are for oil imports and do not reflect the reality because of the storage kept from year to year, combined with the high instability in the region that increased the illegal import and export of oil products.

On the other hand, the electricity reform paper stated that, until 2010, the increase in demand was estimated

Figure 8: Primary energy consumption per resource in 2010



Source: El Assad & El Khoury, 2016.

at 7% in terms of electric energy. However, the second NEEAP 2016–2020 (Mortada, El Khoury, & El Assad, 2016) has set a target to lower that demand until 2020, as shown in Figure 9.

Based on data provided by EDL, the peak load increased from 1,984 MW in 2006 to 3,088 MW in 2014, with an annual average increase of approximately 7%.

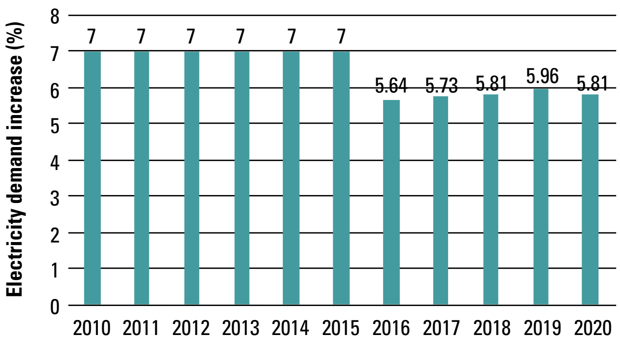
3.4 Energy intensity

Energy intensity in the case of this study is calculated, based on the primary energy consumption in Lebanon (El Assad & El Khoury, 2016) where it amounted to 6,069 ktoe in 2010. In the same year, the World Bank estimated the population at 4,337,156 and the GDP at US$ 38,010 million (current US$).

This means that the energy intensity in 2010 in the case of Lebanon was approximately 0.16 toe/1,000 US$. On the other hand, the yearly primary energy consumption per capita aas about 1.4 toe/capita.

For a wider look at the Lebanese situation, it may be practical to compare it to the case of surrounding countries as in Figure 10, where the relatively high GDP of Lebanon gives it a good position compared to other countries in the region.

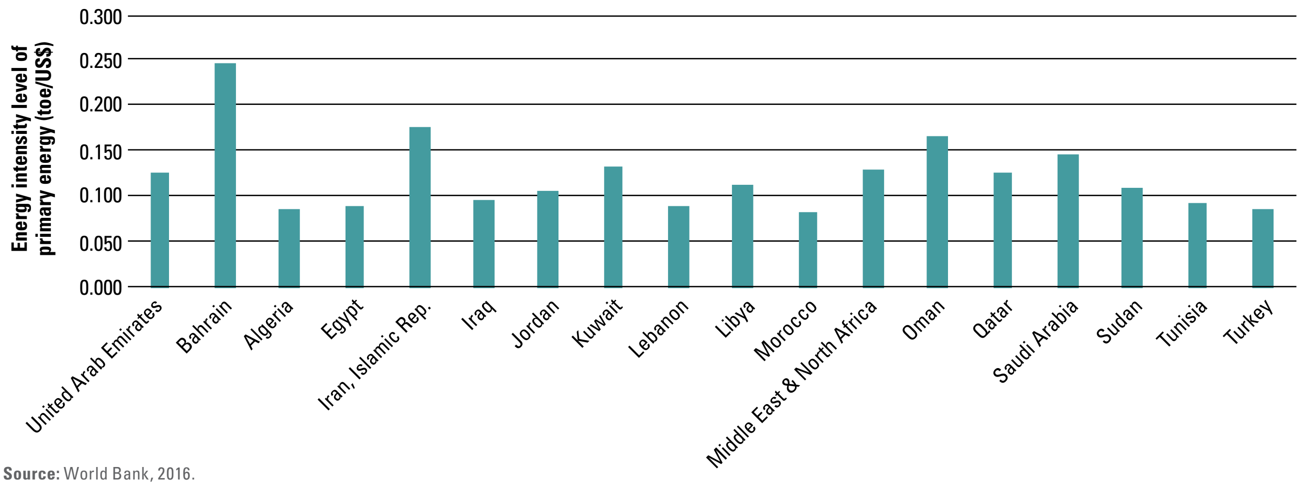
Figure 9: Electricity demand increase based on the second NEEAP for Lebanon



Source: Mortada, El Khoury, & El Assad, 2016.

Source: Shutterstock, Diego Fiore.

Figure 10: Energy intensity of primary energy (toe/2011 US$ purchasing power parity (PPP) GDP)



Source: World Bank, 2016.

3.5 Energy–water nexus

It is difficult to study the energy–water nexus for several reasons, starting with the lack of data but it takes a different aspect in Lebanon, where the main discussions focus on the viability and efficiency of damns.

Precipitation in Lebanon is typically mediterranean and Lebanon is endowed with higher precipitations levels than other parts of the region. The Lebanese, however, did not know how to take advantage of the water in the rivers flowing to the sea without exploring their potential in terms of drinking water, irrigation or ¨electricity production. Combined with this was a modification in the amount of precipitation during the period 1985–2011 that was characterized by a drop of 8% and seems to be ongoing (Sogreah-Artelia, 2012).

The Lebanese territory is drained by 17 main rivers, three of which have their course only partially in Lebanon (El Kebir River, Oronte River, and Hasbani River). Due to the absence of precipitation during the summer period, seasonal variations in river flows are very important.

On the other hand, the projected changes in rainfall will put tremendous pressure on national water security and produce knock-on effects in sectors such as agriculture, where around 70% of the available water is being used for irrigation (Sogreah-Artelia, 2012).

All this puts great pressure on developing renewable energy projects, especially, hydroelectric projects, where competition creates risks between water for irrigation priorities and electricity generation.

This problem was encountered with the Litani River Canal 800 project, which is expected to draw 110 million m3/year (50% of the total static water volume) from the Qaraoun reservoir in the Southern Bekaa to the south of the country. Most of this water will be used for the irrigation of some 14,700 ha of farmland. Although the canal will accommodate a 3 MW hydro unit, it will have a major impact on the production of the main hydroelectric power plant. This impact was estimated as being a reduction of 142 GWh/year in dry years; 303 GWh/year in average years and 295 GWh/year in wet years.

This is an example of the nexus between water and electricity production to be considered as of the design phase to allow both irrigation and electricity generation.

3.6 CO_2 emissions/footprint

Concerning the CO2 footprint of Lebanon, the World Bank estimated that CO2 intensity in terms of kg of CO2 per kg of oil equivalent energy consumed is as represented in Figure 11 (World Bank, 2016). For the baseline year of 2010, it was approximately 3.143.

Figure 12 presents the CO2 footprint for Lebanon for the period 2001–2013, which represents more or less the current situation and combines the data for Figure 11 with the primary energy data for the same period.

IV. Renewable energy potential

It is always difficult to estimate the absolute potential for renewable energy in a country where many parameters intervene. In fact, theoretical potential will always be reduced because of:

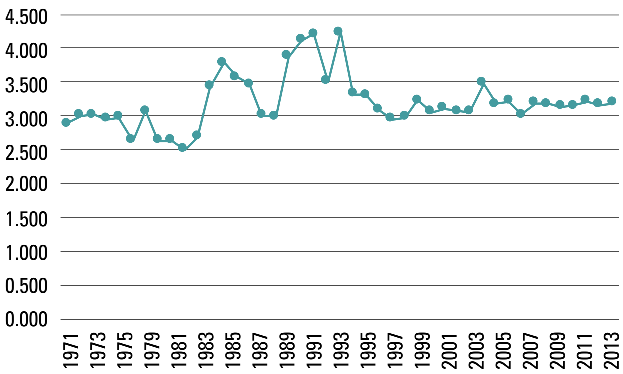
- Geographical constraints: usually derived from the topography, forests, roads, etc.;
- Urban constraints: dictated by the value of the land to be used, the development of cities and the specificity of the land to be used;
- Agricultural constraints: many renewable energies require large plots of land which can conflict in some cases with agricultural development;
- Financial constraints: the price of the land can have a critical impact on the feasibility of renewable energy projects.

All these constraints and others were considered in the development of NREAP for Lebanon (El Assad & El Khoury, 2016). They resulted in three scenarios that were developed by the authors: pessimistic, optimistic and realistic.

The realistic scenario was considered to set the renewable energy target for 2020; the pessimistic scenario represented the worst-case scenario for the development of renewable energies; and the optimistic scenario was found to be the closest to the feasible potential of renewable energies.

