LEBANESE REPUBLIC
MINISTRY OF ENERGY AND WATER

LCEC
LEBANESE CENTER FOR ENERGY CONSERVATION
المركز اللبناني لحفظ الطاقة

The National Renewable Energy Action Plan for the Republic of Lebanon 2016-2020

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The National Renewable Energy Action Plan for the Republic of Lebanon 2016-2020

Prepared by the Lebanese Center for Energy Conservation (LCEC)

November 2016

Foreword

Lebanon has embarked on the path of sustainable energy since the commitment launched in Copenhagen in 2009 by the Lebanese Government to develop renewable energy (RE). That famous commitment, well defined in the 2010 Ministry of Energy and Water (MEW) *Policy Paper for the Electricity Sector*, has become a source of challenge and pride for our country, a real challenge to all concerned parties to reach this target by 2020 and a real pride because this commitment has boosted sustainable energy development in Lebanon to a high priority level.

On behalf of MEW, it gives me great pleasure to help release *The National Renewable Energy Action Plan for the Republic of Lebanon* (NREAP 2016-2020). This document, a follow-up report to *The National Energy Efficiency Action Plan for Lebanon* (NEEAP 2011-2015), is important because it clarifies-quantitatively rather than qualitatively-all the individual targets for the different RE technologies needed to reach the 12% target first set in 2009.

In terms of set numbers, our main target is to implement RE projects that would actually produce approximately 767 kilotonnes of oil equivalent (ktoe) in 2020, equivalent to 12% of the projected total electricity and heating demand in Lebanon during that year. MEW is aware that this target is challenging, but we are also confident that aligning the efforts of all national players and international allies would lead to achieving this target.

Three main paths need to be developed in order to reach this 12% target. Wind energy for electricity production would represent one major milestone with a projected share of 2.06% of the total Lebanese demand for Energy in 2020. Solar energy-including solar photovoltaics (PV), concentrated solar power (CSP), and solar water heaters-would be another important milestone with around 4.20%. In addition, benefitting from hydro resources for electricity production would be essential with a percentage of around 3.24%. Finally, biomass would cover around 2.50%.

MEW will exert all possible efforts to set the right policies and the needed mechanisms to make our 767 ktoe target a reality. We count on all our partners to support us in this promising journey, and we look forward to celebrating the implementation of NREAP 2016-2020 by 2020 as a success for Lebanon, all of Lebanon.

Arthur Nazarian
Minister of Energy and Water

| Acknowledgments

While developing this document, the LCEC team was supported by a large number of energy experts, public officials, and university professors. LCEC is thankful to those who contributed to fine-tuning this document and enriching it with comments and suggestions.

LCEC is also thankful to the team of the Country Energy Efficiency and Renewable Energy Demonstration Project for the Recovery of Lebanon (CEDRO) project, specifically to the project manager of CEDRO Dr. Hassan Harajli. The supportive work done by CEDRO throughout the past few years was essential in giving the NREAP of Lebanon its scientific backbone. LCEC also extends thanks to the United Nations Development Programme (UNDP) Lebanon for all the support offered to the development of sustainable energy in Lebanon.

The European Union has been accompanying all national efforts to develop the RE in Lebanon. The generous support of the European Union has left very positive marks on this sector, namely through the different initiatives and projects-Energy Efficiency in the Construction Sector in the Mediterranean (MED-ENEC), Mediterranean Development of Support schemes for solar Initiatives and Renewable Energies (MED-DESIRE), Technical Assistance and Information Exchange (TAIEX) program, and CEDRO. LCEC is thankful to the European Union.

NREAP 2016-2020 follows the model developed by the Energy Department at the League of Arab States (LAS) and the Regional Center for Renewable Energy and Energy Efficiency (RCREEE). LCEC is keen to thank both institutions for their support and valuable advice.

NREAP 2016–2020 wouldn't have its national value without the support and adoption of the MEW. LCEC is thankful mostly to the Minister of Energy and Water His Excellency (H.E.) Mr. Arthur Nazarian for all his support, trust, and encouragement. The efforts of our national partners are highly appreciated, especially the management and engineering teams at the national electric utility Electricité du Liban (EDL). EDL plays a major role in the development of Lebanon's RE.

All other national players have offered LCEC a lot of support, namely the Office of the Prime Minister, the Ministry of Foreign Affairs, the Ministry of Industry (MOI), the Ministry of Environment (MOE), the Central Bank of Lebanon (BDL), the Order of Engineers and Architects in Beirut, the Industrial Research Institute (IRI), and the Lebanese Standards Institution (LIBNOR).

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Abbreviations

A	ampere
AECID	Spanish Agency for International Development Cooperation
AENOR	Spanish Association for Standardization and Certification
AFD	Agence Française de Développement
BDL	Banque du Liban (Central Bank of Lebanon)
BOT	build-operate-transfer
BRSS	Beirut River Solar Snake (demonstration project)
BTU	British thermal unit
CDR	Council for Development and Reconstruction
CEDRO	Country Energy Efficiency and Renewable Energy Demonstration Project for the Recovery of Lebanon
CO_2	carbone dioxide
COM	Council of Ministers
COP	Conference of the Parties
CPV	concentrated photovoltaic
CSP	concentrated solar power
DIN CERTCO	Certification organization of the TUV Rheinland and DIN, the German institute for standardization
DNI	direct normal irradiation
DREG	Small Decentralized Renewable Energy Power Generation (project)
DQS Hellas	Certification Body for Management Systems, Products and Persons - Athens
E	exa (1,000,000,000,000,000,000)
EC	European Commission
EDL	Electricité du Liban
EE	energy efficiency
EGS	enhanced geothermal system
EIB	European Investment Bank
EPC	energy performance contract
ESCO	energy service company
EU	European Union
G	giga (1,000,000,000)
GCC	Gulf Cooperation Council
GDP	gross domestic product
GEF	Global Environment Facility
GHG	greenhouse gas
GHI	global horizontal irradiance
GOL	Government of Lebanon
GSHP	ground-source heat pump
GWh	gigawatt-hour
GWth	gigawatt thermal
HAWT	horizontal axis wind turbine
H.E.	His Excellency
ICA	International Copper Association

IEA	International Energy Agency
INDC	Intended Nationally Determined Contributions
IRENA	International Renewable Energy Agency
IRI	Industrial Research Institute
J	joule
k	kilo (1,000)
K	kelvin
LAS	League of Arab States
LBP	Lebanese pound
LCEC	Lebanese Center for Energy Conservation
LCOE	levelized cost of energy
LG	liquid gas
LIBNOR	Liban Normes; Lebanese Standards Institution
LMSEP	Lebanon Municipal Service Emergency Project
LPG	liquid petroleum gas
LRA	Litani River Authority
LRF	Lebanon Recovery Fund
M	mega (1,000,000)
MDG	Millennium Development Goal
MENA	Middle East and North Africa (region)
MED-ENEC	Energy Efficiency in the Construction Sector in the Mediterranean (project)
MED-DESIRE	Mediterranean Development of Support schemes for solar Initiatives and Renewable Energies (project)
MEPS	minimum energy performance standards
MEW	Ministry of Energy and Water
MMC	Medrar Medical Center
MOA	Ministry of Agriculture
MOE	Ministry of Environment
MOF	Ministry of Finance
MOI	Ministry of Industry
MOPWT	Ministry of Public Works and Transportation
MW	megawatt
MWh	megawatt-hour
MWp	megawatt peak
NAMA	Nationally Appropriate Mitigation Action
NEEAP	National Energy Efficiency Action Plan
NEEREA	National Energy Efficiency and Renewable Energy Action
NREAP	National Renewable Energy Action Plan
O&M	Operation and Maintenance
PG	private generators
PPA	power purchase agreement
PV	photovoltaic
RCREEE	Regional Center for Renewable Energy and Energy Efficiency
RE	renewable energy
RFP	request for proposal

SCADA	supervisory, control and data acquisition
SHW	solar hot water
SME	small and medium enterprise
SUDEP	Sustainable Urban Demonstration Energy Projects (programme)
SWH	solar water heater
t	tonne
T	tera (1,000,000,000,000)
TAIEX	Technical Assistance and Information Exchange (instrument)
tCO_2e	tonne CO_2 equivalent
toe	tonnes of oil equivalent
TOU	time of use
UNDAF	United Nations Development Assistance Framework
UNDP	United Nations Development Programme
UNEP	United Nations Environment Programme
UNFCCC	United Nations Framework Convention on Climate Change
UNIFIL	United Nations Interim Force in Lebanon
USAID	United States Agency for International Development
USD	US dollar
V	volt
VA	volt-ampere
VAR	volt-ampere reactive
VAT	value added tax
VAWT	vertical axis wind turbine
W	watt
WB	World Bank
WEC	World Energy Council
Wh	watt-hour
Wp	watt-peak
y	year

Declaration of the Government of Lebanon, 2009

«اعتماد خريطة طريق وطنية مبنية على مفاهيم بيئية حديثة (الطاقة الخضراء) وتعتمد على مصادر الطاقة المتجددة وصولاً إلى تأمين حوالي ١٢٪ من استهلاك لبنان، عن طريقها، في العام ٢٠٢٠.»

"The adoption of a national road map built on modern environmental concepts (green energy) and counting on renewable energy sources to reach 12% of Lebanon's needs by the year 2020."

Introduction

The famous commitment launched in 2009 by the Lebanese Government to reach 12% of renewable energy (RE) by 2020 has never been more realistic than today. Both the Ministry of Energy and Water (MEW) *Policy Paper for the Electricity Sector* (2010) and *The National Energy Efficiency Action Plan for Lebanon* (NEEAP 2011-2015) fostered this important target. While these documents set targets for the period 2010-2015, now is the time for Lebanon to review its national plans, update them, and set clear paths to reach the RE objectives for the year 2020.

This report, *The National Renewable Energy Action Plan for the Republic of Lebanon* (NREAP 2016-2020), is the main national document that will ideally lead the way for Lebanon to develop the different RE technologies needed to reach the 12% target by the year 2020. By adopting this document, the MEW is hereby creating the path that all national efforts and international support need to follow to develop RE in Lebanon. Being the main authority to develop the energy sector, MEW, through the work of the Lebanese Center for Energy Conservation (LCEC), is striving to align all efforts towards sustainable energy.

Initially, the Lebanese Government was not clear in defining the 12% target. In fact, the commitment of the Lebanese Government launched during the 2009 Conference of the Parties (COP) meeting in Copenhagen was more a political vision to promote RE in Lebanon. In 2010, MEW strengthened this vision in its *Policy Paper for the Electricity Sector* by stating that the target was to reach “12% of the electric and thermal supply” not just “12% of Lebanon’s needs”.

In order to define more explicitly the target for Lebanon in 2020, LCEC considers that the 12% national target translates as follows: “the amount of energy produced by RE sources in 2020 should be equal to 12% of the total amount of energy needed for electricity and heating demand in the country”.

To have a well-structured NREAP, LCEC has divided this document into three main parts as follows:

- Part A-Current situation, trends, and objectives
- Part B-Development of renewable energy technologies
- Part C-Policies and tools

Part A starts with describing the current situation of the energy sector in Lebanon including the development of RE prior to 2015. This part also defines year 2010 as the baseline year and estimates the demand growth in terms of electricity and heating through 2020. The the national objective, 12% of the total electricity and heating demand, is then calculated.

Part B offers a detailed description of the different RE technologies to be used in Lebanon to meet the 2020 objective, including the target for each technology, the financial appraisal of the technology, the needed budget, and the way forward.

It is important to note that for each technology, three different scenarios are considered. The three scenarios are labeled *pessimistic*, *realistic*, and *optimistic*. While the two extreme scenarios are used as flexibility margins, the realistic scenario targets the 12% objective. Based on the realistic scenario objective in 2020, estimations for the 2030 target are then presented.

Finally, Part C discusses the policies and tools that Lebanon needs to follow and use to reach the set objectives. This part deals with legal issues and legislation, awareness raising, capacity building, quality control, financing mechanisms, and grid code.

Part A

Current situation, trends, and objectives

Mr. Ghassan Baydoun, Director General, General Directorate of Exploitation, MEW

The General Directorate of Exploitation at the MEW is supporting all efforts to achieve our national targets for RE development. We sincerely believe that our national objectives for 2020 are tangible and feasible. Under the guidance of the Minister, we will keep supporting the work of LCEC, both administratively and financially, towards reaching a greener future for our country.

Chapter 1: The Evolvement of Renewable Energy in Lebanon

1.1 A Bit of History

The first RE power plant in Lebanon was installed back in 1924. Using hydroelectric power, the Bécharé plant was built under the French mandate, and it is still operational today, though partially.

Lebanon experienced fast development of hydropower plants between the 1920s and the 1970s, when the civil war began. It is impressive to know that in 1976 approximately 70% of the total electricity production in Lebanon came from hydroelectricity (see Figure 1). Today, hydropower accounts for merely 2% to 4% of the total electricity generation.

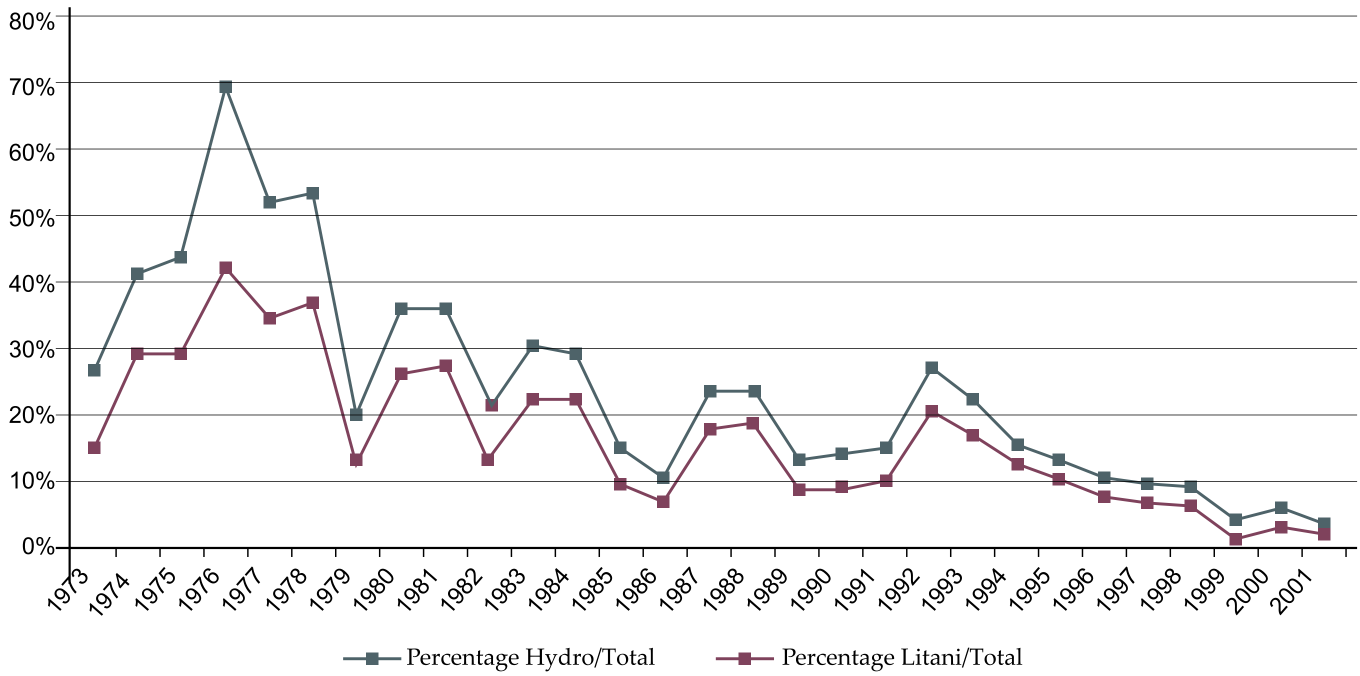


Figure 1. Percentage of hydropower production versus total electricity production (1973–2001). *Reprinted from The use of natural gas for power generation in Lebanon: analysis of the proposed solutions for the Beddawi and Zahrani power plants* (master's thesis), by P.T. El Khoury, 2006, Beirut: American University of Beirut.

Following the end of the civil war in 1990, Lebanon witnessed some efforts to reintroduce RE technologies to the market, especially the use of solar water heaters in residential applications. Few projects were actually executed. Large traditional power plants were then built between 1990 and 1998 to supply this increasing demand for electricity that the country witnessed during this period. RE was not a priority.

In 2005, and following the setup of the LCEC project at MEW, the RE and energy efficiency (EE) themes started to reemerge as serious alternatives to curb the energy demand, to supply clean energy, and to help reduce the negative effects on the environment.

A national momentum was evolving in the country, specifically thanks to the numerous projects initiated by the United Nations Development Programme (UNDP) in Lebanon and afterwards by the European Union and other donors whose efforts were echoing the international momentum to fight climate change. However, the first real milestone for the development of RE came out in 2009 when the Lebanese Government committed to reach 12% of RE by 2020.

A national vision and strategy

At the fifteenth session of the COP to the United Nations Framework Convention on Climate Change (UNFCCC) meeting in Copenhagen, Denmark, former Prime Minister H.E. Mr. Saad Hariri announced in presence of former Minister of Energy and Water H.E. Mr. Gebran Bassil that Lebanon is committed to reach 12% of RE by 2020.

Following this political commitment, the *Policy Paper for the Electricity Sector* adopted by the Lebanese Government in 2010 clearly states "this policy commits to launching, supporting, and reinforcing all public, private and individual initiatives to adopt the utilization of renewable energies to reach 12% of electric and thermal supply" (Bassil, 2010).

1.2 The year 2010: a turning point

By 2009, the average available electricity production capacity (including imports) was 1,500 megawatts (MW) while the average demand was 2,000–2,100 MW. The instantaneous peak demand in the summer of 2009 was estimated at 2,450 MW. The total energy demand in 2009 was 15,000 gigawatt-hours (GWh) although the total produced energy (including imports) was 11,522 GWh. Accordingly, the electric energy deficit in Lebanon was estimated to be 3,478 GWh (Bassil, 2010).