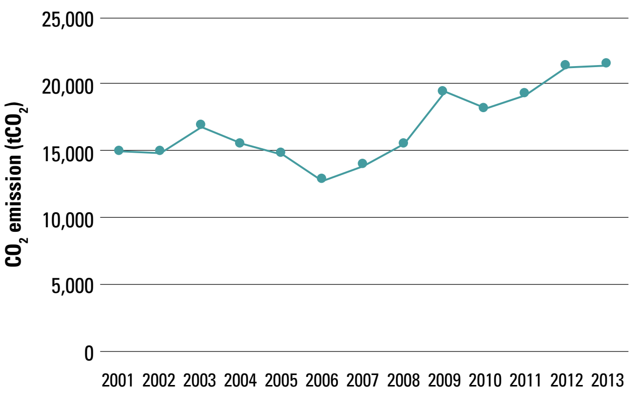
The theoretical potential was not evaluated for all resources; some considered directly scenarios based on pilot projects or considered feasible potentials of renewable energy. In the case of these resources, the potential will be considered as being the optimistic scenario.

Figure 11: CO2 intensity (tonnes of CO2 per tonnes of Oil Equivalent (TOE) e of energy use)



Source: World Bank, 2016.

Figure 12: CO2 emission in Lebanon for the period 2001– 2013



Source: World Bank, 2016.

Source: Shutterstock, Dana.S.

4.1 Renewable energy potential for power generation

The first category of renewable energies considers centralized and decentralized potential used for power generation from renewable energy (small, medium and large scale) connected or not to the grid.

The following table, based on series of studies such as Vallvé (2013), UNDP-CEDRO (2011), UNDP CEDRO (2012), Sogreah-Artelia (2012), summarizes the potential of these resources.

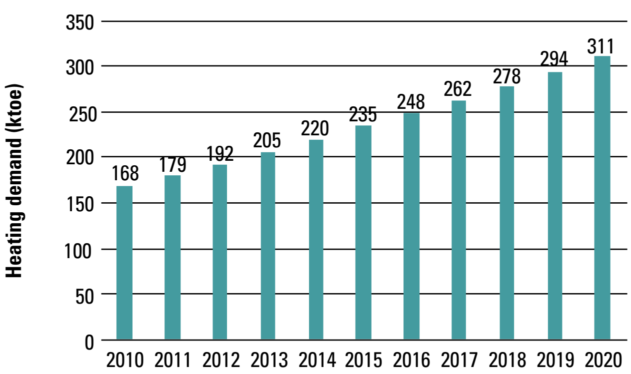
In the case of the first three resources listed in Table 1, it is more or less the theoretical potential that is listed. Whereas, in the case of distributed photovoltaic (PV) it is difficult to assess the complete national potential and the optimistic target was listed. Finally, regarding hydroelectric resources, the listed potential is the result of the hydroelectric masterplan for Lebanon that identified 32 sites for future development of hydroelectric power plants in Lebanon (Sogreah-Artelia, 2012). It is to be noted that this does not include the potential of micro-hydro resources or even non-river resources that were not evaluated in Lebanon.

Table 1: Potential of renewable power generation in Lebanon

	MW	GWh
Wind	5,408	12,139
Photovoltaic farms	87,600	146,130
Concentrated solar power	8,065	18,275
Distributed photovoltaic	170	280,500
Hydro	368	1,363

Source: Vallve (2013), UNDP-CEDRO (2011), UNDP CEDRO (2012), Sogreah-Artelia (2012)

Figure 13: Demand for heating resources in Lebanon (ktoe)



Source: Based on baseline of NREAP

4.2 Renewable energy potential for direct uses

This section presents the energy potential for resources that can be provided directly by dedicated renewable energy systems, without the need for producing electricity as an intermediary step.
More explicitly, these sources are used for thermal applications in the domestic, commercial, recreational, industrial or agricultural sectors.

In Lebanon these resources are SWHs, geothermal and biomass systems. There were no studies developed for heating demand in Lebanon and the baseline was developed in an approximate way in the second NEEAP (Mortada, El Khoury, & El Assad, 2016). The increased demand for heating resources in Lebanon was not targeted by any studies; the most reasonable way to estimate the increase is to evaluate it with the same values as for the electricity demand as shown in Figure 9.

Based on the baseline defined in NREAP, the evaluation of heating demand can be projected until 2020 as shown in Figure 13.

Not only were detailed studies lacking to assess the demand for heating resources; even more data was lacking to evaluate the renewable energy potential, an exception being the bioenergy strategy for Lebanon (UNDP CEDRO, 2012). This strategy estimated the bioenergy resources from several inputs, concluding the potential summarized in Table 2.

The four scenarios represented essentially the economic and political situation in Lebanon and not the technical considerations for the development of these resources. The potential represented in this table is therefore based on the considerations within the scope of this study. The NREAP did not tackle any

Table 2: Potential of renewable power generation in Lebanon

ENERGY USE	Scenario I	Scenario II	Scenario III	Scenario IV
Primary energy (GWh)	6,953	2,354	517	1,543
Final energy				
Electricity (GWh)	934	475	73	261
Electricity (MWe)	119	62	9	33
Heat (ktoe)	131	78	14	39
Heat (MWt)	222	134	23	66
Transport (ktoe)	271	28	14	39

Source: UNDP CEDRO,2012.

potential related to the transport sector so the final potential that was considered within its scope in the share of bioenergy is 39 ktoe as stated in Scenario IV. As for geothermal resources, another study by UNDP CEDRO (UNDP CEDRO, 2014), looked at the potential of this resource in terms of stored heat. The study was more qualitative than quantitative, identifying four zones, highlighted, that are the most promising in terms of heat recovery from underground (Figure 14).

The potential assessment of SWH is difficult as, theoretically the Sun is emitting more than enough energy any roofs with SWHs. The targets given in several studies (CEDRO, 2014) were 1 million m3 of installations in 2020, whilst knowing that the potential is much higher than this.

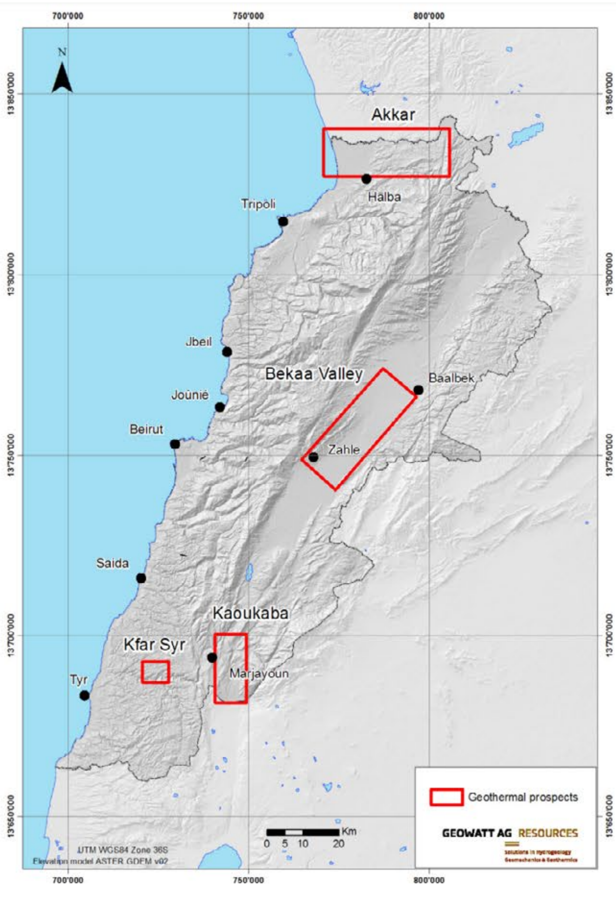
Combining the data that were mentioned above, Table 3 that shows the potential or targets correspondingly of these renewable resources for heating purposes:

Table 3: Potential of renewable energy sources for heating in Lebanon

	GWh
SWH	1,105
Geothermal	109
Biomass	606.5

Source: Based Optimistic Scenario in NREAP, 2016.

Figure 14: Location of identified geothermal prospects in Lebanon



Source: UNDP CEDRO,2012.

All potentials presented in this table represents the optimistic scenarios noted in NREAP. This is mainly due to difficulties of potential assessment in the case of biomass and SWHs and because geothermal energy is still in its infancy in Lebanon.

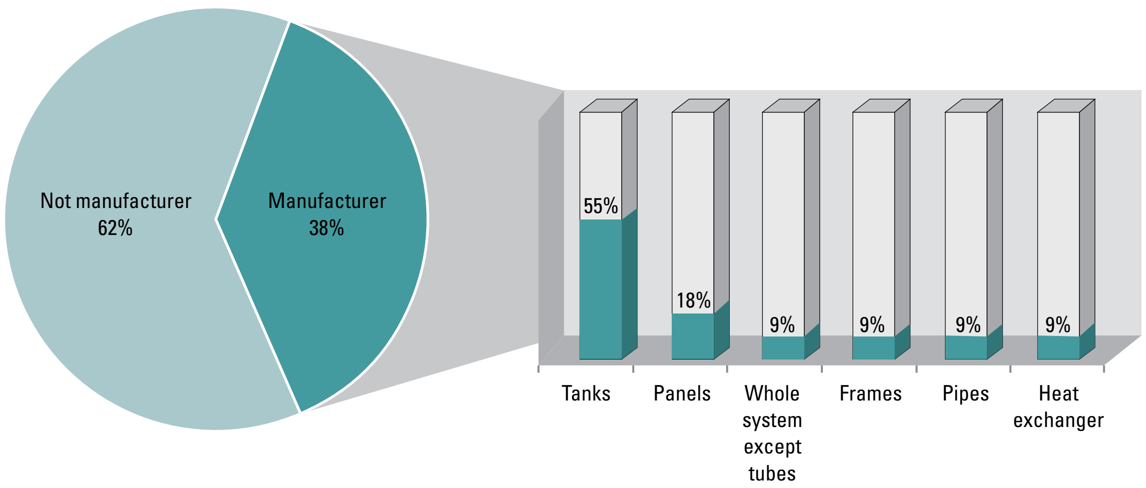
4.3 Potential for local integration and manufacturing

Many countries have witnessed a development of the local manufacture of components for renewable energy systems. Lebanon is no exception and the SWH market proves that Lebanon can interact with market development. As can be seen in Figure 15, 38% of the SWH systems installed in Lebanon were partially or totally manufactured in Lebanon (Hajj Shehadeh, 2012).

On the other hand, a study prepared jointly by the International Renewable Energy Agency (IRENA) and ESCWA looked at the potential of job creation by manufacturing renewable energy systems locally (IRENA & ESCWA, 2016). The study focused on three pilot countries, namely Jordan, Lebanon and the United Arab Emericates (UAE) and made an assessment of local manufacture in these countries.

The study identified the main strengths for local manufacture in Lebanon, where industries related to electronics, electricity, steel, aluminum and plastics are well developed and can play an important role in stimulating the renewable energy industry. Moreover, established university programmes related to renewable energy research mean that the available technical know-how is of an acceptable standard, while the financing environment is good for both the renewable energy and manufacturing markets.

Figure 15: Local manufacture of SWH equipment in Lebanon



V. Assessment methodology

5.1 Solar PV

The assessment for large-scale PV in this case study was based on a UNDP-CEDRO publication entitled Photovoltaic Plants in Lebanon (Vallvé, 2013).
The calculations were based on input from the solar-med-atlas (Solar-Med-Atlas, 2016) in order to evaluate the surfaces within each irradiance level. The mean value of these irradiances was then used assuming mono-crystalline silicon panels. Finally, based on a conservative 15.5% of system losses and 97.5% of inverter efficiency, the potential for each global horizontal irradiance (GHI) category was calculated as shown in Table 3.

The estimated life-cycle assessment of solar PV (NREL, 2012) resulted in an equivalent emission of 44 gCO2e/kWh. On the other hand, the national emission

Table 4: Potential PV power capacity and power output in Lebanon

GHI	Area (km2)	Assumed App. capacity Factor* (%)	Potential capacity in MW (assuming 10,000 m2/MW)	Potential energy output (MWh)
1700–1800	36.6	16.6	3,660	5,322,226
1800–1900	124.3	17.3	12,430	18,837,416
1900–2000	187.3	18.0	18,730	29,533,464
2000–2100	188.7	19.5	18,870	32,233,734
2100–2200	269.0	20.1	26,900	47,364,444
2200–2300	70.46	20.8	7,046	12,838,376
TOTAL			**87,636**	**146,129,660**

Source: Solar-Med-Atlas,2016.

factor in the case of Lebanon was estimated at 650 gCO2e/kWh (Hajj Shehadeh, 2012). This means that the estimated GHG emission reduction is approximately 606 gCO2e/kWh when comparing PV electricity generation to generation from the national grid.

5.2 Solar CSP

The main reference for potential estimation of concentrated solar power (CSP) in Lebanon is (Téllez, Obeid, & Karam, 2013). In this case the considered parameters are the following:

- Direct normal irradiance (DNI) equal to or larger than 2,100 kWh/m^2/year
- Solid and unpopulated land
- Land slope less than or equal to 3°
- Water availability
- Minimum land area of 1 km^2
- Parabolic trough technology

The land-use factor is considered to be 30% and the annual average total efficiency of the system is considered to be 15%.

The same methodology that was used for PV is used in the case of CSP to estimate the emission savings. In this case, the estimated life-cycle assessment of solar CSP is 23 gCO2e/kWh leading to a GHG emission reduction of approximately 627 gCO2e/kWh when comparing CSP electricity generation to generation from the national grid (NREL, 2012).

Source: Shutterstock, Riccardo Piccinini.

Table 5: Concentrated solar power potential in Lebanon

DNI (KWH/ M2)	Surface area (km2)	Capacity (MW)	Annual yield (GWh)
2100–2200	18.5	925	1,790
2200–2300	17.2	860	1,741
2300–2400	10.9	545	1,153
2400–2500	8.9	445	981
2500–2600	30.9	1,545	3,545
2600–2700	50.8	2,540	6,058
2700–2800	16.0	800	1,980
2800–2833	8.1	405	1,027
Total		**8,065**	**18,275**

Source: Téllez, Obeid, & Karam, 2013.

5.3 Wind energy

In 2011, UNDP-CEDRO published The National Wind Atlas of Lebanon, on behalf of MEW. The main purpose was to estimate wind potential in Lebanon and to highlight the best zones for the development of wind farms. It was based on a mesoscale and microscale model for the entire country to produce a wind map at heights of 50 m and 80 m above ground level at a resolution of 100 m (Garrad Hassan, 2011).

Table 5 illustrates the potential land area per wind-speed category for the country based on the following:

- Assumption of a more conservative maximum slope of 14 °, based on the sensitivity analysis used in the national wind atlas;
- The consequent capacity potential is evaluated assuming 8 MW/km²
- Power output where capacity factors from respective average wind speeds is adopted from (Shawon, 2013);
- Assumptions on installation density and minimum wind speeds required.

As indicated in Table 5, Lebanon has an onshore wind-power potential capacity of 5.41 GW that can produce approximately 12,139 GWh (Garrad Hassan, 2011). As for the CO2 emission reduction, based on a life cycle assessment of wind farms, the equivalent emission factor for these farms is 11 gCO2e/kWh in the case of ground-based onshore wind turbines (NREL, 2012). This leads to an emission reduction of 639 gCO2e/kWh for each kWh produced from wind farms in Lebanon.

Source: Mark Roger Bailey - Fotolia.com.

5.4 Methodology for other renewable energy technologies

The potential assessment for all the remaining renewable energy technologies was based more on pilot project studies that tried to generalize their results. All the corresponding references were cited previously.

VI. Current and prior policy status

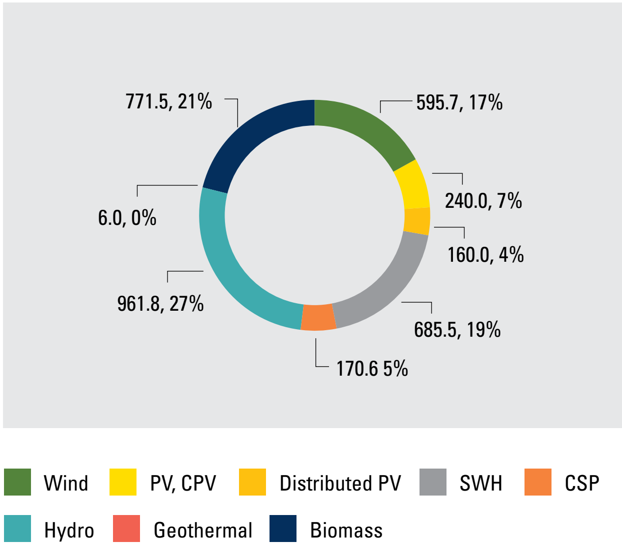
6.1 Renewable energy strategy and targets

During the 2009 COP meeting in Copenhagen, the Lebanese Government launched a commitment to have 12% of renewable energy in 2020. This commitment was more of a political commitment and lacked a clear definition of the energy mix of which 12% is renewable energy. In 2010, MEW strengthened and clarified this vision in their Policy Paper for the Electricity Sector (Bassil, 2010) by stating that the target was to reach “12% of the electric and thermal supply” and not just “12% of Lebanon’s needs”. This policy paper did not, however, set a clear path towards the 12% not did it set shares for each renewable energy technology. All this was completed in The National Renewable Energy Action Plan for the Republic of Lebanon where a clear path was set towards the 2020 target of 767 ktoe of renewable energy (equivalent to 12%). Moreover, a clear distribution of the 2020 among the different renewable resources proposed as shown in Figure 16 (El Assad & El Khoury, 2016).
It is to be noted that these targets were set on the primary-energy level, which explains the toe unit used (El Assad & El Khoury, 2016). Setting targets on the primary- energy level can be more challenging since the efficiency of the plants has to be taken into consideration.