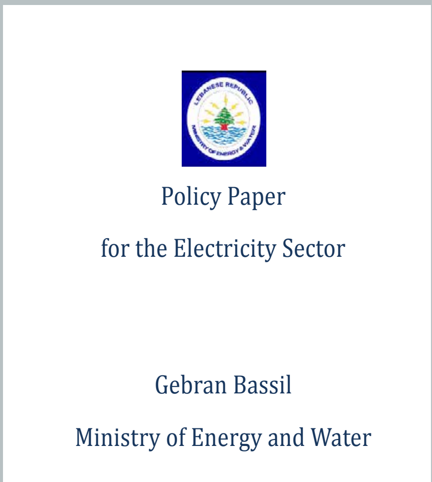
In Lebanon, electricity is basically generated from thermal and hydroelectric power plants. Approximately 7.5% of the total electricity production in 2009 was purchased from Syria (589 GWh) and Egypt (527 GWh) through regional interconnections. In addition to the deficit in electricity supply, the Lebanese electricity sector was facing several problems such as load shedding, technical losses, and the aging of power plants. This situation resulted in technical and financial impacts on customers, the Government, and the entire economy. The Lebanese end-users were forced to rely on diesel generators to overcome the electricity shortages.

To overcome all these problems, MEW published a comprehensive energy policy (the 2010 *Policy Paper for the Electricity Sector*) that was approved by the Council of Ministers (COM) on June 21, 2010. In addition to proposing a strategic solution to the electricity sector in Lebanon, the Policy Paper also built on the 12% commitment of RE to propose some future milestones. The year 2010 is then considered the turning point in the development of the electricity sector and, more specifically, RE in Lebanon.

1.3 Policy Paper for the Electricity Sector in Lebanon

The *Policy Paper for the Electricity Sector* covers all the aspects of the energy sector in Lebanon and includes 10 initiatives, 3 of which are dedicated to EE and RE.

The Policy Paper for the Electricity Sector - A strategic milestone


Policy Paper

for the Electricity Sector

Gebran Bassil

Ministry of Energy and Water

The COM approved the Policy Paper for the Electricity Sector on June 21, 2010. The Policy Paper includes 10 initiatives grouped as follows: infrastructure (generation, transmission, and distribution), supply and demand (fuel sourcing, RE, demand side management/EE, and tariffs), and legal framework [norms and standards, corporatization of Electricité du Liban (EDL), and legal status].

In terms of RE, the Policy Paper focused on the development of hydropower, wind energy, solar photovoltaic (PV) applications, solar water heaters, and waste-to-energy.

The *Policy Paper for the Electricity Sector* has set the strategic path for the development of RE in Lebanon.

In terms of conventional supply, the *Policy Paper for the Electricity Sector* includes solutions for the identified problems in the electricity sector (generation, transmission, and distribution). On the generation side, the target is to reach "a total installed capacity of 4,000 MW by 2014 and 5,000 MW thereafter to meet a load of 2,500 MW (summer 2009), 500 MW of demand not currently supplied (i.e., self-generation), future demand corresponding to an annual load growth of 7%, and approximately 15% of peak load reserve" (Bassil, 2010). Per the Policy Paper, the proposed measures cost approximately 4,513-4,739 million US dollars (USD 4,513-4,739 million) (Bassil, 2010).

It is important to note that the purpose of this current document is not conventional energy production. However, NREAP 2016-2020 relies on the commitment of the Lebanese Government set in the Policy Paper as a baseline to estimate the planned electricity generation, from which renewable electric energy production will be deduced.

Important assumptions!

In this report (NREAP 2016–2020), it is clearly assumed that the Lebanese Government will be implementing the initiatives of the 2010 *Policy Paper for the Electricity Sector* in terms of conventional energy and conventional electricity production.

The report also assumes that the annual load growth on electricity demand is 7% (Bassil, 2010).

At the transmission and distribution levels, the Policy Paper sets targets to reduce technical losses, to ensure adequate connections, and to complete and improve the systems infrastructure. The overall infrastructure improvements were estimated to cost USD 5,770–6,005 million (Bassil, 2010). The cost included a three-phase strategy with targets for each phase (short-term, mid-term, and long-term).

Among the many set objectives, the Policy Paper "commits to launching, supporting and reinforcing all public, private and individual initiatives to adopt the utilization of renewable energies to reach 12% of electric and thermal supply" (Bassil, 2010). The Policy Paper also commits to "control the energy demand growth in order to save a minimum of 5% of the total demand" (Bassil, 2010). As mentioned earlier, three initiatives of the Policy Paper deal with EE and RE. In terms of RE, the Policy Paper insists on the development of a wind atlas and a feasibility study for PV farms and the promotion of clean energy among the public (Bassil, 2010). The Policy Paper covered many aspects of RE development, namely:

- Increasing the share of hydraulic power production through maintenance, rehabilitation, and/or replacement of existing hydro plants, and facilitating the implementation of additional capacity on a build-operate-transfer (BOT) basis

- Introducing wind power via the private sector by building wind farms (60–100 MW)

- Encouraging the private sector to adopt waste-to-energy technology for power generation and to investigate geothermal energy

- Increasing the penetration of solar water heaters (SWH) and devising innovative financing schemes in collaboration with the banking sector to achieve the slogan "A solar heater for each household

The RE initiatives of the Policy Paper (in addition to the EE measures) are actually the main milestones around which NEEAP 2011–2015 was developed. It is worth noting that NEEAP 2011–2015 included both EE and RE measures. The next section of this report will review the NEEAP 2011–2015 initiatives and focus on the RE sections in this document.

1.4 The National Energy Efficiency Action Plan for Lebanon (2011–2015)

The COM of Lebanon adopted the NEEAP for Lebanon on November 10, 2011 (Decision Number 26). NEEAP 2011–2015 includes 14 initiatives that tackle EE and RE. It was prepared in conformance with the Arab energy efficiency guideline (based on EU directive 2006/32/EC on energy end-use efficiency and energy service), and Lebanon was the first Arab country to officially adopt such a plan. The initiatives are correlated and cross sectorial.

The 14 initiatives of NEEAP 2011–2015 are:

- Initiative 1: Towards banning the import of incandescent lamps to Lebanon

- Initiative 2: Adoption of the energy conservation law and institutionalization of the LCEC as the national agency for Lebanon

- Initiative 3: Promotion of decentralized power generation by PV and wind applications in the residential and commercial sectors

- Initiative 4: Solar water heaters for buildings and institutions

- Initiative 5: Design and implementation of a national strategy for efficient and economic public street lighting in Lebanon

- Initiative 6: Electricity generation from wind power

- Initiative 7: Electricity generation from solar energy

- Initiative 8: Hydro power for electricity generation

- Initiative 9: Geothermal, waste-to-energy, and other technologies

- Initiative 10: Building code for Lebanon

- Initiative 11: Financing mechanisms and incentives

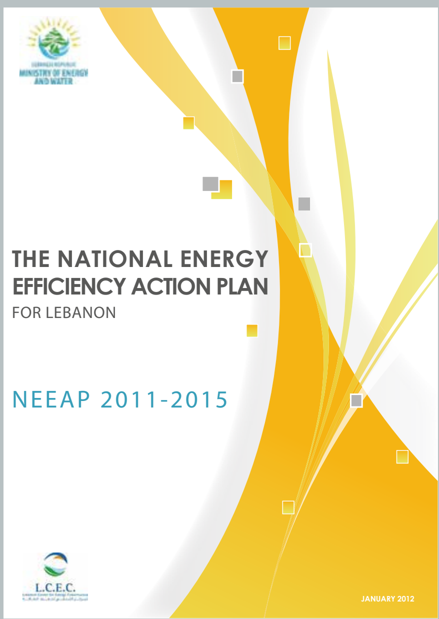
- Initiative 12: Awareness and capacity building

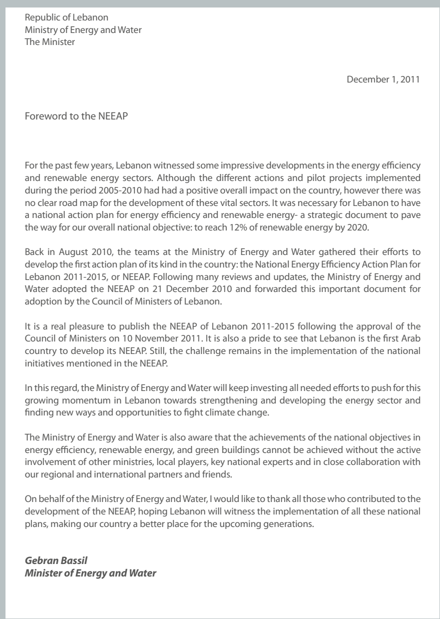
- Initiative 13: Paving the way for energy audit and energy service company (ESCO) business

- Initiative 14: Promotion of energy-efficient equipment

As mentioned earlier, NEEAP 2011–2015 is developed in accordance with the measures of the Policy Paper. From 2011 to 2015, MEW through LCEC invested all efforts toward implementing the 14 initiatives. While many initiatives have been implemented, some initiatives were delayed or encountered obstacles. The implementation of NEEAP 2011–2015 was evaluated in November 2014 in collaboration with the European Union-funded MED-ENEC project.

Seven renewable energy initiatives in The National Energy Efficiency Action Plan for Lebanon




Republic of Lebanon
Ministry of Energy and Water
The Minister

December 1, 2011

Foreword to the NEEAP

For the past few years, Lebanon witnessed some impressive developments in the energy efficiency and renewable energy sectors. Although the different actions and pilot projects implemented during the period 2005-2010 had had a positive overall impact on the country, however there was no clear road map for the development of these vital sectors. It was necessary for Lebanon to have a national action plan for energy efficiency and renewable energy- a strategic document to pave the way for our overall national objective: to reach 12% of renewable energy by 2020.

Back in August 2010, the teams at the Ministry of Energy and Water gathered their efforts to develop the first action plan of its kind in the country: the National Energy Efficiency Action Plan for Lebanon 2011-2015, or NEEAP. Following many reviews and updates, the Ministry of Energy and Water adopted the NEEAP on 21 December 2010 and forwarded this important document for adoption by the Council of Ministers of Lebanon.

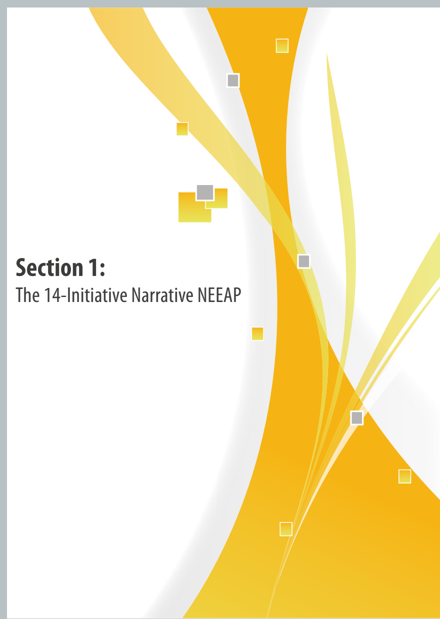
It is a real pleasure to publish the NEEAP of Lebanon 2011-2015 following the approval of the Council of Ministers on 10 November 2011. It is also a pride to see that Lebanon is the first Arab country to develop its NEEAP. Still, the challenge remains in the implementation of the national initiatives mentioned in the NEEAP.

In this regard, the Ministry of Energy and Water will keep investing all needed efforts to push for this growing momentum in Lebanon towards strengthening and developing the energy sector and finding new ways and opportunities to fight climate change.

The Ministry of Energy and Water is also aware that the achievements of the national objectives in energy efficiency, renewable energy, and green buildings cannot be achieved without the active involvement of other ministries, local players, key national experts and in close collaboration with our regional and international partners and friends.

On behalf of the Ministry of Energy and Water, I would like to thank all those who contributed to the development of the NEEAP, hoping Lebanon will witness the implementation of all these national plans, making our country a better place for the upcoming generations.

Gebran Bassil
Minister of Energy and Water



The Lebanese Government approved NEEAP 2011–2015 on November 10, 2011. NEEAP 2011-2015 includes 14 initiatives, out of which 7 are dedicated to RE.

Each of the 14 initiatives is evaluated individually to get a view on how much has been implemented over the past years. While NEEAP 2011-2015 defines a number of "Milestones and Proposed Steps" for each of the 14 initiatives, only the most relevant milestones were used in the evaluation as indicators on the level of achievement of the initiative.

Each milestone was then translated into a quantifiable target. In many cases, the milestones set in NEEAP 2011–2015 were qualitative (e.g., "conduct a market survey") and were translated into quantifiable percentages of completion (0% to reflect "not reached", 50% to reflect "partly completed", and 100% to reflect "completely achieved") (MEW/LCEC, 2012). With quantitative targets, the level of completion could be measured directly. The percentage of completion is calculated based on the target and the status quo. For instance, if the objective of measure is to conduct four trainings, while actually only three took place, then a 75% completion rate is reported (see Table 1 for completion results of all 14 NEEAP 2011–2015 initiatives). This percentage is the ratio of achievement to target. Multiplied with the weighting factors of the milestone, the total score of each initiative is then calculated.

Table 1. Evaluation results for the National Energy Efficiency Action Plan of Lebanon 2011-2015

Initiative	Description	Percentage of completion
1	Towards banning the import of incandescent lamps to Lebanon	45
2	Adoption of energy conservation law and institutionalization of LCEC as the national agency for Lebanon	40
3	Promotion of decentralized power generation by PV and wind applications in the residential and commercial sectors	30
4	Solar water heaters for buildings and institutions	53
5	Design and implementation of national strategy for efficient and economic public street lighting	60
6	Electricity generation from wind power	23
7	Electricity generation from solar energy	42
8	Hydro power 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 energy-efficient equipment	8

The evaluation of the first NEEAP (2011-2015) identified many gaps in the development of EE and RE in Lebanon. For instance, NEEAP 2011-2015 lacks a clearly defined, overall target regarding RE. An overall target is not only relevant for completeness but can help to monitor the initiatives. In addition, the evaluation shows that some measures are correlated, so progress is attributed to more than one measure, making evaluation difficult and incorrect. It is also worth noting that NEEAP 2011–2015 included measures for EE and RE jointly.

The difficulties faced in the evaluation of NEEAP 2011-2015 were taken into account when developing this document. Mainly, NREAP 2016-2020 includes only measures regarding RE and includes several scenarios in the development of RE in Lebanon. In addition, one of the main identified gaps in NEEAP 2011–2015 is the lack of a clear baseline. This issue is the first to be tackled in the following chapters.

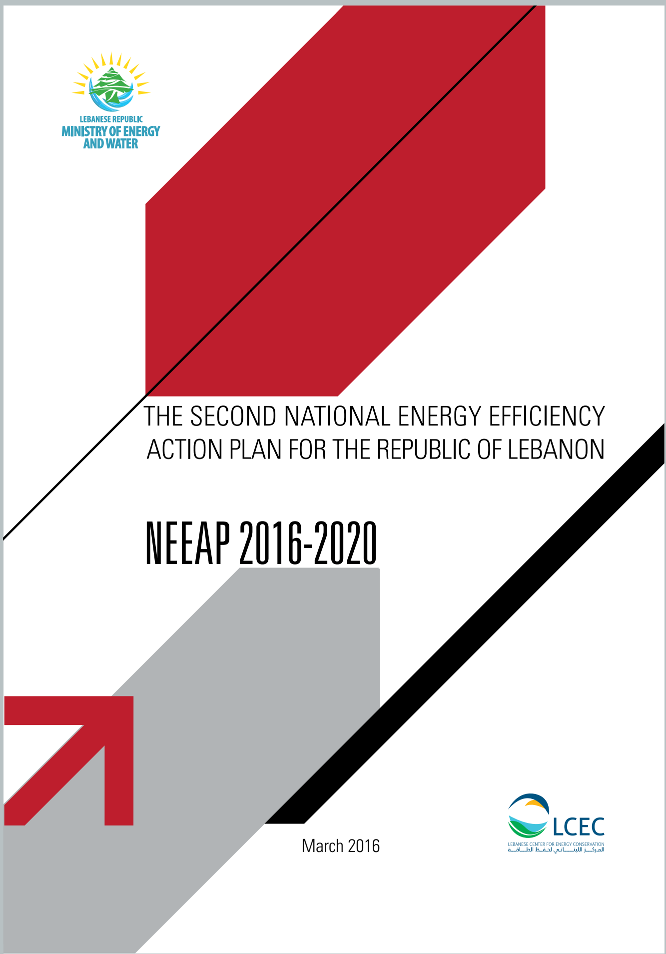
Finally, it is worth noting that The *Second National Energy Efficiency Action Plan for the Republic of Lebanon* was published in March 2016.

The Second National Energy Efficiency Action Plan for Lebanon dedicated solely to energy efficiency

The *Second National Energy Efficiency Action Plan for the Republic of Lebanon* (NEEAP 2016-2020) builds on the EE initiatives proposed in the first NEEAP 2011-2015 and complements them. The implementation of the second NEEAP 2016-2020 would need USD 600-950 million over a period of five years, creating a huge positive market momentum (MEW/LCEC, 2016).

NEEAP 2016-2020 is divided into two main sections: the power sector measures and the end-use measures. The power sector measures tackle EE in electricity generation, transmission, and distribution. The end-use section includes five chapters: (1) horizontal end-use measures (2) end-use measures in the building sector, (3) end-use measures in industry and agriculture, (4) measures in mobility and transport, and (5) end-use measures in the public sector.

Moreover, NEEAP 2016–2020 includes different types of measures regarding policies, regulations,



action plans, and implementation. Each measure is written in a tabulated form followed by a section explaining the savings calculation methodology. The tabulated form includes the aim of the measure, its description, its estimated savings, indicators (input, output, and outcome), funds for completion, and next steps.

The implementation of NEEAP 2016-2020 would result in savings exceeding USD 225 million per year (y) starting in 2020 (MEW, 2016). The sum of the overall estimated savings of the proposed measures over the five years of the second NEEAP's implementation are 686.1 GWh for the power sector and 828.1 GWh for end-use energy (MEW, 2016). That implies a total saving of 1,514.2 GWh over the five years and leading to average yearly savings of 302.9 GWh (MEW, 2016) .

By implementing the second NEEAP's 26 initiatives, the actual electric power growth rate of 7% could be reduced to 5.81% in 2020 (MEW, 2016). NEEAP 2016-2020 is available at:

http://www.lcec.org.lb/en/LCEC/DownloadCenter/Others#page=1

Ms. Aurore Feghali, Director General, Directorate of Oil, MEW

The General Directorate of Oil at the Ministry of Energy and Water is fully aware of the importance of renewable energy development in Lebanon.

The Directorate is the official source for preparing and publishing the national energy bill of the country, and we know that the energy bill places a huge burden on the national economy. Having an accurate set of data is of prime importance, because data is the main source upon which we build our national policies.

| Chapter 2: Current energy trends and definition of the baseline year

2.1 Energy imports to Lebanon

Lebanon relies essentially on oil imports as its main resource for energy production. An analysis of the oil imports to the country including amounts, flows, shares, and trends is a major step to be able to set a clear baseline. At this stage, it is important to note that the next analysis is based on many data sources and analysis done by the LCEC team. LCEC considers all data presented in this subsection as the closest to reality. LCEC is keen to tune this data whenever new data facts emerge.

The country's primary energy imports cover essentially the following types of oil products: liquid gas, gasoline, gas oil, fuel oil, kerosene, and asphalt. Fuel oil is actually used by two main consumers, EDL and the local market. A considerable share of the fuel oil and gas oil imported goes to EDL, while another minor quantity goes to the local market (mainly used in industries). Liquid gas, gasoline, kerosene, and asphalt go directly to the local market (see Figure 2).

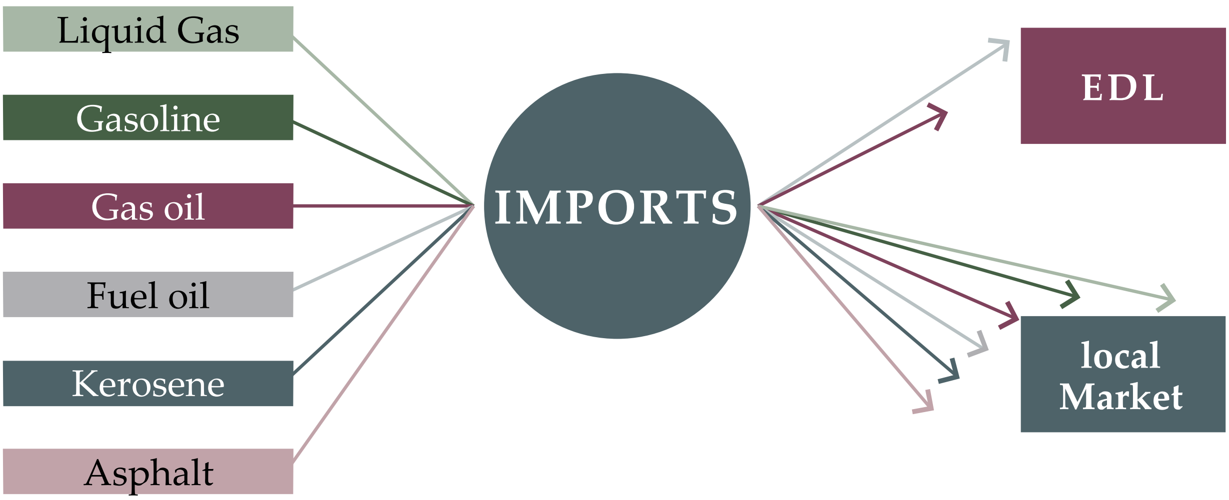


Figure 2. Flow of oil products in the Lebanese Market

Figure 3 shows the evolution of the import of all oil products between 2001 and 2014 (measured in tons of oil and in tons of oil equivalent (toe). It is important to note that the curve in this figure shows an expected increasing trend, with the sudden decrease in 2006 being the direct cause of the war that took place during that year.

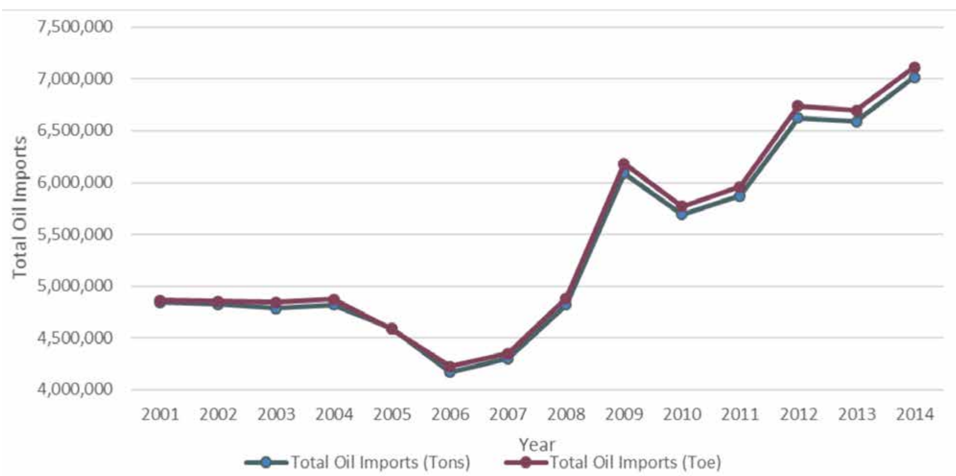


Figure 3. Total oil imports between 2001 and 2014

Figure 4 shows the yearly distribution of oil imports as measured in toe. From this graph, it can be clearly seen that gasoline, gas oil, and fuel oil have the major shares. The large quantity of gasoline is due to the large number of vehicles in Lebanon using this type of fuel. On the other hand, fuel oil and gas oil are the essential sources of the major power plants of the country.

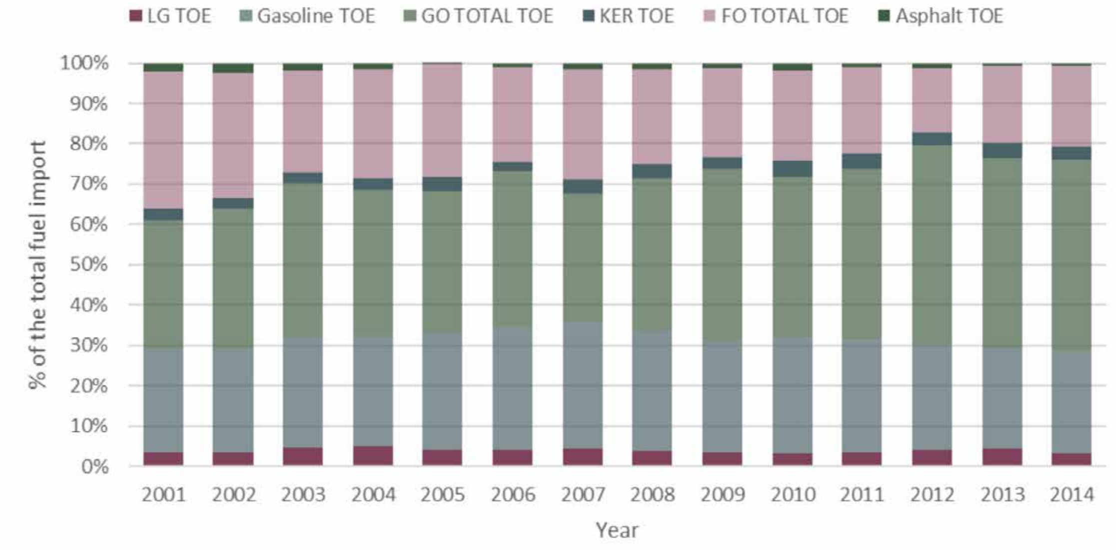


Figure 4. Shares of oil products imported between years 2001 and 2014

2.2 Primary energy mix in the 2010 baseline year

NREAP 2016–2020 considers the year 2010 as the baseline year and the year 2020 as the target year. The selection of the year 2010 is done according to the recommendations of the League of Arab States (LAS) for both the second NEEAP and the NREAP. In addition, the choice of this year is also dependent on the relative stability in the oil trends shown in the section above.

Referring again to the recommendations of LAS, national RE action plans in the different countries of the Arab World must present a unified baseline in 2010 consisting of the following info:

- Electricity generation from non-RE resources

- Electricity generation from RE resources

- Heating from all resources

- Cooling from all resources

In order to quantify the baseline, a clear primary energy mix in 2010 is needed. Other than the overall oil imports, the primary energy mix of Lebanon in 2010 includes all types of primary energy consumed in Lebanon. Accordingly, electricity imports from neighboring countries, hydroelectric generation, and other RE sources are to be included in the primary energy mix.

Standardizing units according to the International Energy Agency

The development of national strategies and actions plans worldwide are subject to different approaches of calculations, measurements, evaluation, and reporting. One main issue of concern is the use of units and conversion factors (specifically for power capacity and energy production).

In the analysis conducted in NREAP 2016-2020, LCEC used the standards of the International Energy Agency (IEA). As per the IEA, LCEC considers that 1 MWh of imported electricity is equivalent to 0.086 toe.

For all hydroelectric power plants, a national conversion factor is calculated based on the fact that in 2010 the total amount of fuel used for thermal electricity generation (both by EDL and the private generators) is 2,982,295 toe generating 13,790,126 megawatt-hours (MWh) of electricity. This leads to a conversion factor of 0.21626 toe/MWh or kilotonnes of oil equivalent (ktoe)/GWh. The primary energy baseline for 2010 in Lebanon, shown in Figure 5, is based on these assumptions (IEA, 2015).

During the 2010 baseline year, the total fuel imports (liquid gas, gasoline, gas oil, fuel oil, kerosene, and asphalt) amount to approximately 5,768 ktoe (5,768,269.94 toe) and are consumed in the different sectors in Lebanon.

On the other hand, electricity imports from both Syria and Egypt amount to approximately 1,248,871 MWh (equivalent to 107,403 toe), whereas hydroelectricity produced by the different hydro power plants on the Lebanese territory amounts to approximately 836,537 MWh (equivalent to 180,909 toe). In addition, the amount of energy produced by solar water heaters installations amount to approximately 12,719 toe (Reference LCEC).

Accordingly, the primary energy mix in Lebanon for the baseline year can be summarized as shown in Figure 5. As per Figure 5, the total consumption in 2010 amounts to 6,069,301 toe, out of which 96.8% were imported from outside Lebanon and the remaining (3.2% from hydro and SWH) was locally produced.

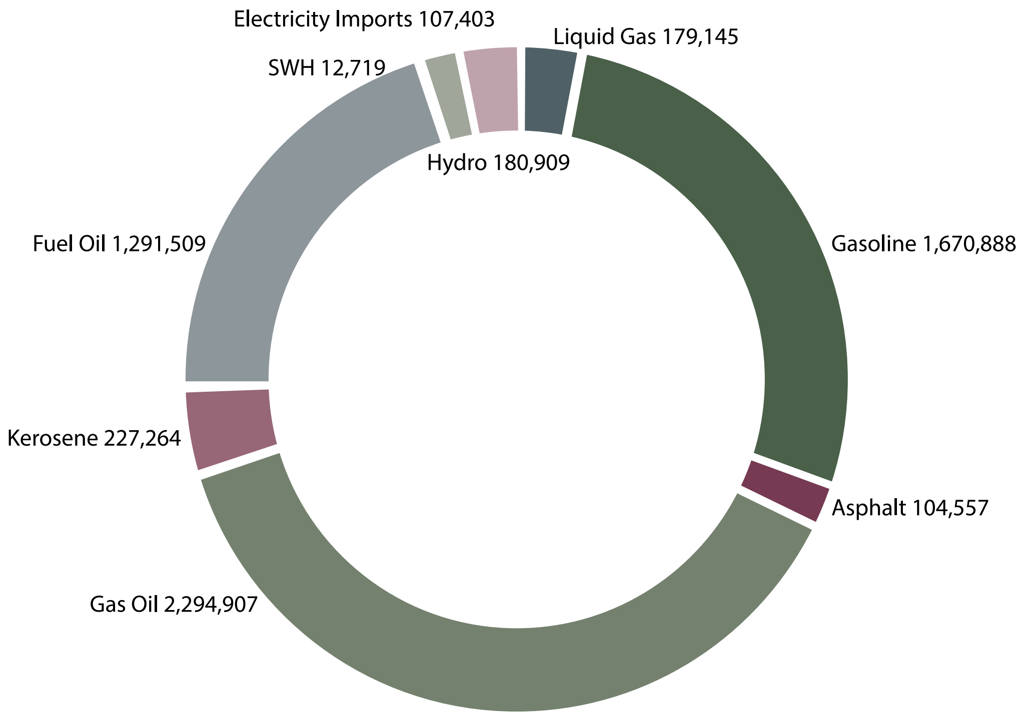


Figure 5. Primary energy mix in 2010 in Lebanon (toe)

2.3 Shares of the different sectors in the 2010 baseline

In order to calculate the shares of the different sectors of the Lebanese economy in terms of energy uses, it is important to note that the final use of some oil products, such as gasoline, kerosene, and asphalt, is essentially for the transport sector. Other products like liquid gas are essentially used in the building sector for cooking or heating. Moreover, the data from MEW shows the quantities of gas oil and fuel oil that were consumed by EDL for electricity generation.

Furthermore, it is considered in the scope of this study [based on discussions with the representatives of the Ministry of Industry (MOI) and other experts], that most of the fuel oil that is dedicated to the local market is actually consumed in the industrial sector.

Figure 6 shows the quantities of energy (in toe) consumed in 2010 in each of the corresponding sectors of the economy. It is crucial to note that the main complication relies in the fact that gas oil imported by both MEW and the private sector is essentially used for heating purposes, private electricity generation, and for transportation in diesel vehicles. At this stage, these three subsectors are grouped as part of the category *"Other"*.

The cooking share was calculated based on the assumption that one third of the Lebanese dwellings (1,377,445 units as per Central Administration of Statistics, 2005) use liquid gas cylinders for heating, and that the average consumption for heating is four, 20 kg cylinders. This leads to 25,600 tons of liquid gas consumed yearly for heating in Lebanon. As it can be seen, the largest shares of consumption are for electricity generation and transportation.

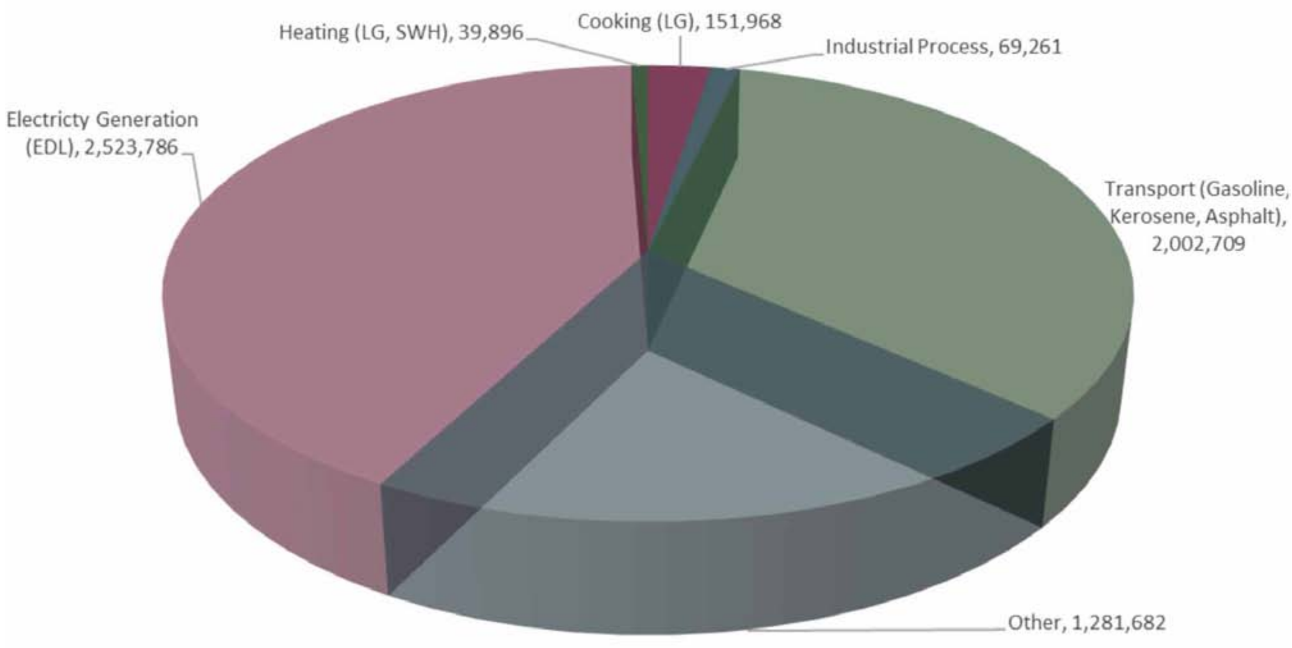


Figure 6. Distribution of the primary energy consumed in 2010 (toe)

A set of assumptions are taken into consideration to explore even more of the energy data of Lebanon:

- For three consecutive years (2009, 2010, and 2011), the Lebanese Government subsidized the prices of gas oil (usually dyed in red) used for heating purposes. This reduction was of 22.5 billion Lebanese pounds (LBP 22.5 billion) based on a LBP 150 reduction per litre of gas oil. The density of gas oil varies depending on the countries specifications. Based on European Union directives 1998/69/EC and 1999/96/EC, this value varies between 833 and 837 kg/m^3, and accordingly, an average value of 835 kg/m^3 is considered. As a conclusion, it is estimated that in 2010, approximately 125,250 tons of gas oil were used for heating purposes.

- Green gas oil is used essentially for transportation purposes in diesel cars.
- The remaining quantity of red-dyed gas oil is used for electricity generation in the private generators distributed in the country.

These assumptions were used to develop Figure 7 where electricity generation accounts for 53.9% of the total oil imports, transportation for 39.7%, heating for 2.8%, cooking for 2.5 % and industry consumes directly 1.1%.