A detailed target and vision present a strong motivation for investors in renewable energies to identify their opportunities and hence help develop this sector even further.

Finally, NREAP also presented sectorial distribution between the electricity generation from renewable energy resources and from direct use of renewable energies for heating. Figure 17 shows that 33% of the 12% target will be consumed directly for heating purposes from renewable energies, whereas 67% will be transformed into electricity before being consumed by the final users.

Figure 16: Shares of each renewable energy technology out of the 12% target in ktoe and as a percentage



Source: El Assad & El Khoury, 2016.

6.2 Present renewable energy policies and institutional framework

6.2.1 Institutional framework

The Ministry of Energy and Water is the main stakeholder in the energy field. The Lebanese Centre for Energy Conservation was present from the beginning of renewable energy and evolved to become the national energy agency. It is a governmental organization affiliated to MEW and is the technical arm of the Ministry in all fields related to energy efficiency, renewable energy and green buildings. LCEC has succeeded in establishing itself as the main national reference on sustainable energy in Lebanon. It offers proven expertise and support to the Government in developing and implementing national strategies for saving energy and money and reducing GHG emissions, with the final target of improving the resilience, safety and comfort of the Lebanese population.

On the other hand, other significant stakeholders have to be included, the most important of which is EDL, the final off-taker of renewable energy on the national grid. EDL involvement is crucial, especially with regard to studying grid requirements and stability for the integration of renewable energies.

6.2.2 Legal framework

Since 2009, several plans have been developed to try to fill this gap, from the electricity reform paper prepared by MEW and adopted by the Lebanese Government in 2010 to the first national energy efficiency action plan prepared by LCEC, which contained both renewable energy and energy-efficiency initiatives.

In 2015, the sector of renewable energy has grown to become one of the most thriving markets in Lebanon and LCEC has decided to dedicate a separate document to present the proposed goals and necessary actions to attain them in the field of renewable energies, namely the National Renewable Energy Action Plan (NREAP).

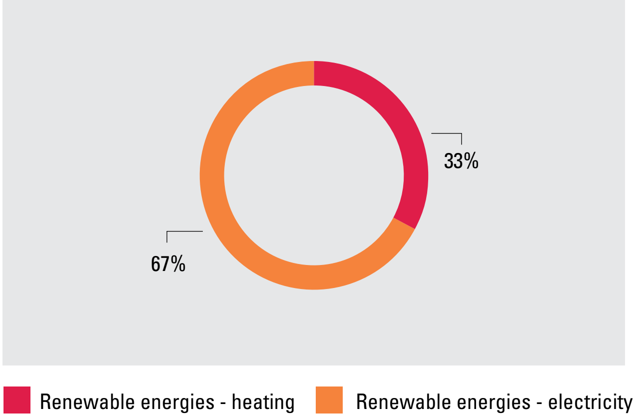
A major barrier facing the deployment of renewable energies in Lebanon is the lack of an institutional framework for its development. This would help initiate a quicker development and utilization of renewable energy resources, attract more investments in the sector and, finally, create many new job opportunities on several levels.

Despite its Copenhagen announcement, the Lebanese Government did not favour renewable energies on the legal level, neither did it distinguish them from traditional resources which remained tied to Law 462 and its amendments.

Law 462 gives EDL a monopoly over electricity generation, transmission and distribution. It was presented in 2002 with the objective of reforming the structure of the sector. It established the Electricity Regulatory Authority (ERA) and allowed it to grant licenses for independent power producers to generate electricity and feed it to the grid.

Although Law 462 has been in force since 2002, it has never been implemented. There is, therefore, no regulatory body to issue licenses for new electricity generation. From 1999 to 2002, the emphasis was on privatization but, after 2002, the emphasis

Figure 17: Sectoral shares of renewable energy in terms of electricity and heating generation



Source: El Assad & El Khoury, 2016.

shifted towards public–private partnerships and corporatization, leaving the law somewhat behind the change in consensus.

Various amendments to the law have been proposed to make it more applicable to current Lebanese conditions and to stimulate the wide spread of renewable resources.

Law 288 (April 2014), further sidelined Law 462, at least for two years, by indicating that the Council of Ministers, upon joint recommendations from MEW and the Ministry of Finance (MoF), can license independent power producers pending the implementation of Law 462, and ERA, for a period of two years (from April 2014 to April 2016). Law 288 indicated that: “temporarily and for a duration of two years and till the appointment of the ERA and assuming its mandate, permits and licenses are offered by a decision from the Council of Ministers based upon a proposal from the Minister of Energy and Water and the Minister of Finance”.

In 2016, Law 288 was extended for another two years until 2018, with no licenses being issued until now. These reviews of the current legal situation in Lebanon show that the sector still requires many efforts from the regulatory point of view in order to cope with those being made on other levels.

Meanwhile, most of the renewable energy projects are limited in size, essentially because of this legal barrier with some slight shift away from the recently organized wind-farm tender by LCEC that could constitute a precedent. In fact, MEW, through LCEC, opened the possibility that wind farms in Lebanon require a tender, inviting, therefore, private-sector participation. The Ministry of Energy and Water and the Ministry of Finance must therefore take the outcome of this tender, jointly, to the Council of Ministers for a decision on licensing under Law 288. Another example of relatively large-scale projects being implemented in Lebanon is the Beirut River Solar Snake (BRS), for which MEW, through LCEC, called for bidding from private-sector participants, with funding available from the Government, for a pre-specified renewable energy capacity. In this case, the private sector will design, build, and transfer the renewable energy generation plant. A similar approach has been adopted in Lebanon for conventional power plants, where the private sector constructs a power plant based on funds paid upfront by the Government.

6.2.3 Financing mechanism

The first NEEAP for Lebanon in 2010 introduced 14 initiatives related to renewable energy and energy efficiency combined. Without any doubt, the most successful initiative was the eleventh, that introduced the National Energy Efficiency and Renewable Energy Action (NEEREA).

NEEREA was created in collaboration with the Central Bank of Lebanon (Banque du Liban (BdL)) in order to provide the private sector with long-term loans at low interest rates for any type of renewable energy or energy-efficiency project. NEEREA is dedicated to supporting the financing of new and existing environmental projects, including energy-efficiency and renewable energy operations.

NEEREA is the only green financing mechanism in the Arab region that has a loan ceiling of US$ 20 million per project and is offered at an interest rate of around 0.6% for periods that should not exceed 14 years, including a grace period of between six months and four years. These loans are provided through any of the Lebanese commercial banks to directly reach the end user.

The European Union also contributed by offering a grant to small or medium enterprises over a share of the investment cost of a maximum of US$ 5 million. This share varies between 15% for non-subsidized sectors and 5% for subsidized sectors, with a ceiling of US$ 750,000 for the first and US$ 250,000 for the latter.
The Central Bank of Lebanon has issued several circulars to ensure the consistency of NEEREA among all Lebanese commercial banks. As per Intermediate Circular 236, they can free some of their required reserves at BdL to finance NEEREA projects. After Circular 236, the sustainability of the NEEREA financing mechanism was secured by several periodic circulars such as 313, 318 and 346.

Moreover, BdL signed an agreement with the Italian Ministry of Environment, Land and Sea whose purpose is to support energy-saving and efficiency investments in Lebanon, including in renewable energy, implemented by, or involving, Italian small and medium- sized enterprises. A grant will be given for all projects having not less than 60% of their costs coming from Italian products and financed through the NEEREA loan in all economic sectors except the residential one. The grant share does not exceed 10% of the value of the NEEREA loan with a ceiling of US$ 2,000,000 for the loan.

NEEREA is experiencing rapid growth and wide acceptance from the public despite the barriers and instabilities in the energy sector. Although there are policies and regulations tackling energy issues, they still lack enforcement and implementation on the ground and some of them are outdated, hence the mistrust of the private sector in the Lebanese Government. In addition, most fossil-fuel prices are highly subsidized, which propels the private sector to rely on diesel-based generators to satisfy its energy needs instead of encouraging investments in renewable energy projects.

Despite all these barriers, NEEREA loans (officially launched in November 2010) are becoming a booming trend in the Lebanese banking sector, where more than 480 projects worth more than US$ 400 million were financed until April 2016.

Based on April 2016 numbers published by LCEC, approximately 74% (289) of these projects were renewable energy projects.

Despite its success, the NEEREA financing mechanism has several constraints regarding large-scale renewable energy projects as it is designed to finance only renewable energy projects dedicated for own consumption and not for independent power production purposes.

6.2.4 Net metering

Net metering was introduced in Lebanon in 2011 through a decision of the board of EDL that was approved by MEW. Efforts to develop net metering started in March 2010 with the involvement of EDL technical and legal teams, MEW advisors, the UNDP-CEDRO project and the LCEC team.