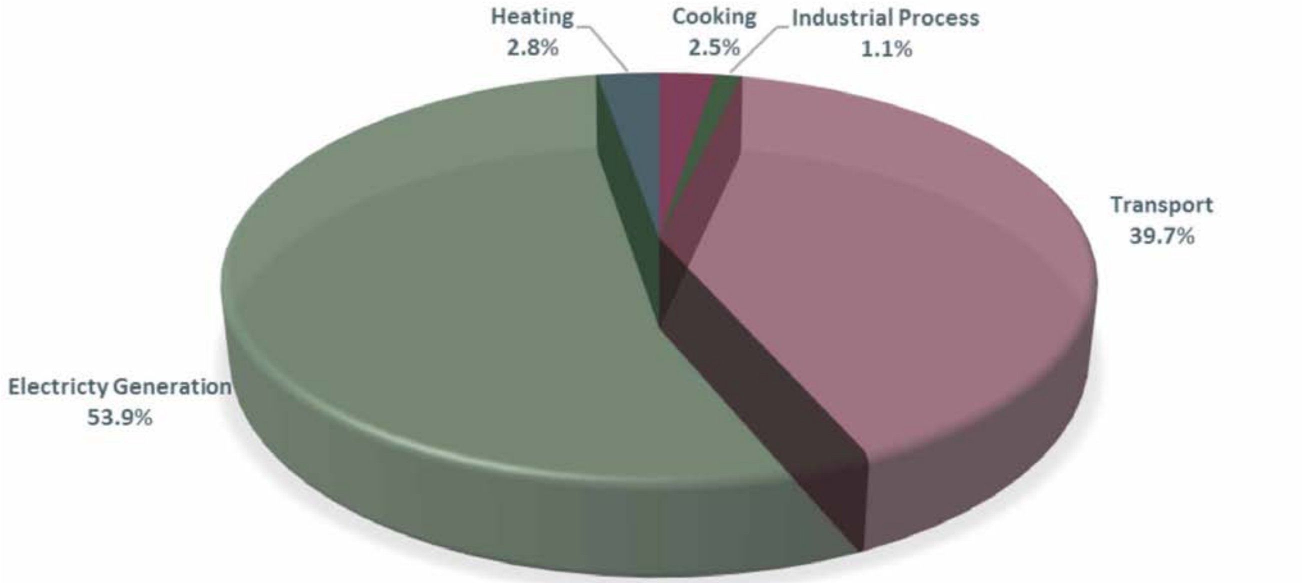


Figure 7. Approximated sectorial consumption of primary energy (2010)

Double-checking assumptions

To confirm the results of Figure 7, a comparative analysis on the quantity of gas oil that is considered for private generation of electricity in 2010 could be useful. The quantity of gas oil is assumed to be 732,862 tons or 877,679,042 litres based on a density of 0.835 kg/l. Based on a generic efficiency of diesel generators of 3.33 kilowatt-hours (kWh)/l, the consumed quantity of diesel would have resulted in a total of 2,950 GWh private electricity generation.

On the other hand, the total electricity generation by EDL in 2010 is 12,089 GWh and the estimated demand was approximately 15,934 GWh, meaning that the electricity deficit is approximately 3,845 GWh. This deficit is partially covered by electricity generated from private sector generators (2,950 GWh), meaning that private generators are satisfying 77% of the blackouts. This percentage is based on the following:

- The load of the capital Beirut is approximately 450 MW.
- Three hours of blackouts in Beirut are rarely covered by private generators.
- Not all of EDL subscribers are connected to private generators.
- Some private generators are turned off during the late night periods of blackouts.

2.4 Baseline definition

In the two previous sections, the primary energy mix and the sectorial distribution of the primary energy are defined for the baseline year 2010. In this section, the unified baseline for the year 2010 will be defined in terms of:

- Electricity generation from non-RE resources

- Electricity generation from RE resources

- Heating from all resources

- Cooling from all resources

The total electricity in Lebanon is generated through the thermal power plants of EDL, the hydroelectric plants, private generators (PG), and imports from Egypt and Syria (see Figure 8). The total amount of energy consumed for electricity production is estimated at approximately 3,271 ktoe (based on the conversion factor of 0.21626 toe/MWh with the efficiency of both EDL and PG combined).

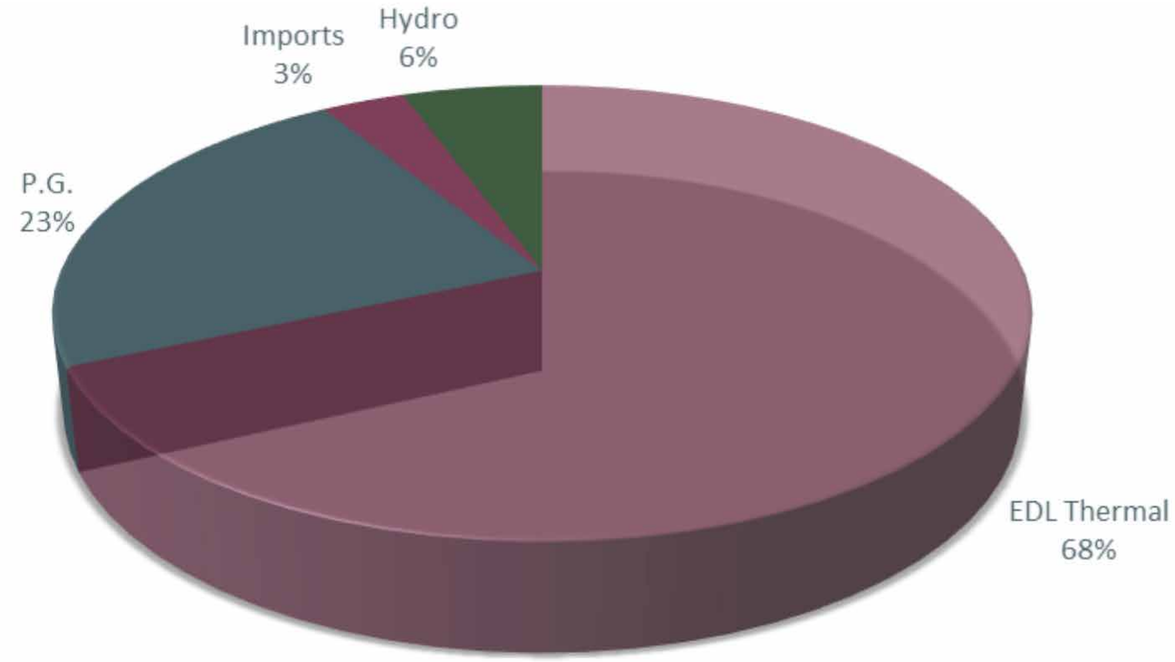


Figure 8. Approximated shares of electricity generation per source based on primary energy conversion (2010)

The non-renewable electricity generation covers the generation from the thermal power plants in Lebanon, the electricity imports from both Egypt and Syria and the estimation of the private diesel generation. PGs only cover approximately 77% of the blackout demand which is equivalent to 5.6% of the total demand. As for electricity generation from RE resources, mainly hydro, the total amount is approximately 181 ktoe. In 2010, the electricity demand is estimated at approximately 15,934 GWh which is equivalent to approximately 3,090 ktoe. Both EDL and the PGs cover approximately 94.4% of the total electricity demand.

On the other hand, the heating estimation induced approximately 154.8 ktoe consumed from non-RE resources (liquid gas and diesel) and 12.72 ktoe from SWH (based on an annual electricity savings of 0.06 toe/m2 for installed SWH surface per Shehadeh, 2012).

Finally, it is important to note that the share of biomass heating (wood and charcoal) is not considered in the analysis due to lack of data. So practically, NREAP 2016–2020 does not consider biomass heating in the mix of RE uses, meaning that the national target by 2020 will not take into consideration biomass heating in the country.

Other estimations regarding heating generated by diesel oil, liquid gas, and SWH installations are also considered. These amounts are estimated to be approximately 167.52 ktoe. However, this number excludes heating generated by biomass resources and by electricity due to the lack of data. It is important to note here that the heating share from electric resources is considered as part of the electricity from non-RE sources. For cooling, no specific data is available in Lebanon, but this will not affect NREAP 2016–2020 since the target as defined in the MEW Policy Paper for the Electricity Sector is based on 12% of the total electrical and thermal supply without defining any sectorial targets (2010). Table 2 specifies the baseline.

Table 2. Baseline definition 2010

Description	Baseline demand (ktoe)	Notes
Electricity generated from non-RE resources	3,090	-
Electricity generated from RE resources	181	-
Heating generated from all resources	167.52	Liquid Gas: 27.2
		SWH: 12.72
		Diesel: 127.6
		Other resources: n/a
Cooling generated from all resources	-	-
Total generation	3,438.52	-

Per Table 2, and for the purpose of this current document, the actual national energy demand for electricity and heating in Lebanon during the baseline year of 2010 is 3,438.52 ktoe. All other numbers emerging from this number are projections for the future based on a number of estimations to be clarified in the following chapters.

Mr. Kamal Hayek, President of the Board and Director General, EDL, MEW

Renewable energy is not a newcomer to the world of EDL since the first hydro plant was installed back in 1924. Yet, developing further these abundant sources of clean energy is a serious challenge. On behalf of EDL, we are ready to support up to our capabilities in developing the national electricity network in a way to be able to integrate RE sources planned in this document. EDL administrative and technical teams will spare no efforts to change gradually the national energy system into a sustainable and environmentally friendly one.

Chapter 3: National energy projections and renewable energy targets

3.1 National energy projections for 2020 and beyond

The objective of this section is to present the national energy projections for the years 2015, 2020, 2025, and 2030 based on the actual national energy demand for electricity and heating in Lebanon during the baseline year of 2010. For the purpose of this document, a number of estimations will be used to complete the projections:

- The MEW *Policy Paper for the Electricity Sector* estimates that the yearly demand increase in Lebanon starting in 2009 is 7% (Bassil, 2010). This same percentage increase will be adopted to estimate the increase of the amount of fuel to generate this electricity and to estimate the heating demand increase in the period 2010 to 2015.

- It is not possible to separate completely the heating and cooling supplies from the electric supply in Lebanon since a large part of both heating and cooling supplies is based on electric appliances. The increase in demand for heating is estimated to be 7% in the period 2010–2015 (similar to the increase in electricity).

- Based on NEEAP 2016–2020, the increase in demand is estimated to drop to 5.81% for the period beyond 2020 due to the implementation of the different measures in EE (between 2016 and 2020).

- Accordingly, it is estimated that the increase in demand for both electricity and heating between 2020 and 2030 is 5.81%.

Based on the previous assumptions and calculations, Figure 9 shows the projected electricity and heating demand for the period 2010-2030.

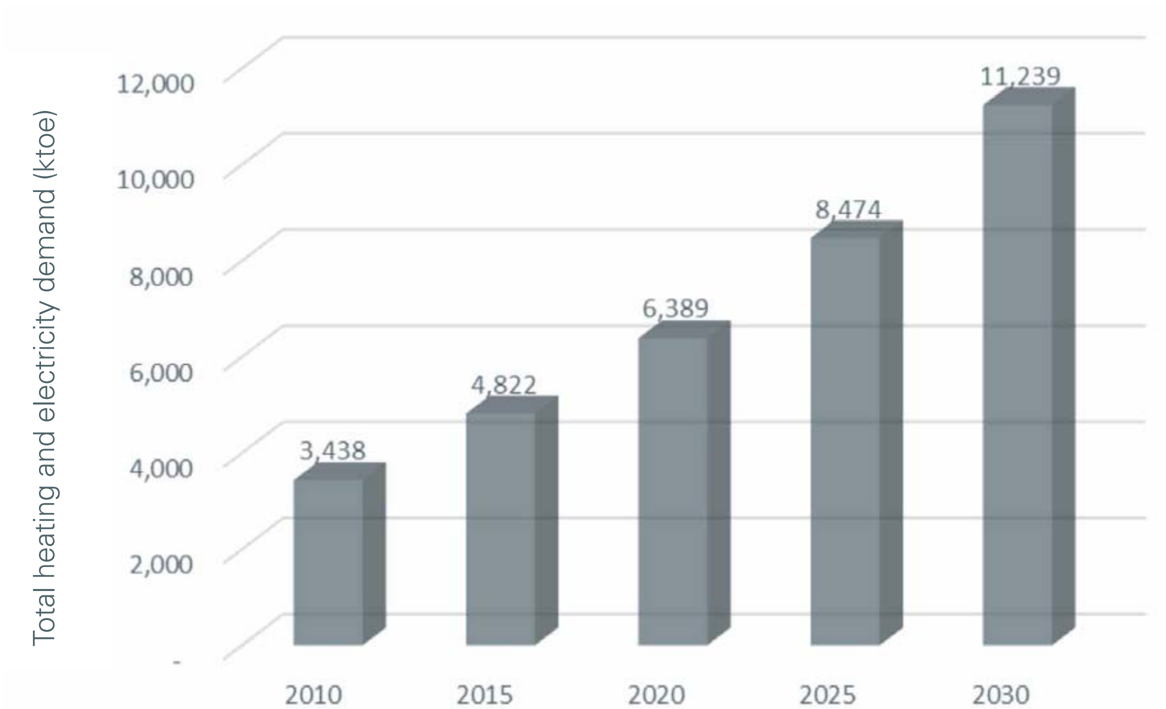


Figure 9. Projection of the heating and electricity demand for the period 2010–2030

The demand increase between 2016 and 2020 is considered as per the NEEAP 2016-2020.

3.2 National renewable energy targets

In the 2009 Copenhagen Climate Summit, the Lebanese Government made a pledge to develop RE production capacity to reach 12%. This political commitment was a major milestone of the *Policy Paper for the Electricity Sector*. Adopted as the national strategy for the electricity sector by the Government on June 21, 2010, the *Policy Paper for the Electricity Sector* clarified the national target as being 12% of the total electricity and thermal supply by 2020.

Given that the projected total electricity and thermal supply in 2020 is approximately 6,389 ktoe, the national objective of Lebanon would be to implement RE projects that would produce approximately 767 ktoe in 2020 (767 ktoe is 12% of 6,389 ktoe).

It is important to remember here that the RE production in 2010 included electricity production from hydro power (181 ktoe) and heat generation from RE sources (12.72 ktoe). It is also assumed that the RE production in 2015 was 246.9 ktoe (hydro being 189 ktoe and heat generation from RE sources being 58.2 ktoe). Table 3 summarizes all the above.

Table 3. Projections of non-renewable energy productions

Year	Baseline year 2010	2015	2020	2025	2030
Total national heating and electricity demand (in ktoe)	3,438 (actual)	4,822	6,389	8,474 (projected)	11,239 (projected)
Total national renewable energy production (in ktoe)	193.72 (actual)	247 (actual)	767(set target)	1,064.8 (long term vision)	1,409.2 (long term vision)
Share of renewable energy production of the total energy production (%)	5.63% (actual)	5.12% (actual)	12% (set target)	12.6% (long term vision)	12.5% (long term vision)

This document has established 2020 as the target year. Whereas, as per Lebanon's INDC the vision of the Lebanese Republic for 2030 is to reach approximately 15%. The 2030 calculations, as per this document, prove that additional efforts are needed to achieve this vision.

3.3 Sectorial energy growth paths

The NREAP template prepared by the LAS and the Regional Center for Renewable Energy and Energy Efficiency (RCREEE) requires member states to set sectorial targets for RE electricity, RE heating, and RE cooling. For the purpose of this NREAP, Table 4 shows the sectorial energy growth paths.

Table 4. Sectorial energy growth paths

Year	Baseline year 2010	2015	2020	2025	2030
Renewable energy electricity	181	181	517	764.2	1,001.40
Renewable energy heating	12.72	58.2	260	368.3	504.1
Renewable energy cooling	-	-	-	-	-
Total national renewable energy production (in ktoe)	193.72 (actual)	239.2 (actual)	767 (set target)	1,064.8 (long term vision)	1,409.2 (long term vision)
Share of renewable energy production of the total energy production (%)	5.63% (actual)	5.12% (actual)	12% (set target)	12.6% (long term vision)	12.5% (long term vision)

It is to be noted that the numbers for RE heating generation are based on the projection of development of SWH installations in Lebanon, while considering an average saving of 0.06 toe/m^2/y.

3.4 Three scenarios for development

The roadmap for the development of RE in Lebanon is based on two main statements:

- The political commitment of the Lebanese Government (launched in 2009) to reach 12% of RE in 2020

- The strategic view of the MEW in the *Policy Paper for the Electricity Sector* (launched in 2010) to adopt the utilization of RE to reach 12% of electric and thermal supply in 2020

According to these two main statements, it is understood that Lebanon will need to achieve 767 ktoe of energy production from RE sources in 2020. This target, 767 ktoe, is actually the national objective for the country to be achieved in the period between 2016 and 2020.

This current document, NREAP 2016-2020 considers the 767 ktoe as the main objective for the whole country, leading practically to the achievement of 12% RE.

The following sections will define the different RE technologies that Lebanon needs to develop to achieve the set target. In addition, this NREAP includes specific sections dealing with the different policies and activities that Lebanon needs to accomplish to support achieving the target.

While developing this document, LCEC truly believed that the 12% target by 2020 (translating into 767 ktoe of RE production by 2020) is achievable. However, LCEC also estimates that some projects and technologies might be developing faster or easier than others.

In this regard, this NREAP considers that in order to achieve the 12% (767 ktoe) objective, a *realistic* scenario will be followed. The realistic scenario will be detailed in the following sections.

However, the implementation of the NREAP might witness obstacles and difficulties. Accordingly, some projects or developments might not be achieved. The delayed implementation of the NREAP is labeled as the *pessimistic* scenario in this current document. On the other hand, the implementation of RE might witness a very positive momentum until 2020. This momentum will be detailed in the *optimistic* scenario.

In the remaining parts of this NREAP, the development of each RE technology will be analyzed for the period 2016-2020 according to the three different scenarios: realistic, optimistic, and pessimistic.

Part B

Development of renewable energy technologies

Dr. Ahmed Badr, Executive Director, RCREEE, Egypt

It has always been a high priority for RCREEE to develop the coordination among Arab countries to transfer know-how and build on success stories. Lebanon has definitely exerted a huge effort to develop sustainable energy initiatives, and RCREEE believes that the development of wind energy is one main milestone towards reaching the country’s national objectives. RCREEE will be always supporting LCEC to help Lebanon integrate the best international practices in this sector.

Chapter 4: Wind energy

Wind energy can be considered one of the most mature RE technologies currently being installed worldwide. In its simplest definition, wind energy is energy produced by using wind turbines or generators to harness the kinetic energy of wind.

There are two basic configurations to wind turbines: horizontal axis (axial flow) and vertical axis (cross flow). Horizontal axis wind turbines (HAWTs) are either upwind machines or downwind machines whereas vertical axis wind turbines (VAWTs) accept the wind from any direction. HAWTs are the most common form of wind turbines manufactured today for large-scale applications, and they are characterized by a streamlined appearance built on improved understanding of aerodynamics (Taylor, 2004). This chapter of the NREAP considers only wind farms using the HAWT configuration for the Lebanese context.

This chapter considers the potential of introducing wind energy production in Lebanon. Starting with an outlook on the development of wind energy worldwide, the analysis focuses on the wind potential in Lebanon, followed by a financial appraisal of this technology. Another section will then define the target for wind energy in Lebanon—including the current initiatives—as well as the needed budget to achieve the set target. This chapter will cover the three possible targets for wind energy according to the three proposed scenarios (realistic, optimistic, and pessimistic).