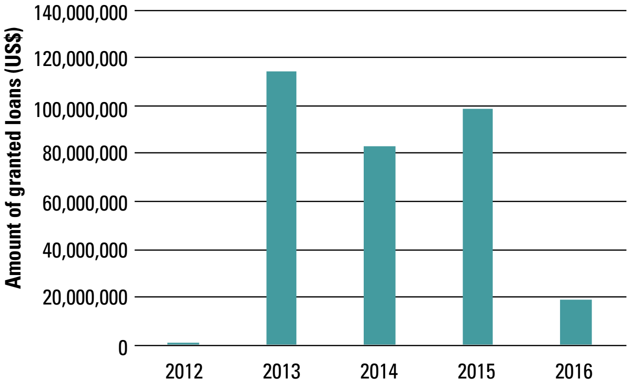
Net metering is a financial agreement by which utility customers generate some of their own electricity and use a single meter to measure the net electricity bought from the utility. At various times, the customer will not use all the electricity generated. The excess is fed back into the grid and makes the meter run backwards. When the meter is read, it will usually show a net purchase from the utility. If, for some reason, the customer generated more electricity than was consumed that month and the meter shows a negative value, it will be read as zero or credited to the next month's bill. In effect, during a single billing period, the customer uses any excess generation to offset electricity the customer otherwise would have had to purchase at the retail tariff.

Net metering offered the first opportunity to connect renewable energy projects to the national grid. Although more than 50 projects are already connected to the network, limitations exist owing to the lack of meters at EDL, requiring the net amounts to be paid to be calculated manually.

6.3 Suitability of current renewable energy policies and institutional framework to meet announced strategies and targets

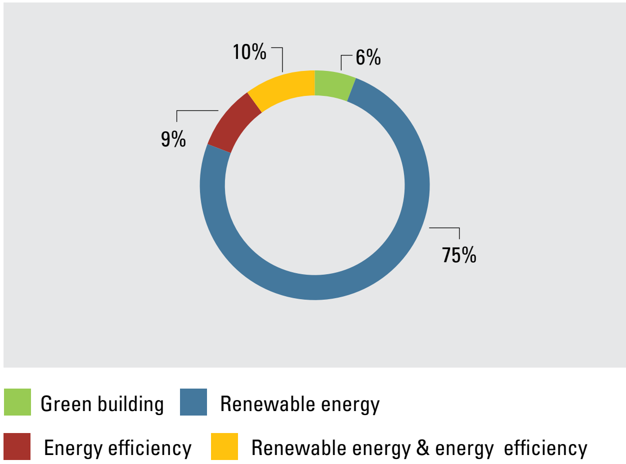
The target that was set in 2009 – 12% of renewable energy – was an ambitious, especially as it target was set for the primary energy level (El Assad & El Khoury, 2016).

Figure 18: Projects per technology



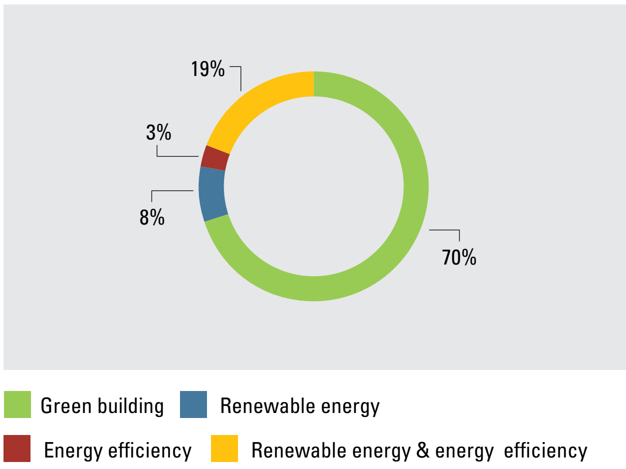
Source: Based on April 2016 LCEC data.

Figure 19: Number of projects per technology based on April 2016 LCEC data



Source: Based on April 2016 LCEC data.

Figure 20: Number of projects per technology



Source: Based on April 2016 LCEC data.

Table 6: Wind potential in Lebanon

Average annual wind speed (m/s)	Capacity factor (%)	Area (km^2)	Approximate potential capacity (MW)	Approximate total potential power output (MWh)
6.5–7.0	22.0	294.4	2,355	4,538,556
7.0–7.5	25.1	187.6	1,500	3,298,140
7.5 – 8.0	28.2	92.8	743	1,835,448
8.0–8.5	31.4	48.0	384	1,056,246
8.5-9.0	34.8	24.8	199	606,648
9.0–9.5	38.4	12.7	102	343,112
> 9.5 (assumed 10)	42.1	15.7	125	460,995
Total	**25.6% (average for Lebanon)**	**676**	**5,408**	**12,139,145**

Source: The National Wind Atlas of Lebanon, UNDP-CEDRO.

Achieving such a target will require clear and supportive legal and institutional frameworks which are still lacking in Lebanon.

The national target was still not clear before the publication of NREAP, 2016–2020 and most renewable energy policies were annexed to other types of policies in the electricity reform paper or in the first NEEAP, 2011–2015.

Additionally, the only possibilities for connections between renewable energy projects and EDL's national grid were limited either in terms of size or clarity of requirements. The absence of a grid code from EDL is also one of the obstacles facing the development of renewable energies.

6.4 Renewable energy policy and institutional reforms being introduced or considered

In 2015, LCEC organized an evaluation study for the first NEEAP 2011–2015 for Lebanon. The main objective was to identify the bottlenecks in the renewable energy and energy-efficiency sectors and to highlight fields in those sectors that still need to be developed.

The nature of the document itself presented major challenges for the evaluation, owing to the following:

- There was no clear baseline defined for the measures to be evaluated;
- The first NEEAP had a unified target for both energy-efficiency and renewable energy initiatives combined;
- Many of the initiatives had qualitative targets without any measure to be evaluated;
- Monitoring and evaluation methodology was not included in the document and had to be designed afterwards, which further complicated the procedure.

The main outcomes of this study are summarized in Table 6.

Table 7: Evaluation of NEEAP 2011–2015

Initiative	Description	Completion (%)
1	Towards banning the import of incandescent lamps to Lebanon	45%
2	Adoption of energy conservation law and institutionalization of LCEC as the energy agency	40%
3	Promotion of decentralized power generation by PV and wind applications	30%
4	Solar water heaters for buildings and institutions	53%
5	Design/implementation of national strategy for efficient and economical public street-lighting	60%
6	Electricity generation from wind power	23%
7	Electricity generation from solar energy	42%
8	Hydropower for electricity generation	34%
9	Geothermal, waste to energy, and other technologies	30%
10	Building code for Lebanon	0%
11	Financing mechanisms and incentives	80%
12	Awareness- and capacity-building	69%
13	Paving the way for energy audit and ESCO business	20%
14	Promotion of energyefficient equipment	8%

Source: Mortada, El Khoury, & El Assad, 2016.

As can be seen in Table 6, the study showed underachievements in most of the initiatives related to renewable energies. This proved the need for a dedicated document to clarify the renewable energy strategy for Lebanon and to set the action plan. The following decision from LCEC was to separate the first NEEAP into two documents for the period 2016–2020: one dealing with energy efficiency and the second dealing with renewable energies, namely NREAP 2016–2020.

The major reviews required in NREAP can be summarized as follows:

- Set the year 2010 as a clear baseline for NREAP, as suggested by the Arab Renewable Energy Framework (AREF) published by the League of Arab States (LAS);
- Set a projection for energy consumption in Lebanon on which the 2020 target can be defined;
- Assess the potential of all renewable energy resources available in Lebanon and set targets for each of the technologies;
- Study the needs in terms of legal and policy reforms for the development of renewable energies;
- Propose an evaluation methodology for the action plan in order to be reviewed and corrected if needed.

Such a revised document will present a comprehensive framework for the development of the renewable energy sector in Lebanon and will increase the trust of both the private sector and international donors therein. In fact, a separate chapter within NREAP is dedicated to the evaluation and monitoring procedures to be followed in order to assess continuously the evolution of NREAP implementation.

VII. Economic, environmental and policy analysis

7.1 Overall impact of the policy measures that were introduced or are being considered for the renewable energy market in Lebanon

The main solution proposed by NREAP to the legal problems facing the development of large-scale renewable energy projects in Lebanon is based on decoupling renewable energy resources from traditional resources (El Assad & El Khoury, 2016).