4.1 Global, regional, and national technology outlook

Globally, more than 35 gigawatts (GW) of new wind power capacity were added in 2013, increasing the global wind capacity by 12.4%, to almost 318 GW (REN21, 2013, 2014) as shown in Figure 10. From 2008 to 2013, annual growth rates of cumulative wind power capacity averaged 21.4% (REN21, 2014).

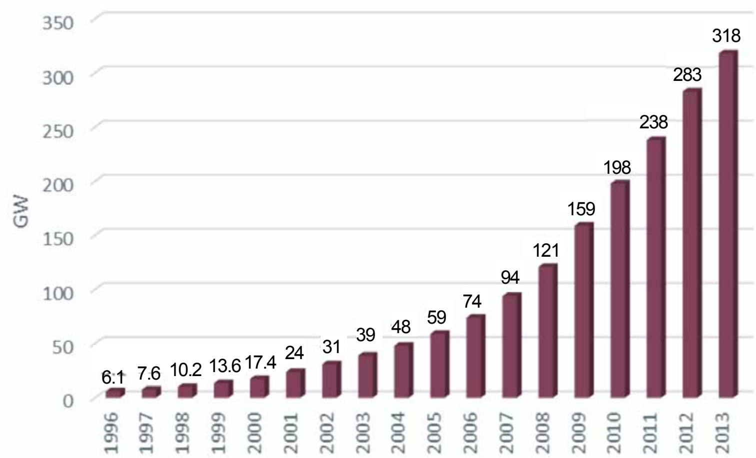


Figure 10. Yearly global cumulative wind power capacity 1996 to 2013 (REN21, 2014)

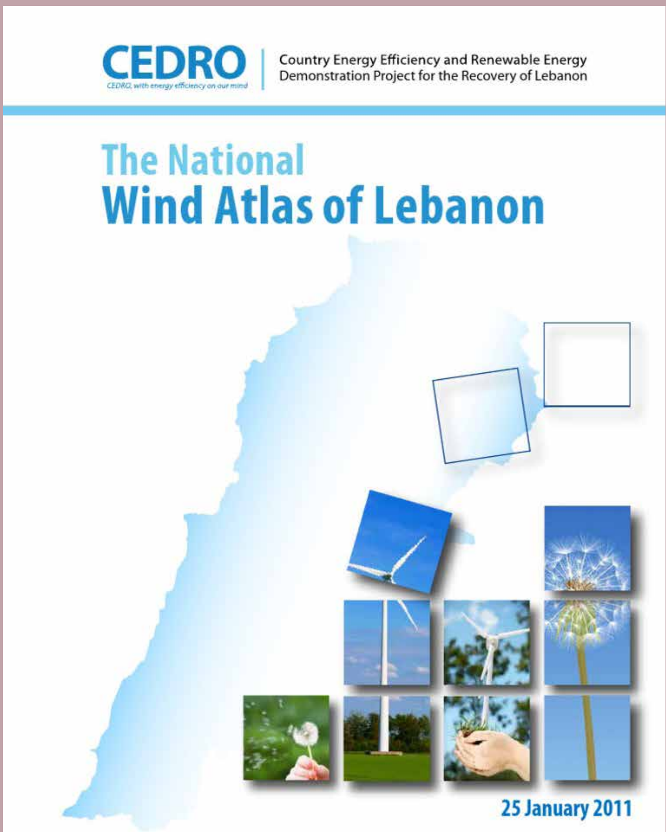
China leads the market in terms of wind turbine installed capacity, followed by the United States, Germany, Spain, and India. Denmark still leads in terms of the installed capacity per inhabitant with approximately 863 W per person (REN21, 2014). More specifically, the total wind power capacity installed in the Middle East and North Africa as of 2012 is 1.13 GW (Global Wind Energy Council, 2012), less than 0.40% of the global capacity installed in that year.

In Lebanon, to date, no wind farms have been commissioned. However, a tender for the first wind farms in the history of the country (each with a capacity of 50–100 MW) is underway. Of 26 companies that expressed their interest at the beginning of the bid, 3 made it to the last stage of evaluation. The final evaluation report was submitted to the Lebanese Government at the end of 2015. Currently, MEW is in the negotiation phase with the three bidders.

4.2 Wind potential in Lebanon

Windmill power technologies, with very limited penetration, have been available in the Lebanese market for decades. Yet, the first real estimation of the national wind potential was done in 2011 by the UNDP-CEDRO project. On behalf of MEW, UNDP-CEDRO published *The National Wind Atlas of Lebanon*, offering a global insight on the national available resources for large-scale wind power generation in Lebanon. The national wind atlas underwent a mesoscale and microscale modeling for the entire country to produce a wind map at heights of 50 m and 80 m above ground level and at a resolution of 100 m (Hassan, 2011).

More information on the National Wind Atlas of Lebanon



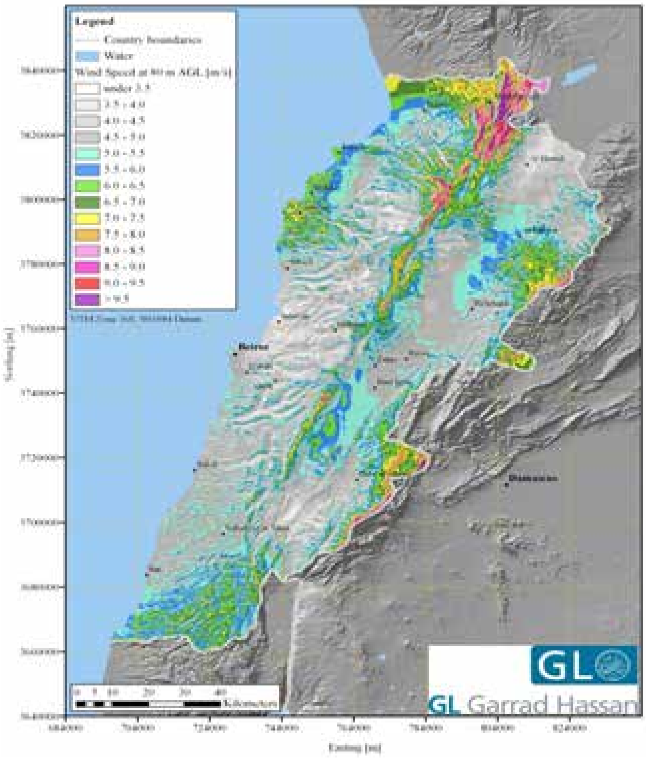
A cooperative effort of MEW and UNDP Lebanon, *The National Wind Atlas of Lebanon* was developed by Garrad-Hassan thanks to the financial support of the Government of Spain to the CEDRO project through the Lebanon Recovery Fund (LRF).

In his foreword to *The National Wind Atlas of Lebanon*, former Minister of Energy and Water H.E. Mr. Gebran Bassil notes that "We do firmly believe that the launching of the national wind atlas will create a growing momentum in Lebanon towards strengthening and developing the RE sector in the country. The wind atlas study shows a promising potential for wind energy in Lebanon, reaching high levels of generation capacity" (Hassan, 2011).

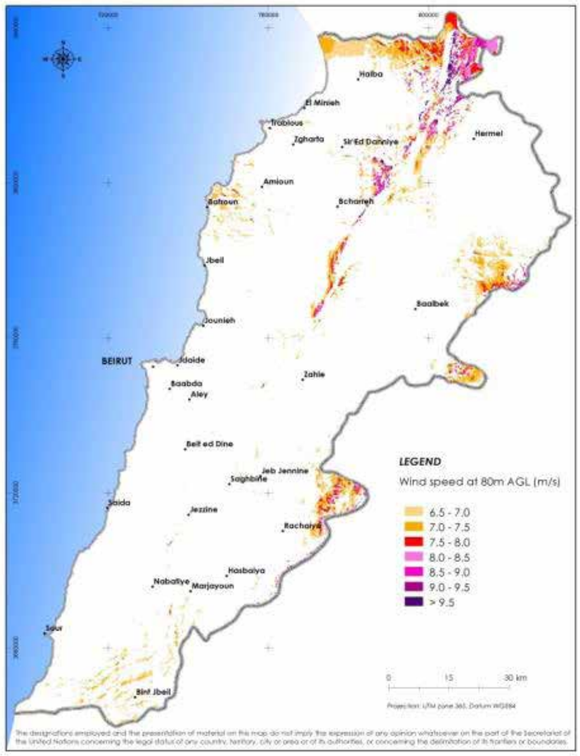
This study's main objective is twofold. The first objective is to indicate to policy makers how much potential Lebanon has in terms of wind power production. This study also helps in identifying constraints where wind farm development cannot occur, such as areas of high population density, of high political instability, military sites, commercial interests (e.g., mining, fisheries, etc.), civil aviation sites, areas in close proximity to radar or telecommunication sites, national parks, and conservation areas (e.g., cedar forests, historic sites, etc.). The second objective is site prospecting, meaning the study identified sites where further due diligence, in the form of local wind resource measurements for example, is needed.

The National Wind Atlas of Lebanon can be downloaded at www.undp.org.lb/communication/publications/downloads/National_Wind_Atlas_report.pdf.

The national maps (Figure 11) show the onshore wind speed at an 80 meter hub height, and the areas that are technically and financially viable for wind farm development. This is fundamental for the private or public sectors in order to secure land for wind farms, through either a rent agreement or a direct purchase agreement.



Average wind speeds at 80 m height – All areas



Areas technically and financially viable for wind farm development (assuming more conservative 8 degree slope limit)

Figure 11. Average wind speeds and technically and financially viable zones (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 8 degrees, part of sensitivity used in the *National Wind Atlas of Lebanon*

- Assumption of the consequent capacity potential (at 8 MW/km^2)

- Adoption of capacity factors from respective average wind speeds from Shawon, El Chaar & Lamont (2013)

Table 5. Wind potential in Lebanon

Average annual wind speed (m/s)	Capacity factor (%)	Area (km^2)	Approximate potential capacity (MW)	Approximate total potential energy output (MWh)
6.5–7.0	22	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	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**

The total available, and economically feasible, wind power potential amounts to approximately 12,139 GWh/year, equivalent to 76.2% of the total electricity demand in 2010 of 15,934 GWh. The approximate capacity calculated amounted to approximately 5.41 GW, varying slightly from the Hassan (2011) calculation due to the additional use of a minimum plot area for the current calculation. The average capacity factor in Lebanon for wind farms is calculated at approximately 25.6%, with a range in capacity factor from 22% to 42.1%.

Hassan (2011) indicates that Lebanon has an onshore wind power potential capacity of 6.1 GW (theoretical value). This amount is decreased to 5.41 GW (adopting assumptions on installation density and minimum wind speeds required, along with a maximum slope of 14 degrees). Hassan (2011) also shows the results of a perturbation analysis, with a worst-case scenario assuming the reduction of all modeled average wind speeds by 10% and a maximum terrain slope where wind farms can be established reduced from 14 degrees to 8 degrees. Accordingly, the national potential is reduced to 1.5 GW (equivalent to 1,500 MW).

It is important to note that wind power is by nature intermittent depending on the availability and speed of wind. The connection of many wind farms to the national grid needs to take into consideration a number of parameters that are related to the stability of the grid. Accordingly, LCEC estimates that a maximum of 500 MW out of the 1,500 MW is actually feasible. This is reflected in the targets for 2020 and 2030.

4.3 Financial appraisal of wind power in Lebanon

Wind power is becoming an increasingly viable and cost-competitive choice for electric power generation. In other words, wind power has reached grid-parity (taking into consideration international known costs of electricity generation using natural gas and coal); particularly if a carbon tax is imposed on conventional thermal power generation units. The calculation of the approximate expected costs of wind farms in Lebanon is subject to several uncertainties mostly due to the fact that Lebanon, to date, has not established any wind farm to be used as a reference for the input cost and energy output values.

A publication by the International Renewable Energy Agency (IRENA, 2012e) provides a clear picture of the costs involved for wind power (as with other selected technologies). Table 6 summarizes the capital investment costs involved for onshore wind (with respective share distribution of cost between categories) and operation and maintenance costs (O&M).

Table 6. Wind power cost distribution

Category	Minimum cost	Maximum cost
Capital investment costs (USD/kW)	1,700	2,450
Wind turbine cost share*	65%	84%
Grid connection cost share†	9%	14%
Construction cost share‡	4%	16%
Other capital cost share§	4%	10%
O&M (US cents/kWh)‖	1.5	3

Source: (IRENA, 2012e) / Notes: O&M (operation and maintenance)
* Wind turbine costs include turbine production, transportation, and installation of the turbine.
† Grid connection costs include cabling, substations and buildings.
‡ The construction costs include transportation and installation of wind turbine and tower, construction of wind turbine foundation (tower), and building roads and other related infrastructure required for installation of wind turbines.
§ Other capital costs here include development and engineering costs, licensing procedures, consultancy and permits, supervisory, control and data acquisition (SCADA), and monitoring systems.
‖ The variation of quoted O&M costs in the IRENA report goes from 1 US cents/kWh in the USA to 4.3 US cents/kWh in Switzerland. A more concise variation is selected here for the Lebanese case that covers the majority of international cases.

Hassan (2011) indicates that average wind speeds that exceed 9.5 m/s are available across various areas in Lebanon. Accordingly, conventional wind units using conventional generators are deployable in approximately 2–4% of its territories, and the use of certain special designs that deploy permanent magnets could increase the penetration of wind units up to approximately 28% (Chaaban, Chedid, & Ginzarly, 2014).

The levelized costs of wind power in Lebanon, adopting the IRENA values listed in Table 6, clearly indicate that higher capital costs are normally combined with expected lower relative O&M, and lower capital costs are combined with expected higher relative O&M. There is a positive association between capital costs and quality and durability of turbines. Using the same figures coupled with capacity factors indicated in Table 7, the LCOE for onshore wind power is shown in Figure 12.

Table 7. Levelized cost of wind power pegged to respective capacity factor, investment and operation and maintenance costs

US cents/kWh			
Capacity factor	**Low capital - high O&M**	**Mean capital - mean O&M**	**High capital - low O&M**
22.00%	13.4	14.9	16.4
25.10%	12.1	13.3	14.6
28.20%	11.1	12.1	13.1
31.40%	10.3	11.1	12
34.80%	9.6	10.2	10.9
38.40%	8.9	9.5	10.1
42.10%	8.4	8.9	9.3

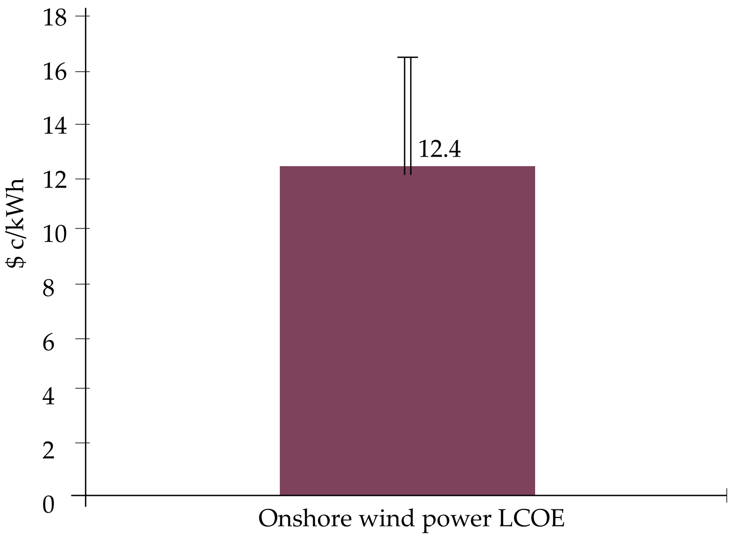


Figure 12. Levelized cost of wind power from onshore wind

Expected costs range from 6.9 US cents/kWh to 17.9 US cents/kWh, depending on capital costs (Hassan2011)(see Table 7), O&M assumed costs, and the capacity factor adopted. In a further publication by IRENA (2015), levelized costs for wind have varied from as low as 6 US cents/kWh to 7 US cents/kWh in Asia, Eurasia and North America, and to 8 US cents/kWh in the rest of the world regions deploying a lot of wind (indicating thereby a mature market).

Based on the preliminary results of the 2015 bids, it seems that the costs of onshore wind farms in Lebanon are below the current average generating costs of EDL (as of May 2015). These average generating costs depend on international oil prices. More importantly, wind power is substantially less expensive than the higher merit generating power plants of EDL using diesel as input fuel, such as the Baalbeck and Tyre power plants.

4.4 Target for wind energy

The targeted objective for wind energy installations in Lebanon is 200 MW by 2020. In this current NREAP, this fairly achievable objective is part of the realistic scenario, while two other targets are considered for the pessimistic and optimistic approaches.

In the case of wind turbines, this is not only reflected in the size of capacities installed but also in the quality of the site affecting the amount of energy generated. These scenarios are shown in Table 8, where it can be seen that for the year 2020, three different targets can be defined envisaging each the installation of 400, 200, and 100 MW respectively. The generated energy is calculated based on the corresponding capacity factor of each of the selected site categories.

The optimistic scenario considers installing wind farms in sites with the highest average annual speed (8-10 m/s) and capacity factors whereas the pessimistic scenario assumes wind farms installation in sites with the lowest average wind speed (7-8 m/s). Table 8 also shows the proposed target scenarios regarding wind speed and capacity factor.

Table 8. Target scenarios of wind energy for the year 2020

Average annual wind speed	(m/s)	7.0–7.5	7.5–8.0	8.0–8.5	8.5–9.0	9.09.5	> 9.5 (assumed 10)	**Total**
Capacity factor	(%)	25.1	28.2	31.4	34.8	38.4	42.1	
Optimistic scenario	MW	-	-	100	100	100	100	**400**
	MWh/y	-	-	275,064	304,848	336,384	368,796	**1,285,092**
	ktoe/y	-	-	59,414	65,847	72,659	79,660	**277,580**
Realistic scenario	MW	60	-	100	50	50	140	**200**
	MWh/y	-	-	275,064	152,424	168,192	-	**595,680**
	ktoe/y	-	-	59,414	32,924	36,329	-	**128,667**
Pessimistic Scenario	MW	50	50	-	-	-	-	**100**
	MWh/y	109,938	123,516	-	-	-	-	**233,454**
	ktoe/y	-	-	-	-	-	-	**-**

Based on the realistic scenario, Table 9 shows the development of the wind power sector between 2010 and 2030.