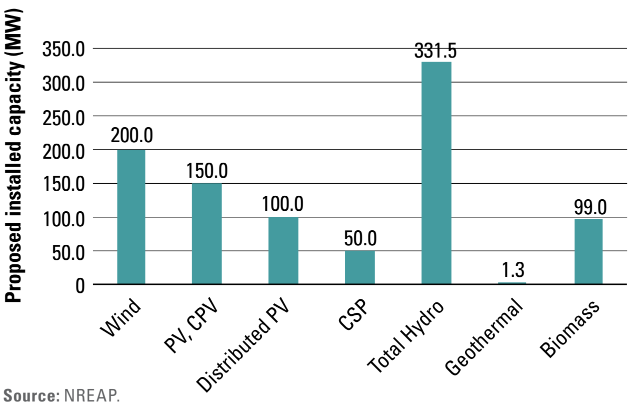
This will be done based on the application of Law 288 (2014) and Law 54 (2015), which will allow the private sector to generate electricity solely and exclusively in the renewable energy sector. The main success of this solution relies on applying it exclusively to electricity production from renewable sources, namely solar PV, solar CSP, hydro and wind, and excluding any other technology of electricity production – namely fuel-based or diesel-based – where there will be a need for a transaction advisor to complete all the necessary tasks.

Applying such a plan will open the door to the introduction of large-scale renewable energy projects in Lebanon and will draw large investments from the private sector both nationally and internationally.

As stated in NREAP, 931.8 MW of renewable energy projects are to be installed in Lebanon by 2020, excluding more than 1 million m2 of SWH collectors. This will be a complete change for the renewable energies market, where many companies have to be created, with others shifting towards renewable energies.

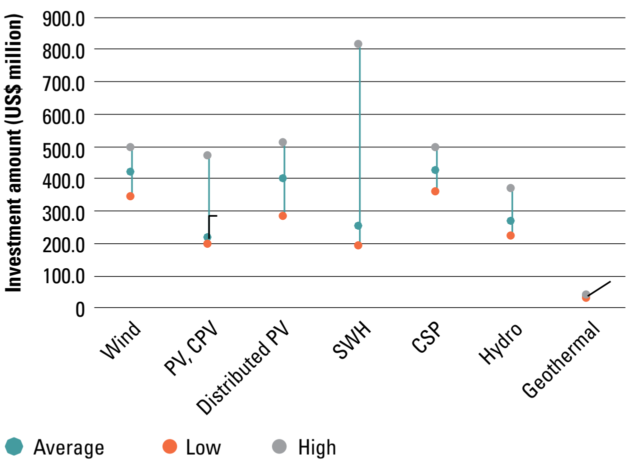
More explicitly, these installations will create a market with investments of between US$ 1,603 and US$ 3,166 million as shown in Figure 22. This excludes the biomass market because of lack of data about the size of investments needed for installations such as those given in the NREAP.

Figure 21: Proposed installed capacities as per NREAP (excluding SWHs)



Source: NREAP.

Figure 22: Market size in the implementation of NREAP (excluding biomass)



Source: NREAP.

Source: Johnsroad7 - Fotolia.com.

7.2 Analysis of potential economic and social impacts of the evolution of the renewable energy market in Lebanon

7.2.1 Direct economic savings

The first impact was that the development of such a renewable energy market in Lebanon could be estimated by comparing the levelized cost of electricity (LCOE) of each of the renewable energies considered with the LCOE of electricity generation by EDL, reported by MEW as approximately 20.2 US cents/kWh.

It can be seen from Figure 23 that all the renewable energy technologies studied have an LCOE lower than the actual cost of electricity production by EDL.

The geothermal LCOE is close, but such systems will be installed as a substitute for hybrid electrical systems, including diesel generators, where the real electricity generation cost is around 35 US cents/kWh, as provided by MEW as an indicative price for private generators.

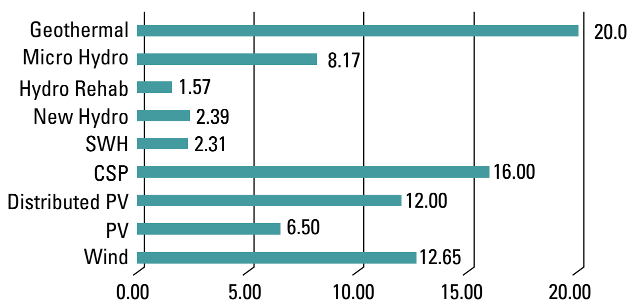
The energy storage capacity of CSP systems also makes them highly feasible since they can be operated as peak-load generators replacing power plants such as Tyr or Baalbeck, where the generation cost is around 32 US cents/kWh, as reported by MEW. All this will build up savings for the Lebanese economy as it can be seen in Figure 24, where the direct cumulative savings would be approximately US$ 319 million.

As already mentioned, the total cost of implementation of NREAP varies between US$ 1,320 and US$ 3,166 million, so if the Lebanese CoM decides to accept the whole investment – which is not recommended – the payback period would be between 4 and 10 years, which still represents a good business case.

7.2.2 Job creation

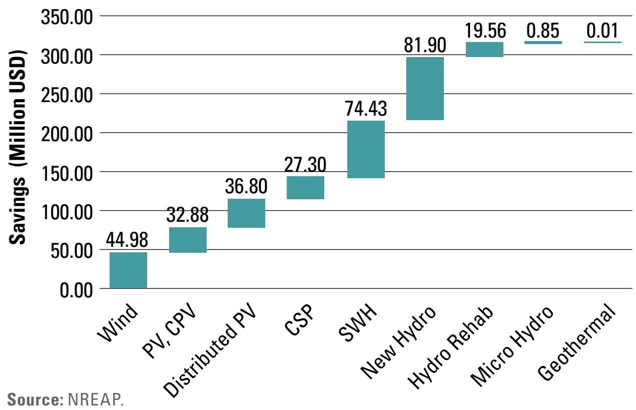
Creating a new market of US$ 1–3 billion will surely create new job opportunities in Lebanon. These will either be created directly by the installation, contracting and operating companies or indirectly in parallel markets that will be opened to serve the main renewable energy activities such as in the fields of electronics, control and automation or jobs in the transport companies.

Figure 23: LCOE of each of the renewable energy resources under NREAP (excluding biomass)



Source: NREAP.

Figure 24: Cumulative savings from NREAP (excluding biomass)



Source: NREAP.

Table 8: Average number of jobs created during the construction and operation phases for each renewable energy technology

	Construction Jobs created/ Mega-Watt power (MWp)	Operation and maintenance Jobs created/MWp
Biomass	0.16	1.37
Geothermal	0.23	1.72
Landfill	0.31	5.04
Small hydro	0.14	1.14
PV	1.02	0.50
CSP	0.27	0.53
Wind	0.28	0.24

Source: Wei, Patadia, & Kammen, 2010.

Wei, Patadia, & Kammen (2010) gave the average number of jobs created for several renewable energy technologies. The average values of their findings are summarized in Table 7 for both the construction and operation phases.

Based on these numbers, the renewable energy market will be creating approximately 680 new job opportunities, excluding the large hydro and SWH markets which represent some 55% of the total market to be created. It should be borne in mind that these are only the direct jobs that will be dealing directly with renewable energy projects.

7.2.3 Social impact

The social impact of renewable energies in Lebanon will not be limited to job creation but will also have a different dimension. EDL serves only about 76% of total electricity needs, the rest is purchased from private generators and leaves about 5.6% of unsatisfied demand. This 5.6% most likely corresponds to the most vulnerable component of the Lebanese population that cannot afford the subscription fees for diesel generators.

The introduction of renewable energies will provide the electric network in Lebanon with extra electric energy that will help close the gap between demand for, and generation of, electricity.

In the case of full implementation of NREAP, the total electricity generated will be equivalent to approximately 3,951 GWh. This will provide extra hours of electric supply in 2020 as shown in Figure 25.

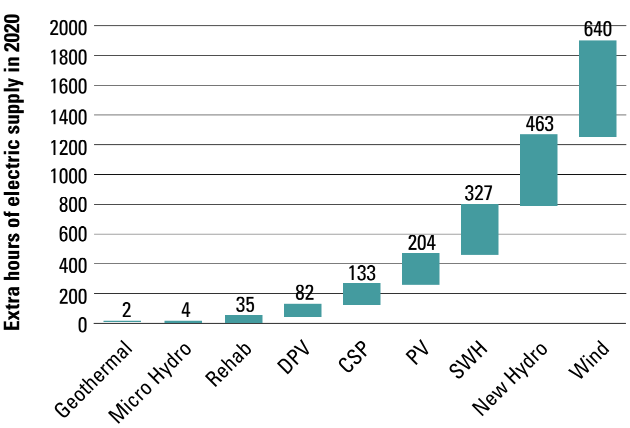
These renewable energy projects will be providing about 1,890 hours of extra electricity in 2020, reducing blackouts and diesel generators shares. This will benefit the least fortunate section of the Lebanese population by lowering the financial burden of their electricity bills.