Table 9. Target of wind energy for the years 2010-2030

		Wind (onshore)	**Wind (offshore)**	**Total**
2010	**MW**	0	-	**0**
	GWh	0	-	**0**
	ktoe	0	-	**0**
2015	**MW**	0	-	**0**
	GWh	0	-	**0**
	ktoe	0	-	**0**
2020	**MW**	200	-	**200**
	GWh	595.7	-	**595.7**
	ktoe	128.7	-	**128.7**
2025	**MW**	350	-	**350**
	GWh	1,087.90	-	**1,087.90**
	ktoe	235	-	**1,087.90**
2030	**MW**	450	-	**450**
	GWh	1,422.60	-	**1,422.60**
	ktoe	307.3	-	**307.3**

This current action plan sets no targets for offshore wind energy. This is mainly due to the lack of mature assessment for this technology especially in the Lebanese context, where offshore sites include very deep waters. In addition, the areas that could be interesting for offshore installations and are highlighted by the Lebanese wind atlas are not economically attractive when compared to the onshore potential installations.

4.5 Needed budget to achieve the 2020 target for wind energy

The needed estimated capital investment to reach the 2020 realistic scenario, and then the 2030 target, is shown in Table 10.

Table 10. Needed investment for the wind energy development in Lebanon

Year	Low capital investment costs (million USD)	High capital investment costs (million USD)	Payback (years)
2020	340	490	7.2 to 12.7
2030	425	612.5	
Total by 2030	**765**	**1,102.50**	

Considering the mean values of Table 8 where the capacity factor ranges between 31.4% and 38.4% as suggested in the realistic scenario, it can be concluded that the levelized cost of wind power (LCOE) in the realistic scenario is approximately 10.3 US cents/kWh. Combining this with the O&M costs from Table 6, the LCOE will vary between 11.8 and 13.3 US cents/kWh. Considering the annual energy generations mentioned in Table 8, the payback periods will vary between 7.2 and 12.7 years based on a cost of production of 20.2 US cents/kWh by EDL power plants.

Furthermore, this extra generation of electricity by wind farms would be reflected as extra hours of supply to the consumers. Based on the electrical demand of 15,934 GWh in 2010 and the projected demand in 2020 (approximately 29,587 GWh), the installed wind farms will supply energy that will satisfy approximately 176 extra hours of electricity for the whole country in 2020.

4.6 The way forward

As mentioned earlier, Lebanon has no operational wind farms yet. At this point in time, the COM is considering the three offers submitted by the private sector to build three different wind farms with a total capacity of 200 MW. Ideally, the three wind farms will be connected to the national grid (at the 220 kilovolt (kV) or 66 kV transmission lines). The needed budget would be USD 340-490 million, and is expected to be covered by private investments. The Lebanese Government, through the national electric utility EDL, would need to commit to annual electricity purchasing totaling approximately USD 60 million.

As per the offers submitted, the three wind farms could be built in a period of approximately two years. The three wind farms would hopefully be commissioned in 2019. The achievement of these projects will be an important milestone in reaching the 2020 target.

Mr. Sarkis Hleiss, Director General, Lebanon Oil Installations, MEW

It is true that Lebanon Oil Installations is the main public administration responsible to import fuel sources to Lebanon, but it is also true that our facilities witnessed the construction of the first solar PV farm in a public facility in the whole country. Our dedication and commitment to RE stem from our belief that Lebanon needs a comprehensive approach joining traditional fuel sources and renewable energies. Lebanon Oil Installations is committed as well to explore further RE projects in its facilities to support reaching our national objectives.

Chapter 5: Solar photovoltaic (PV) farms

Large centralized PV power systems with capacities of 1 MW or more take into account economies of scale in purchasing and installing large numbers of PV modules and associated equipment. These systems can be located on sites that are optimal in terms of solar radiation (Boyle, 2004).

This chapter covers the potential of using solar energy for electricity production in Lebanon. More specifically, this chapter deals with solar PV farms to be connected to the national grid (or probably to small micro-grids in the future) in Lebanon with a capacity size of 1 MW or more.

In the context of this NREAP, it is important to note that when using the term *solar PV farms,* LCEC means solar farms that are built on favorable sites for electricity production without being connected for local consumption. In this regard, all the output of the solar farm would be exported to the national grid according to a clear long-term power purchase agreement (PPA).

Other solar farms that are built on existing facilities and are connected to the facility's local consumption as well as to the national grid through net metering are in fact part of another chapter of this NREAP. In fact, these solar farms would be labeled as *distributed generation* and will be covered in a separate chapter of this document.

That being said, Lebanon has a favorable climate for PV power plants given the solar irradiance levels, the relative lack of dust or sand (when compared to countries in the Gulf region for instance), and a relatively mild climate that ensures a more optimal operation in terms of efficiency.

The only existing solar PV farm currently in Lebanon is the 1 MW Beirut River Solar Snake (BRSS) demonstration project in the middle of the capital. Initiated by the MEW and the LCEC in 2013, the project is now fully operational and connected to the national grid. The BRSS has opened the door to the introduction of solar PV technology in the Lebanese mindset.

In this current chapter, the following sections will present an outlook on the development of solar PV energy worldwide, followed by the potential of solar PV farms in Lebanon, including the financial appraisal of this technology. This chapter will then define the target for solar PV energy in Lebanon-including the current initiatives-as well as the needed budget to achieve the set target. The chapter will cover the three possible targets for solar PV energy according to the three proposed scenarios (realistic, optimistic, and pessimistic).

Beirut River Solar Snake project: the pillar for solar development

The 1 MWp BRSS solar PV farm is the first grid-connected plant in the history of Lebanon. The idea of the BRSS project dates back to 2013, when MEW adopted the proposal of the LCEC to build a first-of-its-kind solar farm project on top of a river (the BRSS project was launched on April 11, 2013 by former Minister of Energy and Water H.E. Mr. Gebran Bassil). The BRSS project has been connected to the Lebanese national grid since September 2015.

The central urban location of the BRSS project contributed to a remarkable increase in awareness on RE as well as in market interest and market activity in the solar PV technology. One main indicator is the increased number of solar PV projects submitted under the NEEREA mechanism since the BRSS project initiation.

Built by a joint-venture made of five partners, the current plant expands over an area of approximately 11,000 square meters (less than 350 m long) between the Yerevan Bridge and the Nahr Bridge. It consists of 30 bays, each including two inverters and 120 solar panels. The plant has a total of 3,600 PV panels with a rated capacity of 300 watts-peak (Wp). It can generate up to 1,665 MWh/year as per the initial simulations, it also has a tested performance ratio (in April) of 88.88%.

The BRSS project is a small step in the journey towards achieving Lebanon's RE goals. Its success was echoed in private sector investments in the technology as well as in public sector entities (such as the Zahrani Oil Installations) taking the initiative to switch toward cleaner sources of energy.

5.1 Global, regional, and national technology outlook

Solar PV power is currently characterized as the RE technology that has the greatest global annual growth, as shown in Figure 13. Exponential growth has been witnessed since the 2004–2005 period, averaging 33% annual growth for this particular period. Almost half of all PV capacity in operation was added in the past three years, and 98% has been installed since the beginning of 2004 (REN21, 2014). Globally, PV installations currently exceed 139 GW, with three countries (Germany, China, and Italy) making up more than half of the existing capacity. (See Figure 14.)

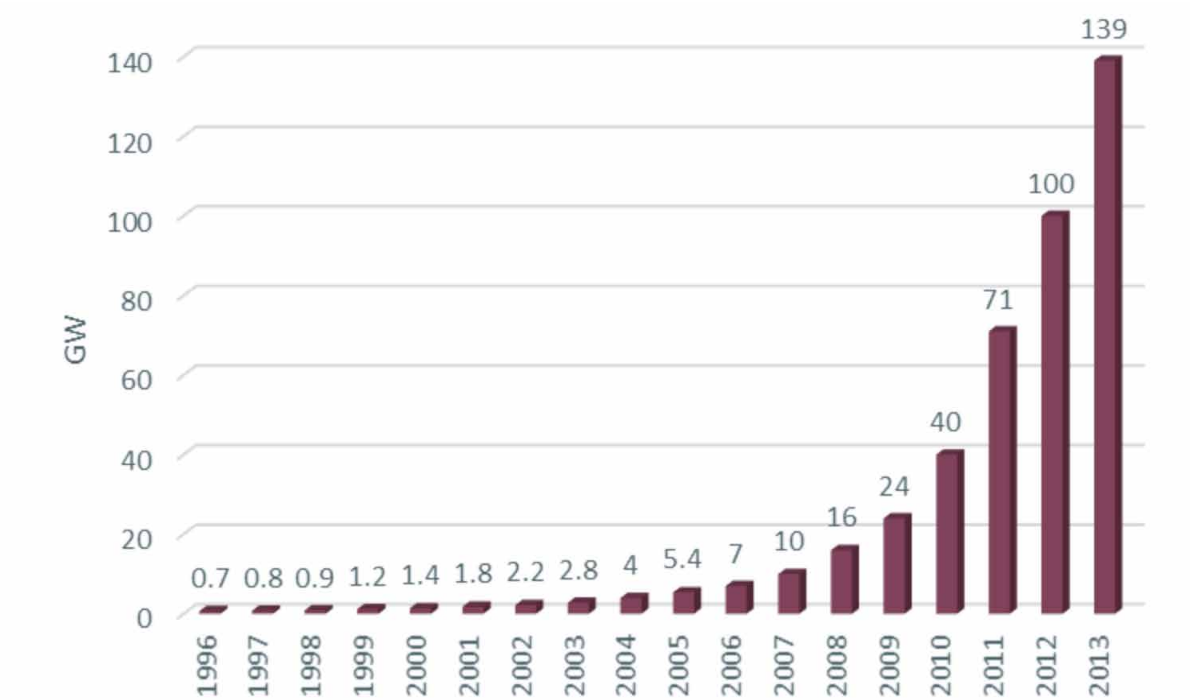


Figure 13. Solar PV global capacity 1996–2013 (REN21, 2013, 2014)

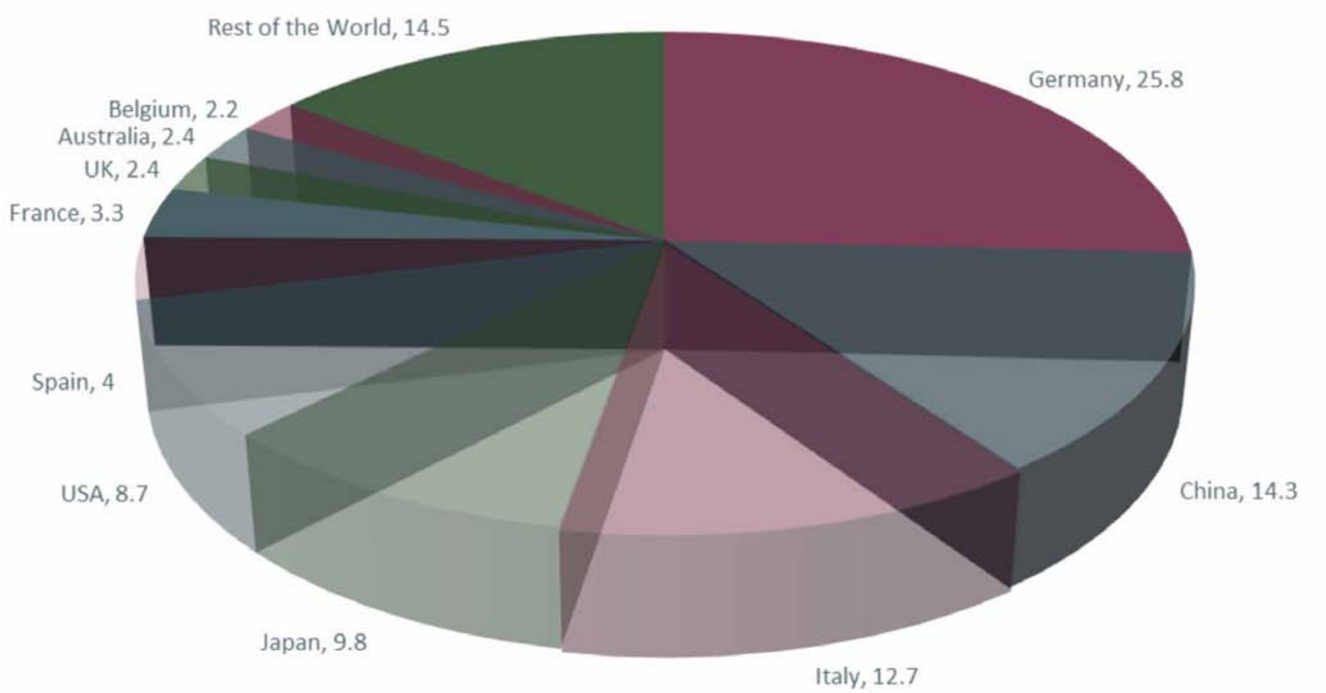


Figure 14. Global distribution (%) of PV capacity (REN21, 2014)

Countries in the Middle East and North Africa (MENA) region still make up a very small share of the global PV capacity. Several large-scale projects have been announced in the region and construction has begun in several countries, especially in Egypt, Morocco, and the United Arab Emirates.

5.2 Potential for photovoltaic farms in Lebanon

Practically, all the Lebanese territories are suitable for solar PV power production. However, to narrow down the selected areas and in order to calculate the potential power capacity and power output for PV farms in Lebanon, constraints that ensure technical viability, environmental sustainability, social security (e.g., food security), and economic considerations need to be taken into account. These can be summarized by the following:

- Omission of agricultural land

- Omission of wooded areas (forestry)

- Omission of urbanized areas [Potential for PV in urbanized areas (rooftop) is substantial, yet are part of distributed generation, which is not covered in this chapter];

- Omission of historic sites

- Omission of wetland and water bodies

- Omission of slopes more than 35 degrees

- Inclusion of south facing slopes only (when land is not flat)

- Omission of land areas less than 10,000 m^2 (to cater for a minimum of 1 MW capacity as a conservative estimate)

Figure 15 illustrates the areas with the different irradiance categories (global horizontal irradiance, GHI) that match the above constraints.

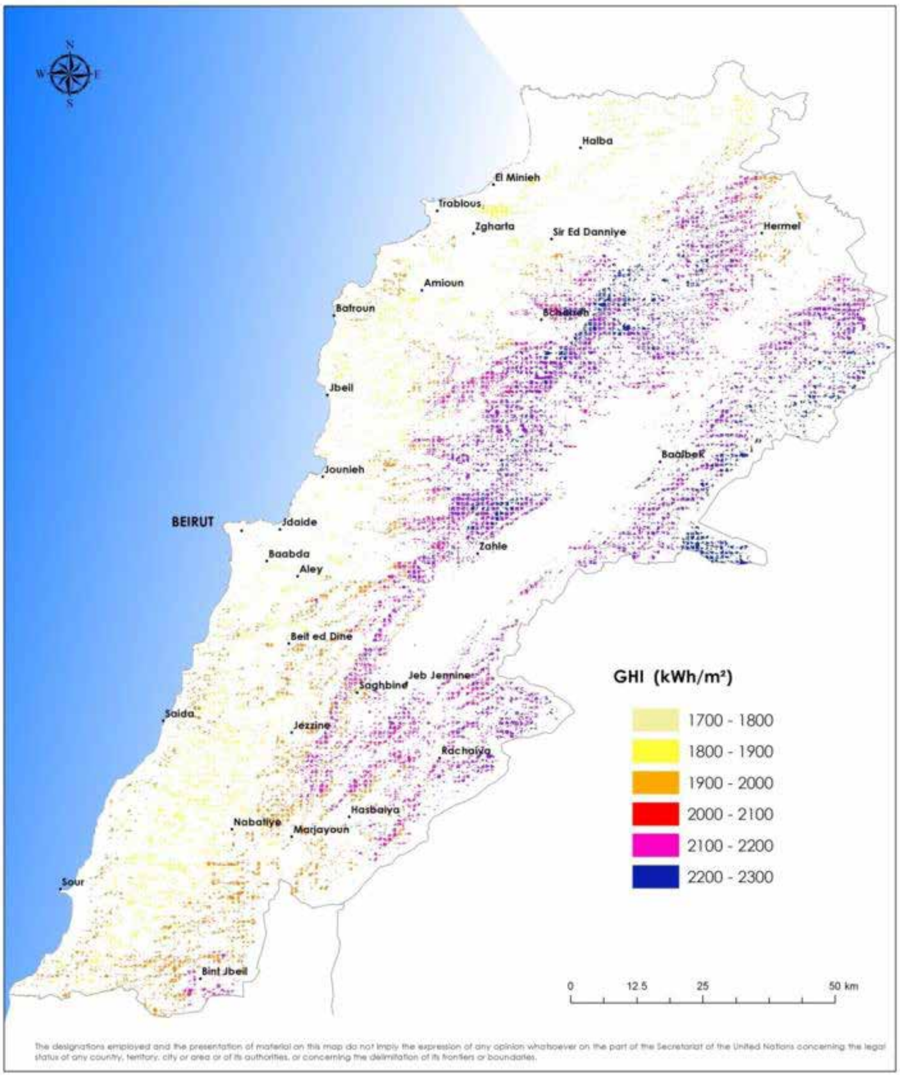


Figure 15. Filtered potential land areas for PV farms in Lebanon. (Source: www.solar-med-atlas.com)

The potential areas for PV farm development within, or for each, global horizontal irradiance (GHI) categories are given in Table 11, assuming mono-crystalline silicon panels. The mean GHI of each category is considered in estimating the capacity factor.

Table 11 indicates an almost limitless potential for PV farms in Lebanon, equivalent to more than 87.6 GW of power output with a subsequent 146,129.7 GWh energy output. This is more than nine times the power demand in Lebanon in 2010.

Table 11. Potential PV power capacity and power output in Lebanon

GHI (unit)	Area (km^2)	Assumed App. capacity Factor* (%)	Potential capacity in MW (assuming 10,000 m^2/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	18,730	29,533,464
2000-2100	188.7	19.5	18,870	32,233,734
2100-2200	269	20.1	26,900	47,364,444
2200-2300	70.46	20.8	7,046	12,838,376
Total			**87,636**	**146,129,660**
Note: * Based on conservative 15.5% system losses and 97.5% inverter efficiency (input from www.solar-med-atlas.com)				

The net potential areas shown in Table 12 have been obtained by removing areas with concentrated solar power (CSP) potential. This is done in order to leave space for CSP development where it is technically and economically feasible, given that CSP requires more stringent location and/or specific climatic requirements. Note that CSP is addressed in details in another chapter.