7.3 Environmental impacts

7.3.1 Positive environmental impacts

Based on the life-cycle assessment studies by NREL (2012), Table 8 shows the average GHG CO2 equivalent emission factors:

Figure 25: Cumulative savings from NREAP (excluding biomass)



Source: NREAP.

Table 9: Average emission factors of different renewable energy technologies

Technology	Emission factor (gCO2eq/kWh)
Wind	11
PV	44
SWH	40
CSP	23
Hydro	9
Geothermal	50
Biomass	45

Source: NREL, 2012.

These numbers can be used to calculate the emission reduction of each renewable energy technology combined with the national emission factor of 650 gCO2eq/kWh for the national grid (Hajj Shehadeh, 2012).

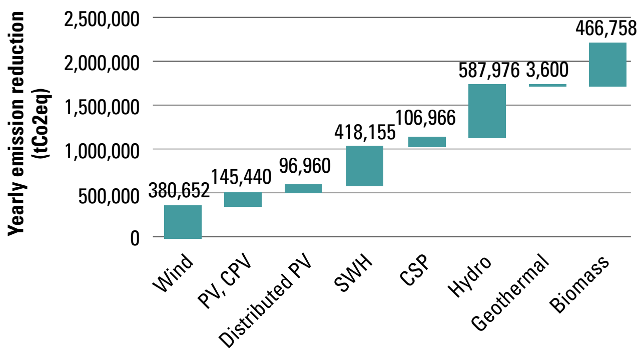
Figure 26 shows the contribution of each of the renewable energy technologies based on the previous assumptions. This leads, in the full application of NREAP to a reduction of more than 2,206 ktCO2eq/year of equivalent GHG emissions, helping to lower Lebanon's contribution from 19,603 ktCO2eq/year by around 11.25% to 17,397 ktCO2eq/year.

7.3.2 Negative environmental impacts

All projects to be developed in Lebanon should undergo an environmental impact assessment (EIA) as per a decision of the Lebanese Government.

Some of the renewable energy projects to be developed in Lebanon have already undergone an EIA, such as the Janneh hydroelectric power plant and damn. Other projects have already been prepared such as for the wind sector through the UNDP-CEDRO publication Environmental Impact Assessment for Wind Farm Developers: A Guideline Report that lays the ground for the major parameters to be studied in order to avoid environmental problems after the planning phase and before implementation (UNDP CEDRO, 2011).

Figure 26: Yearly emission reduction for each of the RE technologies (ktCO2eq)



VIII. Policy design considerations

8.1 Main driving factors that are shaping renewable energy policies and institutional framework in Lebanon

Efforts for the development of a complete strategy for renewable energies began in Lebanon in 2009 soon after the announcement of the 12% target for 2020. Early signs of these efforts began with the electricity reform paper in 2010 (Bassil, 2010) and the introduction of the concepts of demand-side management and renewable energy into electric planning.
This was further developed in 2011, in the first NEEAP for Lebanon for 2011–2015 through 14 initiatives combining both renewable energies and energy efficiency.

Soon afterwards, in 2012, LAS lunched AREF, followed by the template of NREAP to be adopted by Arab countries in 2014. Lebanon was one of the first countries to adopt both documents and to develop its NREAP following this template.

The geopolitical situation of the region constituted supplementary motivation as imports of electricity from Egypt and Syrian Arab Republic became very unstable following the situation in those countries. This led to an increased need of secured endogenous energy resources to cope with all the variations. In addition, oil and gas exploration underwent several delays, adding to the instabilities in the sector. One of the few stable elements remains renewable energies, which stimulated even further the finalization of NREAP.

Introducing permit schemes for renewable energy technologies and setting platforms for fruitful collaboration between governmental entities and with private-sector participation, is essential to attain the objectives of NREAP. The gradual introduction of the private sector into EDL through IPPs is one such step in the right direction. Moreover, it is critical to attract new expertise to EDL through a regular employment process, while updating the existing governance and management bylaws. All of this was an essential component within NREAP to provide a long-term strategy for renewable energy integration into the national grid.

8.2 Intended Nationally Determined Contribution (INDC/COP21-Paris)

Lebanon presents its INDC in a situation of development challenges, including, among other issues, a lack of security due to regional turmoil and a high level of poverty. To all of this was added the arrival of 1.13 million registered refugees from the Syrian crisis, who increased road transport, as well as the use of energy, water resources and infrastructure.
As submitted during COP 21 Paris in December 2015, the Lebanese mitigation targets can be summarized as follows:

The energy sector is at the heart of Lebanon's INDC, including the refurbishment, replacement and extension of conventional power-generation capacities and the switch to natural gas as laid down in the Policy Paper for the Electricity Sector (Bassil, 2010). Energy-efficiency measures from the second NEEAP for Lebanon (Mortada, El Khoury, & El Assad, 2016) were considered for reducing energy demand in line with the unconditional target of 3% compared to BAU in 2030. Another conditional target was set for energy efficiency: 10% energy savings compared to BAU in 2030.

Finally, NREAP is at the heart of the INDC, reflecting its targets through the use of renewable energy resources, 12% of power and heat demand supplied through renewable energy sources in 2020. The unconditional target for renewable energy in the INDC is 15% supplied in 2030, while the conditional target remains at 20%, being slightly more optimistic than NREAP.

Table 10: Conditional and unconditional targets submitted in Lebanon's INDC

Initiative	Description
Unconditional target	A GHG emission reduction of 15% compared to the business-as-usual (BAU) scenario in 2030
	15% of the power and heat demand in 2030 is generated by renewable energy sources
	A 3% reduction in power demand through energy-efficiency measures in 2030 compared to the demand under the BAU scenario
Conditional target	A GHG emission reduction of 30% compared to the BAU scenario in 2030
	20% of the power and heat demand in 2030 is covered by renewable energy sources
	A 10% reduction in 2030 in power demand through energy-efficiency measures compared to demand under the BAU scenario

Source: COP 21 Paris in December 2015.

The energy sector is at the heart of Lebanon's INDC, including the refurbishment, replacement and extension of conventional power-generation capacities and the switch to natural gas as laid down in the Policy Paper for the Electricity Sector (Bassil, 2010). Energy-efficiency measures from the second NEEAP for Lebanon (Mortada, El Khoury, & El Assad, 2016) were considered for reducing energy demand in line with the unconditional target of 3% compared to BAU in 2030. Another conditional target was set for energy efficiency: 10% energy savings compared to BAU in 2030.

Finally, NREAP is at the heart of the INDC, reflecting its targets through the use of renewable energy resources, 12% of power and heat demand supplied through renewable energy sources in 2020. The unconditional target for renewable energy in the INDC is 15% supplied in 2030, while the conditional target remains at 20%, being slightly more optimistic than NREAP.

IX. Barriers/challenges facing implementation of renewable energy projects and lessons learned

9.1 Economics and financial challenges

The renewable energy market began developing recently through small-scale projects backed up by the NEEREA financing mechanism. No financing mechanisms were adopted for large-scale projects, however, such as PPA. This is still preventing the market of renewable energies from progressing to the large-scale level.

Another barrier that still faces the development of the renewable energy market in Lebanon is the problem of EDL bankability; for any investor or lender, EDL is a company in deficit that will be the main customer for all large-scale projects. This can be a risk factor to be included in the risk study of the whole investment and will surely affect the final price.

Another risk component is the political stability in the country that is directly related to the development of markets and the economic bankability of the projects. Moreover, some of renewable energy components are considered by the tax authorities as luxury components, thereby increasing their customs fees without any clear and precise rule.

9.2 Market challenges

Lebanon's market has proved itself able to cope with any new products introduced. In 2013, the market for decentralized solar PV began to grow and suppliers began flourishing: more than 107 suppliers were accredited by LCEC in 2016.

This rapid growth in the number of suppliers has a downside to it, however, since it is difficult to monitor the quality of the suppliers.

Some of them moved from other market fields and began selling renewable energy products or even added these systems to the list of services they were providing. This constitutes a challenge for keeping the quality of these installations at good levels.

A final challenge related to the market of renewable energy in Lebanon is related to the fact that most parts of the renewable energy system are being imported from outside Lebanon and, with the high volatility of their prices, most of the local suppliers do not keep large stocks on their premises. This can cause delays in shipment of products and components that may reflect badly on the whole value chain.

9.3 Political, institutional/governance, regulatory and administrative barriers

Institutional barriers exist in the power sector in Lebanon, notably in the form of the existing and outdated legal framework for the power networks and utilities. Their regulations are based on industrial traditions, standards and codes that are not up to date with the developments of the sector. According to these regulations, EDL, already suffering from an ageing staff and administration and from a severe financial deficit, is in control of all power-network stages: generation, transmission and distribution, with most of its staff being recruited without taking into consideration the development of renewable energies. There is no dedicated directorate or department within EDL's hierarchy for planning, integrating or monitoring renewable energies on the national grid.