Table 12. Net feasible areas for PV farms

GHI (unit)	Area (km^2)	Assumed App. capacity Factor* (%)	Potential capacity in MW (assuming 10,000 m^2/MW)	Potential energy output (MWh)
1700-1800	0	16.6	0	0
1800-1900	0.3	17.3	30	45,464
1900-2000	4.52	18	452	712,714
2000-2100	6.69	19.5	669	1,142,786
2100-2200	22.29	20.1	2,229.00	3,924,734
2200-2300	5.24	20.8	524	954,770
Total			**3,904**	**6,780,468**

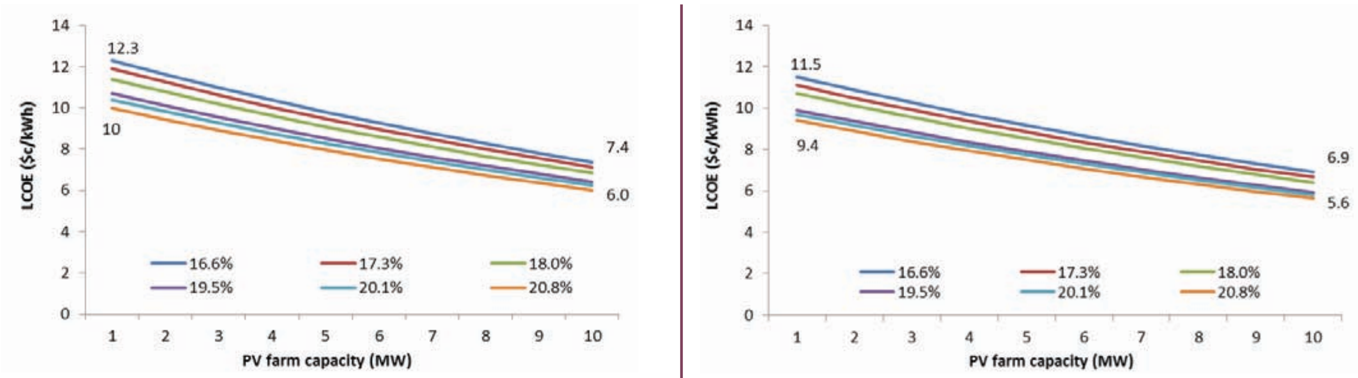
Note: *Based on conservative 15.5% system losses and 97.5% inverter efficiency (input from www.solar-med-atlas.com)

5.3 Financial appraisal of solar photovoltaic technology

There is currently only one PV farm in Lebanon (BRSS) with a capacity of 1 MW. Another demonstration project of 1 MW has also been developed in the Zahrani Oil Installations in South Lebanon, but the latters' architecture that of distributed generator especially that it also feeds into the internal grid of the facility. The construction of the BRSS project on an artificial river bed, with the unique structure required, cannot be taken as indicative of the common ground-mounted structures that are expected elsewhere in Lebanon.

With respect to land values, they vary significantly in Lebanon. Focusing on barren and unproductive lands, prices vary according to regions in Lebanon, and according to proximity to urban areas, roads, touristic resorts, water bodies, and so forth. Current (end of 2014) barren land prices can range from USD 2.5/m^2 (and sometimes less) to USD 40/m^2 (and sometime more). For the 1 MW PV farm, the minimum land requirement is approximately 10,000 m^2, and purchase prices can range from USD 250,000 to USD 400,000. In the average land calculations adopted, the land price would be taken to be approximately USD 10/m^2, assuming that land of high value will not be devoted to solar farms from an opportunity cost and competition perspective. (Goodrich, James, & Woodhouse, 2012).

The cost parameters are combined with the capacity factors of Table 12, obtaining LCOE shown in Figure 16. O&M costs are assumed at approximately 0.01 USD kWh for PV farms. A gradual decline of levelized cost is assumed with increasing PV farm size, as noted in Goodrich et al. (2012), starting from the estimated LCOE for the 1 MW PV farm, until a 40% reduction that is reached for PV farms with sizes greater than 10 MW.



LCOE with taxes subject to PV farm size and capacity factor (with min. and max. values shown on each respective capacity and capacity factor end)

LCOE without taxes subject to PV farm size and capacity factor (with min. and max. values shown on each respective capacity and capacity factor end)

Figure 16. Expected levelized cost estimates of photovoltaic farms in Lebanon

Figure 16 indicates the various expected levelised costs from PV farms in Lebanon, subject to increasing capacity size of PV farms and various capacity factors that are retrieved from Table 12. Figure 16 shows that PV farms can reach grid parity with power systems run on natural gas at international standards.

Finally, and as shown in Figure 16, removing the 10% value added tax (VAT) and customs (approximately 5%) on RE lowers the levelized costs. It is important to note here that any reduction in upfront capital is a saving not just equal to the amount of the reduction, but equal to the amount reduced plus any interest on equity or debt.

5.4 Target for large scale photovoltaic energy

Given the existing high potential of development of solar PV farms in Lebanon, this current NREAP assumes that a target of 150 MW of solar PV installations by 2020 is very realistic. It is also important to note that the decreasing prices of solar PV farms installations is making this technology extremely appealing.

The three scenarios developed for the year 2020 are presented in Table 13. As for the case of wind energy the choice of the site will have a high impact on the generated energy especially in terms of irradiance and hence capacity factor.

Table 13. Target scenarios of photovoltaic energy for the year 2020

GHI (unit)		1700-1800	1800-1900	1900-2000	2000-2100	2100-2200	2200-2300	Total
Assumed App. capacity Factor (%)		16.6	17.3	18	19.5	20.1	20.8	
Potential capacity in MW (assuming 10,000 m²/MW)		0	30	452	669	2,229.00	524	
Optimistic scenario	MW	-	-	75	75	75	75	300
	MWh	-	-	118,260	128,115	132,057	136,656	515,088
	ktoe	-	-	25.5	27.7	28.5	29.5	111
Realistic scenario	MW	-	-	50	50	50	-	150
	MWh	-	-	78,840	85,410	88,038	-	252,288
	ktoe	-	-	17	18.4	19	-	54
Pessimistic scenario	MW	-	5	45	50	-	-	100
	MWh	-	7,577	70,956	85,410	-	-	163,943
	ktoe	-	1.6	15.3	18.4	-	-	35

Based on the 2020 realistic scenario, Table 14 shows the potential progress of solar PV farms until 2030.

It is very difficult at this stage to define the GHI categories for the development of PV farms. This is why, in the calculation of the 2020 realistic target a conservative generation factor of 1,600 kWh/kWp is considered as shown in table 14.

Table 14. Target of photovoltaic energy for the years 2010 - 2030

Solar		PV, CPV
2010	MW	-
	GWh	-
	ktoe	-
2015	GWh	-
	MW	-
	ktoe	-
2020	MW	150
	GWh	240
	ktoe	51.8
2025	MW	200
	GWh	320
	ktoe	69.1
2030	MW	300
	GWh	480
	ktoe	103.7

Concerning photovoltaic technologies, the focus in Lebanon is on regular PV panels with no known projects being developed using concentrated photovoltaic (CPV). However, based on international experiences, it is well known that CPV can be a major game changer in solar technologies. It was not included in the scope of this plan because it is still subject to many unidentified parameters in the scope of the Lebanese case.

5.5 Needed budget to achieve the 2020 target for solar photovoltaic

Knowing that the indicative price of USD 1.5 million is used for each 1 MW farm, the total investment for the installation of all 150 MW in 2020 is approximately USD 225 million. In addition, the cost of land is estimated at approximately USD 15 million. Accordingly, the total investment cost would be approximately USD 240 million.

On the other hand, the 150 MW PV farms will be producing approximately 4,370 GWh during a 20-year lifetime considering a fair 1% decrease of output per year. This leads us to an average of 5.5 US cents/kWh to which the cost of 1 US cents/kWh of operation and maintenance should be added, making the LCOE for large scale PV in Lebanon approximately 6.5 US cents/kWh. This would mean that the installed PV farms would be saving approximately USD 32.9 million per year, leading to a payback period of 7.3 years for the whole investment [based on the average production cost of EDL (0.202 US cents/kWh)]. Moreover, the installed PV farms would be supplying approximately 71 extra hours of electricity in 2020.

5.6 The way forward

The achievement of the objective of the 150 MW solar PV farms needs to be done according to four main axes of development:

- Solar PV farms to be owned by EDL

- Solar PV farms to be owned by other public administrations

- Solar PV farms to be owned by the private sector (to be connected to the national grid)

- Solar PV farms to be owned by municipalities

For the purpose of this NREAP, the fourth axis of development will not be considered for the realistic case.

To start with, the existing BRSS project has a capacity of 1 MW with the potential to be expanded to 10 MW. EDL is the main owner of the BRSS. EDL is also considering building other solar PV farms in the different regions of Lebanon. Ideally, EDL could be the owner of approximately 20 MW of solar PV farms by 2020. Based on the budget calculation, an investment of approximately USD 38 million would be allocated by EDL.

On the other hand, other public administrations in the country could be building solar PV farms to be connected to the national grid through PPA. It is estimated that approximately 10 MW of installations could be achieved by 2020, requesting approximately USD 19 million of public investments.

Most importantly, the private sector could intervene to build large solar PV farms. The realistic scenario considers that approximately 120 MW of solar installations could be done once the legal framework is set up in Lebanon (to be addressed in a later chapter). The needed budget would be USD 180–228 million, and is expected to be covered by private investments. The Lebanese Government, through EDL, would need to commit to annual electricity purchasing totaling approximately USD 20 million.

Since most regions of Lebanon offer high solar potential, solar PV installations could be divided according to the following approach:

- Mount Lebanon-30 MW

- North-30 MW

- South Nabatieh-30 MW

- Bekaa-30 MW

Industrial Research Institute and Lebanese Center for Energy Conservation launch the Fonds d'Aide au Secteur Privé solar training platform

A training platform for PV installers is now available in Lebanon. The platform contains different types of solar panels, inverters, and batteries and three main training courses (grid-tied systems, off-grid systems, and high voltage applications). The platform is built thanks to the programme "FASEP Formation Professionnelle"of the French Government. The "Fonds d'Aide au Secteur Privé (FASEP)" is a financial instrument for development assistance implemented by the Directorate General of Treasury in France.

On September 14, 2011, a delegation from LCEC visited a solar training platform owned by Transénergie in Ecully, Lyon, France. The visit was organized by the project "Support to the LCEC (EuropeAid/129347/D/SER/LB)". Following this visit, fruitful discussions were held with the French company regarding the transfer of this platform to Lebanon. The project was put in place and was approved on November 14, 2013. This project consists of the creation of a platform for French companies to display their products in Lebanon, and for the Lebanese market to perform trainings on these products. For this purpose, a club of French companies was created, in parallel, a market analysis was performed in order to know the training needs of the local installers and the Lebanese technical vocational sector. A club of Lebanese companies was later created in order to allow them to contribute to the project and to facilitate collaboration with their French counterparts.

The FASEP solar photovoltaic training platform is built at the premises of the IRI at the Lebanese University campus in Hadath. UNDP is the main partner of this project. Trainings will start in 2017.

Ms. Léna Dergham, Director General, LIBNOR, MOI, Lebanon

At LIBNOR, our mission is to improve the quality and safety of products, services and organizations, protect the environment and the well-being of society in Lebanon, and enhance economic development and business competitiveness, by developing and promoting consensus based standards in collaboration with many national stakeholders, organizing training programs. We will continue to support all efforts to make these high safety standards implemented at the national level for all products whether imported or locally manufactured.

| Chapter 6: Solar photovoltaic distributed generation

Distributed generation generally refers to energy systems where the energy is produced in proximity of the demand in opposition to centralized traditional systems. This architecture has been developed as a trend for renewable energies especially in countries preparing or adopting smart grids in order to ease the congestion on their grids. Germany and Spain were amongst the first countries to push for such a decentralized RE generation.

In the framework of this NREAP, this chapter deals specifically with solar PV distributed systems. In terms of terminology, LCEC considers *solar PV distributed generation* equivalent to *rooftop solar PV systems* or *solar PV systems with consumption at source.* It is also important to note that solar PV distributed generation includes systems of all sizes.

Given that that the outlook of solar PV energy technology worldwide is covered in the previous chapter, this current chapter covers the potential of solar PV distributed generation in Lebanon, followed by the target for solar PV distributed generation in the country. This chapter also covers the current initiatives as well as the needed budget to achieve the set target. The targets will be covered according to the three proposed scenarios (realistic, optimistic, and pessimistic).

6.1 Solar photovoltaic distributed energy resources

The previous chapter already introduced the large scale PV farms having size greater than 1 MW while being connected to the grid. This section will focus on projects used for self-consumption but that can also be connected to the national grid through net metering.

Electricité du Liban fosters the use of net metering in Lebanon

Net metering is a RE incentive through which consumers with small RE systems can offset the cost of power drawn from the utility. This works by installing a meter that records the bidirectional energy flow, allowing the excess power to be transmitted to the grid. The exported energy from the system is subtracted from the imported energy, and the net output is calculated. Net metering is a start-up tool used to promote clean energy through giving back incentives to customers.

Net metering was launched by the MEW to be adopted by EDL in December 2011. The idea of net metering was initiated by UNDP and was developed by national stakeholders through the establishment of the net metering committee including EDL, UNDP-CEDRO, LCEC, and national experts.

Generally, net metering is most applicable to low voltage users (i.e., residential users). However, medium voltage users can submit a request to EDL who will study each case individually.

With net metering, the consumer receives a bimonthly electricity bill covering only the *net consumption*, calculated by subtracting the exported electrical energy from the imported electrical energy. If the energy produced by the system exceeds that imported from the grid, the excess is saved as an energy credit and can be used in the following months. However, at the end of each year, the account is reset to zero, and the consumer is not compensated. Due to the frequent blackouts in the national electricity network, backup batteries are needed and are considered essential to the functioning of net metering in Lebanon.

At the time of the preparation of this current NREAP, the EDL board issued a new decision regarding the collective net metering approach. Collective net metering allows a group of consumers willing to install a RE system to apply net metering to the individual meters collectively. For instance, a 250 kilowatt peak (kWp) centralized solar PV system will be installed in the village of Kabrikha, south of Lebanon. Hopefully, collective net metering will be applied to the village, allowing all the village consumers to reduce their electricity bills based on the output of the solar plant (remote billing and monitoring).

In the region, where most of the countries focused on the larger scale projects in order to achieve more visibility for their goals, there is no clear policy about distributed generation. Lebanon is currently witnessing a remarkable increase in the installation of solar PV distributed generation.

In fact, the MEW has pushed through LCEC for the development of distributed solar PV generation mainly through the National Energy Efficiency and Renewable Energy Action (NEEREA) financing mechanism that was setup by the Central Bank of Lebanon and LCEC back in 2012.

National Energy Efficiency and Renewable Energy Action, a worldwide-renowned financing mechanism

NEEREA is undoubtedly one of most successful financing mechanisms in the world. A highly efficient financing mechanism developed by the Banque du Liban/Central Bank of Lebanon (BDL). NEEREA has proven to be an extremely effective way to boost EE, RE, and green buildings development in Lebanon.

The concept of having a national action called *NEEREA* was proposed by LCEC in 2009. The *Policy Paper for the Electricity Sector* adopted the NEEREA concept, to be mentioned later in NEEAP 2011-2015. The concept of NEEREA resonated with the BDL circulars that promoted environmentally friendly projects in the country (e.g., Circular No 184 in 2009). On November 25, 2010, BDL issued Loan Facilities Circular No 236 setting the conditions of application for green loans under the NEEREA financing mechanism. Then, on November 25, 2013, BDL issued three circulars to strengthen the status of NEEREA (313, 318, and 346).

NEEREA is dedicated to supporting the financing of new and existing EE, RE, and green building projects. NEEREA allows private sector entities (individuals, subject matter experts, or corporate bodies) to apply for subsidized loans for any type of EE or RE project. Loans are available to all sectors (industrial, agricultural, tourism, information technology, research, residential, commercial, and non-profit). NEEREA finances new environmentally friendly projects as well as those that enhance the conditions of existing projects to become environmentally sound.

The characteristics of NEEREA are various, starting from the fact that loans amount can be as low as USD 2,000 and as high as USD 20 million. The NEEREA interest rate is low, typically 1.075% and reaching as low as 0.3%. The repayment period for existing projects is up to 10 years (including a two-year grace period), while the repayment period for new project is 14 years (including a two-year grace period). Another extremely important characteristic of NEEREA is that green loans are provided through any of the Lebanese commercial banks to directly reach the end user.

During its start-up phase between 2011 and 2014, NEEREA benefited from a generous grant offered by the European Union of 15 million euros (EUR 15 million). The European Union has in fact contributed to NEEREA by offering a grant over a share of the investment done by beneficiaries. It is also important to note that the European Union support to the BDL includes two major support tools. A small part of the European Union grant is dedicated to finance the technical unit of LCEC. Another part is dedicated to launch a nationwide marketing campaign to promote the use of green loans in the country. LCEC works as the technical arm of BDL in the review of NEEREA loan requests.

The NEEREA has helped to fund more than 350 projects through the end of 2015. A recent UNDP-LCEC study conducted by the Small Decentralized Renewable Energy Power Generation (DREG) project shows that more than 600 small-scale PV projects are installed in Lebanon, accounting for total installations of more than 20 MW. This market continues to develop, especially under the current situation of the electricity sector where these systems are being installed to compensate for diesel generators during blackout periods, which makes them attractive economically. Furthermore, commercial PV system projects, led by the seven UNDP-CEDRO and UNDP-DREG projects (ranging in size from 130 kW to over 300 kW per site), are currently being executed.

European Union-funded United Nations Development Programme-Country Energy Efficiency and Renewable Energy Demonstration Project for the Recovery of Lebanon project: 10 years of support to national policies

The European Union-funded UNDP-CEDRO IV project is a 3.5-year (2014-2017) project that provides on-going assistance to the Government of Lebanon (GOL) to develop and implement a national sustainable energy strategy and action plans to mitigate climate change. The interventions of CEDRO IV are in line with the United Nations Development Assistance Framework (UNDAF) for Lebanon (2010-2014), and in line with the Millennium Development Goal 7 (MDG 7) of achieving environmental sustainability.

The CEDRO IV project builds on the previous three phases of CEDRO (2007–2013), funded by the Spanish Development Agency (AECID) through the LRF. During the first three phases, more than 100 small-scale RE applications have been demonstrated nationwide, ranging from PV and micro-wind systems to large-scale solar hot water (SHW), pico-hydro, and ground-source heat pump projects. In addition, CEDRO developed assessments for various RE resources (e.g., wind atlas, bioenergy strategy, hydro from non-river sources, geothermal applications, and others).