Typical required measures include introducing regular reforms, amending Law 462 for EDL corporatization, introducing permit schemes for technologies as suggested in NREAP, and by setting platforms for fruitful collaboration among governmental entities and with private sector participation.

The implementation of mitigation plans is negatively impacted by political instability and frequent changes in the constituents of the Government. As a result, strategies and decisions to restructure the power sector, if any, are lost in the political turmoil and the ever-changing governance and alliances of political parties. Furthermore, the fact that a large number of decision-makers and local authorities are not aware that renewable and alternative technology plays a supportive role in the social and economic development of the country adversely impacts this sector.

9.4 Cultural, behavioural and educational barriers

On the cultural level, and because of the various instabilities Lebanon has undergone throughout its history, the Lebanese people have become hesitant about large investments; they prefer to pay less in the short term, even if it implies paying more in the longer term. This can constitute a barrier to the development of decentralized renewable energy projects, where, despite the facilities provided by NEEREA, some people still do not wish to invest in a renewable energy project and prefer continuing the payments for a diesel generator.

On the educational level, most specialized engineers are recent graduates and do not have the experience to design large-scale projects. More precisely, the lack of expertise is even more apparent when it comes to operating large-scale projects. Vocational training is still missing in the specialized fields of each of the renewable energy technologies if advantage is to be taken of the job opportunities created.

9.5 Technical/technological challenges

One of the most important technical challenges lies in the adoption of a grid code that is adapted to the Lebanese situation and will allow the protection of both the national grid and the renewable energy projects from any instabilities.

The real challenge is that no grid code exists internationally that could be adopted as it is and there will be a major need to adapt it to the Lebanese situation in terms of operation and dispatching capabilities.

Finally, there are still some technical challenges that are caused by the lack of development of certain technologies, such as geothermal energy or biomass bricketting. Many unknowns still surround geothermal systems and we do not fully understand the technical challenges that will face such projects in Lebanon. In the case of biomass brickettes, it is still difficult to find good-quality raw products to operate stoves using them.

X. Conclusion and recommendations

The National Renewable Energy Action Plan presents a baseline for energy consumption in 2010, defines the national target for Lebanon in 2020 and sets the action plan aiming to achieve the 12% target.

This report presents the basic methodology behind the development of NREAP along with the evaluation of its impact on the Lebanese market. Implementation of NREAP will promote direct savings, due to cost differences between renewables and traditional EDL power plants, amounting to US$ 319 million.

The electricity reform paper (Bassil, 2010), based on a World Bank study, estimated that the cost of non-supplied electricity is around 700 US$/MWh. This results in indirect savings of more than US$ 2,765 million, based on a 3,951 GWh generation of renewable energies in 2020.

Not only financial and economic impacts were studied but also the environmental impact of the whole action plan assessing GHG emission reduction. It was estimated that, in 2020, when entirely operational, national emissions would be reduced by approximately 17,397 ktCO2eq yearly.

Renewable energies are usually developed in rural areas where the cost of land is not high and most of the resources are usually present. Most of the jobs created by these power plants therefore will be rural job opportunities fixing people in their home regions and limiting internal migration to the big cities. Adding renewable energies will help close the gap between the generation of and demand for electricity supplying approximately, at full load in 2020, 1,890 extra hours of electricity.

As for the recommendations of this study it is important to focus on some of the barriers that were discussed and that include:

- Adopting a clear and transparent custom fee to be applied to all renewable energy products;
- Working on lowering – in order to completely remove later on – all taxes on renewable energy products;
- Establishing a clear and transparent financing model for large-scale renewable energy projects, namely PPA;
- Solving the problem of EDL bankability through the use of another agency related to the Ministry of Energy and Water in Lebanon to function as a buffer customer for renewable energy projects;
- Political, security and economical stabilities are important factors for the development of the renewable energy market;
- Creating a licensing scheme for renewable energy installers and suppliers in order to be able to monitor and control the quality of components and systems introduced into the market, avoiding

thereby any negative advertising. The development of local manufacture of renewable energy systems, parts of the systems or components, must be considered also as a complementary step for the development of the renewable energy market in Lebanon;

- A serious implementation of the energy policies is needed in order to build trust in the field of energy in Lebanon and to send a clear message of commitment to the renewable energy field.

Bibliography

[1] Hassan, G. (2011): The National Wind Atlas of Lebanon. UNDP-CEDRO, Beirut, Lebanon.

[2] Bassil, G. (2010): Policy paper for the electricity sector. Ministry of Energy and Water, Beirut, Lebanon.

[3] Bouri, E. and J. El Assad (2016): The Lebanese Electricity Woes: An Estimation of the Economical Costs of Power Interruptions. Energies, 9–21.

[4] CIA (Central Intelligence Agency) (2016): The World Factbook: Lebanon.

[5] El Assad, J. and P. El Khoury (2016): National Renewable Action Plan for Lebanon, 2016–2020. Lebanese Centre for Energy Conservation, Beirut, Lebanon.

[6] Hajj Shehadeh, N. (2012): The Lebanese national CO2 emission factor. Lebanese Centre for Conservation Energy, Beirut, Lebanon.

[7] Harake, W. and E. Le Borgne (2016): Lebanon Economic Monitor: A geo-economy of risks and reward. World Bank, Beirut, Lebanon.

[8] IRENA (International Renewable Energy Agency) and ESCWA (United Nations Economic and Social Commission for Western Asia) (2016): A roadmap towards localizing the potential of manufacturing of appropriate RE technologies in the Arab Region. Beirut, Lebanon.

[9] Mortada, S., P. El Khoury and J. El Assad (2016): The Second National Energy Efficiency Action Plan for the Republic of Lebanon, NEEAP 2016–2020. Lebanese Centre for Energy Conservation, Beirut Lebanon.

[10] NREL (National Renewable Energy Laboratory) (2012): Life Cycle Assessment Harmonization: http://www.nrel.gov/analysis/sustain_lcah.html

[11] Shawon, M.E. (2013): Overview of wind energy and its cost in the Middle East. Sustainable Energy Technologies and Assessments, 1–11.

[12] Map 4282 United Nations, January 2010. http://www.un.org/Depts/Cartographic/map/profile/lebanon.pdf

[13] Sogreah-Artelia (2012a): Plan Directeur Hydroélectrique du Liban. Ministry of Energy and Water, Beirut, Lebanon.

[14] Sogreah-Artelia (2012b): Schéma Directeur Hydroélectrique du Liban. Ministry of Energy and Water, Beirut, Lebanon.

[15] Solar-Med-Atlas (2016): solar-med-atlas. Retrieved from solar-med-atlas, 28 August: www.solar-med-atlas.com

[16] Téllez, F., J. Obeid and C. Karam (2013): Concentrated Solar Plants. UNDP-CEDRO, Beirut, Lebanon.

[17] UNDP-CEDRO (2011a): Environmental impact assessment for wind farm developers, a guideline report. UNDP-CEDRO, Beirut, Lebanon.

[18] UNDP-CEDRO (2011b): The national wind atlas of Lebanon. Beirut, Lebanon.

[19] UNDP-CEDRO (2012a): Concentrated Solar power for Lebanon: A Techno-economic Assessment. Beirut, Lebanon.

[20] UNDP-CEDRO (2012b): National Bioenergy Strategy for Lebanon. Beirut, Lebanon.

[21] UNDP-CEDRO (2014a): The National Geothermal Resource Assessment of Lebanon. Beirut, Lebanon.

[22] CEDRO-UNDP (2014b): Lebanon's First National Survey of the Solar Water Heaters Market. Beirut, Lebanon..

[23] Vallvé, X. (2013): Photovoltaic plants in Lebanon. UNDP-CEDRO, Beirut, London.

[24] Walley, C.D. (2016): The Geology of Lebanon: A Summary. Retrieved from American University of Beirut, 11 August: http://ddc.aub.edu.lb/projects/geology/geology-of-lebanon/

[25] Wei, M., S. Patadia and D. M. Kammen (2010): Putting renewables and energy efficiency to work: How many jobs can the clean energy industry generate in the US? Energy Policy, 919–931.

[26] World Bank. (2016a): Data Bank of the World Bank. Retrieved from CO2 intensity (kg per kg of oil equivalent energy use) (27 August): http://data.worldbank.org/indicator/EN.ATM.CO2E.EG.ZS?view=map

[27] World Bank (2016b): Energy intensity level of primary energy (MJ/$2011 PPP GDP). Retrieved from World Bank, 11 October: http://data.worldbank.org/indicator/EG.EGY.PRIM.PP.KD?end=1994&locations=LB&name_desc=true&start=1994&view=map

[28] World Bank (2016c):World Bank National Accounts Data, and OECD National Accounts Data Files. Retrieved from the World Bank August 24: http://data.worldbank.org/indicator/NY.GDP.MKTP.CD?locations=LB

E17-00730