Currently, CEDRO IV work on low-carbon energy generation is focused on the following activities:

- RE applications-Eight demonstration projects on hybrid PV systems, in collaboration with the European Union MEDSOLAR project and with a cumulative capacity of 1.36 MW, are being implemented with the objective of reducing the electricity bill of commercial, industrial, and other beneficiaries.

- Community RE solutions-A 250 kWp centralized solar PV system for the village of Kabrikha, South of Lebanon, is under construction. This project is paving the way for community led net metering and remote billing and monitoring, in collaboration with the MEW and EDL.
- Bioenergy application (for heating) from forestry residues-Given that the Bioenergy Strategy of 2012 indicated that forestry and agricultural residues form the most important resource in terms of biomass, two briquette processing plants-one in Aandket (in northern Lebanon) and one in Bkessine (in southern Lebanon)-are set up to produce 1,000 tons/year of biomass briquettes from sustainably-harvested forestry residues.
- Ground-source heat pumps-A 1.08 MW ground-source heat pump is under construction to satisfy the partial demand for heating, cooling and hot water for the Medrar Medical Center (MMC), (in collaboration with and co-financed by the MEW).

Furthermore, the CEDRO IV project will publish technology and other guideline reports specifically on: (1) solar-PV hybrid systems, (2) net metering guidelines, (3) grid code (with LCEC and DREG), (4) ground-source heat pumps (GSHP), and (5) briquette machine guidelines.

For more info on the CEDRO project, visit: www.cedro-undp.org/.

United Nations Development Programme keeps up the positive momentum: The Small Decentralized Renewable Energy Power Generation project

The DREG project objective is to reduce greenhouse gas (GHG) emissions by the removal of barriers to the widespread application of decentralized RE power generation. The DREG project is funded by the Global Environment Facility (GEF) and implemented by the UNDP Lebanon. The project is nationally executed by MEW in coordination with the LCEC.

The project started its activities in September 2014 with a budget of USD 1,575,000 from GEF-UNDP and USD 500,000 in-kind from MEW. The project provides technical and financial support to facilitate the installation of 2.6 MW of decentralized solar PV systems for various private sector entities. The project will provide a 25% grant (capped at USD 150,000) of the total value of each project while the remaining will be funded through the NEEREA financing mechanism. These systems will generate approximately 4,000 MWh per year and, thereby, will help reduce at least 43,000 tons of CO_2eq in GHG over their lifetime.

The DREG project is also working on:

- A grid code study that will help EDL in connecting RE plants to the grid in a safe and efficient manner thereby maximizing their output and performance
- A de-risking RE investment study that will identify the risks that affect the financing costs and competitiveness of RE and recommend policy and financial de-risking instruments in order to mitigate or eliminate these risks
- A solar PV national status report that will be the first annual report to quantify and monitor the growth of the PV market in Lebanon
- Equipment and installation quality control measures that will ensure that all equipment being used in solar PV systems in Lebanon conforms with international standards and that PV technicians are certified to install, diagnose, maintain, and repair PV systems
- Capacity building workshops that target technical and financial topics to increase local knowledge, know-how, and awareness about decentralized RE

For more info on the DREG project, visit: www.lb.undp.org/dreg.

6.2 Target for solar photovoltaic distributed generation

Loan requests received from the BDL as part of the NEEREA financing mechanism show that more than 10 MW were under installation in the first six months of 2016. Given the current market trends and the increasing positive momentum in the Lebanese market, LCEC assumes that a total of 100 MW of solar PV distributed generation seems very realistic by 2020.

On the other hand, if current momentum is lost as per the pessimistic scenario, only approximately 50 MW of installations will occur by 2020. In the optimistic scenario, 170 MW of solar PV distributed generation is expected. Table 15 summarizes the three possible scenarios.

Table 15. Target scenarios of solar photovoltaic distributed generation energy for the year 2020

Solar photovoltaic distributed generation	Pessimistic			Realistic			Optimistic		
	MW	MWh	ktoe	MW	MWh	ktoe	MW	MWh	ktoe
Industrial sector	10	16,500	3.6	30	49,500	10.7	40	66,000	14.3
Commercial sector	25	41,250	8.9	40	66,000	14.3	60	99,000	21.4
Agriculture sector	5	8,250	1.8	10	16,500	3.6	20	33,000	7.1
Residential sector	5	8,250	1.8	10	16,500	3.6	20	33,000	7.1
Others (public, municipalities)	2	3,300	0.7	5	8,250	1.8	20	33,000	7.1
Public street lighting	3	4,950	1.1	5	8,250	1.8	10	16,500	3.6
TOTAL	**50**	**82,500**	**17.8**	**100**	**165,000**	**35.6**	**170**	**280,500**	**60.6**

Table 16 presents the potential development of solar PV distributed generation until 2030 under the *realistic* scenario.

Table 16. Target of photovoltaic distributed generation energy for the years 2010-2030

		Distributed PV
2010	**MW**	-
	GWh	-
	ktoe	-
2015	**MW**	-
	GWh	-
	ktoe	-
2020	**MW**	100
	GWh	160
	ktoe	34.6
2025	**MW**	125
	GWh	200
	ktoe	43.2
2030	**MW**	150
	GWh	240
	ktoe	51.8

Oil installations turn green: Zahrani 1 MW solar farm

With the first 1 megawatt peak (MWp) solar PV plant being installed at Oil Installations' premises in Zahrani, it is becoming clear that RE is infiltrating the strongholds of fossil fuel energy. Originally intended to receive and refine light Arabian crude oil from Saudi Arabia through oil pipelines, the main activity of Zahrani Oil Installations is currently importing, storing, treating, and distributing conventional fuel (fuel oil, gas oil, and 92 octane gasoline) in the local market through distribution companies.

The tender for the 1 MWp solar PV plant in Zahrani was announced during September 2014. It was clearly mentioned that it will be the first phase of a larger project aimed at producing PV energy and feeding it to the national grid. The 1 MWp plant is divided into four parts, each linked to a different connection point. The produced energy is mainly used at the facility. The excess is directly fed to the national grid through four net meters. It has a total number of 3,524 modules of 310 Wp each with an East-West orientation and a tilt angle of 10 degrees. The site has a great potential for a pumping storage application.

6.3 Needed budget to achieve the 2020 target for Solar photovoltaic distributed generation

Thanks to the NEEREA financing mechanism, LCEC is able to produce average costs of solar PV distributed generation. Figure 17 shows an indicated normalized gaussion distribution of off grid system prices in Lebanon.

Given that the price range is between USD 3.21/Wp and USD 6.00/Wp in the case of figure 17, the total investments needed to reach the 100 MW target (realistic scenario) would be between USD 321 million and USD 600 million over the next five years.

In the context of this NREAP, the cost of USD 3.21/W will be considered for all type of the decentralized PV installations for two main reasons. First, the solar PV market is witnessing a sharp decrease in solar system prices worldwide and in Lebanon. Second, a thorough review of the NEEREA projects shows that most of the installations are close to the price of USD 3.21/W.

On the other hand, the 100 MW installations will be producing approximately 2,913.5 GWh during a 20-year lifetime considering a fair 1% decrease of output per year. This would lead to an average of 11 US cents/kWh to which the cost of 1 US cent /kWh of operation and maintenance should be added making the LCOE for decentralized PV in Lebanon approximately 12 US cents/kWh.

Knowing that the decentralized PV systems are being installed as replacement to diesel generators (with an average production cost of 35 US cents/kWh), the payback period of the whole investment will be approximately 8.7 years (with savings of approximately USD 36.8 million). They will allow for the supply of 47 extra hours of electricity in 2020.

It is to be mentioned that most of the investments will be made by the private sector. This makes this type of installation very important because demand is decreasing indirectly without the need for any direct investment by the Lebanese Government.

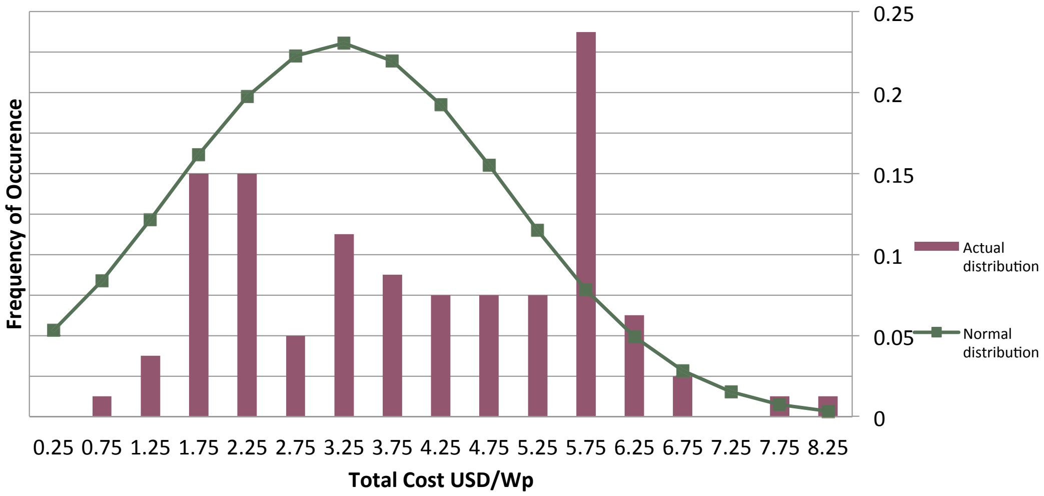


Figure 17. Price distribution for distributed solar PV based on NEEREA implemented projects

More than 20,000 solar public street lighting systems in Lebanon by 2020

More than 2,600 solar public street lighting systems were installed by MEW between 2010 and 2015. In addition, the Chinese Government offered MEW a grant of 500 solar public street lighting systems in 2015. Additionally, the Ministry of Public Works and Transportation (MOPWT) installed a similar number of systems during that period.

Furthermore, international donors and institutions-United Nations Interim Force in Lebanon (UNIFIL), UNDP, European Union, European Union Sustainable Urban Demonstration Energy Projects (SUDEP), United States Agency for International Development (USAID), and others-are supporting local municipalities and unions of municipalities with a large number of donations. To date, LCEC estimates that Lebanon has more than 8,000 solar public street lighting systems installed nationwide. This number is expected to increase to reach approximately 20,000 installations by 2020. The installed capacity of these systems would be approximately 6 MWp.

6.4 The way forward

The national financing mechanism NEEREA, initiated by BDL and LCEC, is undoubtedly the main market driver to reach the 100 MW target of solar PV distributed generation by 2020. For the next five years, NEEREA support is expected to continue at an increasing rate with more than 20 commercial banks now being involved in this process.

On the other hand, international support and donor support initiated by many players (mainly the European Union and UNDP) have an extremely positive effect on the development on the market.

In addition, increased awareness among public sector officials and decision makers has positive contribution. Public authorities like MEW, the Council for Development and Reconstruction (CDR), and the Oil Installations are making huge efforts to boost the momentum through tangible initiatives and actual projects.

Public water wells use solar PV systems

The Lebanon Municipal Service Emergency Project (LMSEP) is an initiative launched and funded by the World Bank (WB) and managed by CDR. The main objective of the LMSEP project is to ease the load on the municipal services, areas, and communities hosting Syrian refugees.

Water supply has always been a challenge in the Northern Bekaa area, and today, due to the sudden increase of the population due to the Syrian refugee influx, water demand has increased tremendously (drinkable water, domestic water, and water for irrigation use). This situation, which is aggravated by the recurrent breakdown of public power and the reliance of municipalities on generator sets to provide power for water pumping during power outages, motivates local authorities to shift to green energy production via solar PV systems.

The LMSEP project will be supporting the installation of approximately 11 solar PV farms to be used for solar pumping in 11 different public wells in the Bekaa area. The total capacity of these projects is approximately 1.2 MWp. Upon the request of the CDR, LCEC is acting as the technical consultant for this project and is currently preparing a request for proposal (RFP) to be shared with companies interested to bid for the 11 solar PV pumping systems.

Ms. Christina Lassen, Head of the European Union (EU) Delegation to Lebanon, European Union (EU)

A few months after the publication of Lebanon's National Energy Efficiency Action Plan (NEEAP) 2016-2020 comes the National Renewable Energy Action Plan (NREAP) 2016-2020. This is a testimony to the country's level of ambitions on such crucial matters. The European Union welcomes these dynamic endeavours, and is keen on accompanying Lebanon in reaching its targets in the framework of our long lasting partnership.

As we know, renewable energy can be produced from a wide variety of sources including wind, solar, hydro, tidal, geothermal, and biomass. Lebanon benefits from many of these sources, and through our EU-funded cooperation projects (in particular the CEDRO IV project, implemented by UNDP) we are demonstrating their relevance and cost efficiency.

The EU reiterates its commitment to support Lebanon in this positive endeavour, while calling upon the decision-makers to ease the deployment of renewable energy sources through legislative and institutional adjustments. These would undoubtedly increase the attractiveness of this green sector and foster national and international investments, for the benefit of Lebanese citizens, and for a more efficient, powerful and greener Lebanon!

Chapter 7: Concentrated solar power

CSP technology uses direct normal irradiation (DNI) to generate electric power. CSP plants use mirrors to concentrate the incident DNI to raise the temperature of a transfer fluid in the receiver and consequently run turbines to generate electricity. Parabolic trough (PT) is the most mature technology, and it continues to dominate the market, representing about 95% of facilities in operation at the end of 2011 and 75% of plants under construction by mid-2012. On the other hand, towers/central receivers (CR) are becoming more common and accounted for 18% of plants under construction by mid-year 2013, followed by Fresnel (6%), and parabolic dish technologies, which are still under development (REN21, 2013).

As mentioned in the previous chapter, Lebanon has a favorable climate for both PV and CSP plants. In this chapter, LCEC considers CSP plants to be connected to the national grid (or probably to small micro-grids in the future) in Lebanon with a capacity size of 1 MW or bigger.

In the context of this NREAP, it is important to note that when using the term CSP plants, LCEC means solar farms that are built on favorable sites for electricity production without being connected for local consumption. In this regard, all the output of the CSP plant would be exported to the national grid according to a clear long-term PPA. Other solar farms that are built on existing facilities and are connected to each facility's local consumption (as electricity or heat) are part of another chapter of this NREAP. In fact, these solar farms are labeled as distributed generation and are covered in a separate chapter.

The following sections present an outlook on the development of CSP plant energy worldwide, followed by the potential of CSP farms in Lebanon, including the financial appraisal of this technology. This chapter will then define the target for CSP energy in Lebanon as well as the needed budget to achieve the set target. The chapter will cover the three possible targets for solar CSP energy according to the three proposed scenarios (realistic, optimistic, and pessimistic).

7.1 Technology global outlook

CSP is a RE technology on the rise. Capacity additions are taking place rapidly. Since 2004, the capacity of CSP has increased more than tenfold, with an average annual growth rate of more than 32% between 2006 and 2014 (REN21, 2013, 2014) (see Figure 18).

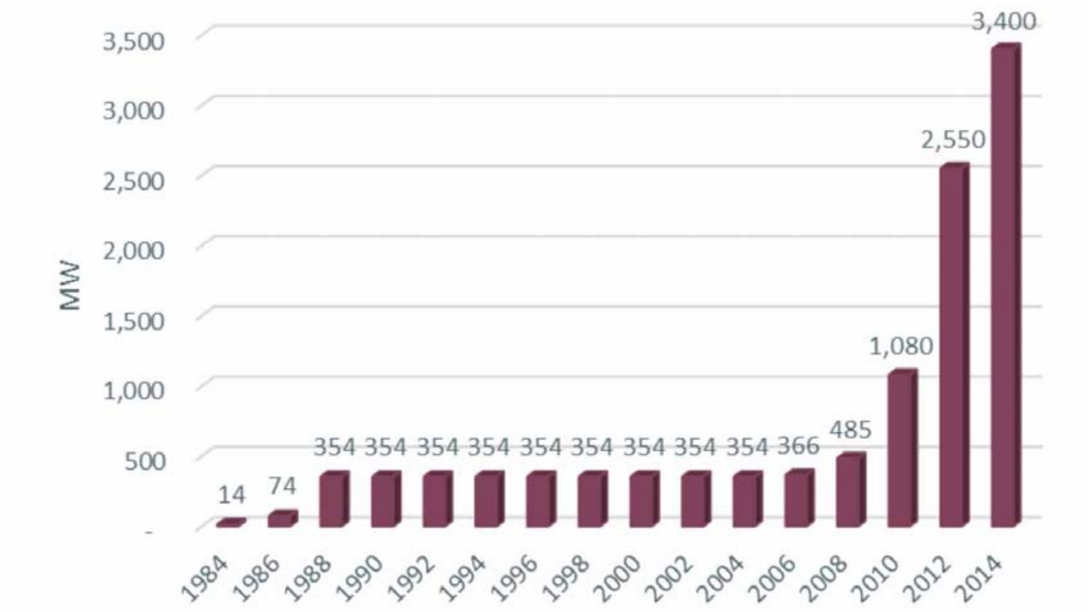


Figure 18. Concentrated solar power global capacity 1984–2014 (REN21, 2013, 2014)

Arab countries, most notably the United Arab Emirates, and to a lesser extent Algeria, Egypt, and Morocco, accounted for 165 MW, or 6.4% of the total capacity until 2013. The United Arab Emirates has the third largest capacity account for CSP plants on a global scale, after the United States and Spain (REN21, 2014). This percentage share fares better than other RE technologies in selected Arab countries, and is expected to increase significantly in the next several years, especially in the Gulf Cooperation Council (GCC) countries (REN21, 2014).

In Lebanon, there are no near-to-medium-term plans for CSP projects for electricity generation. Though there is one 2.8 MW CSP plant that exists on an industrial site. However, this plant is for thermal energy not electrical power.

7.2 Potential of CSP technology in Lebanon

The potential for CSP in Lebanon was estimated taking the following criteria into account (Téllez, Obeid, & Karam, 2013):

- DNI equal to or larger than 2100 kWh/m^2/year

- Solid and unpopulated land

- Land slope less than or equal to three degrees

- Water availability

- Minimum land area of 1 km^2

The CSP technology that is used in this assessment is the parabolic trough. Other technologies like solar tower might lead to a different potential considering that this technology can be implemented on hilly sites. The potential areas are shown in Figure 19.

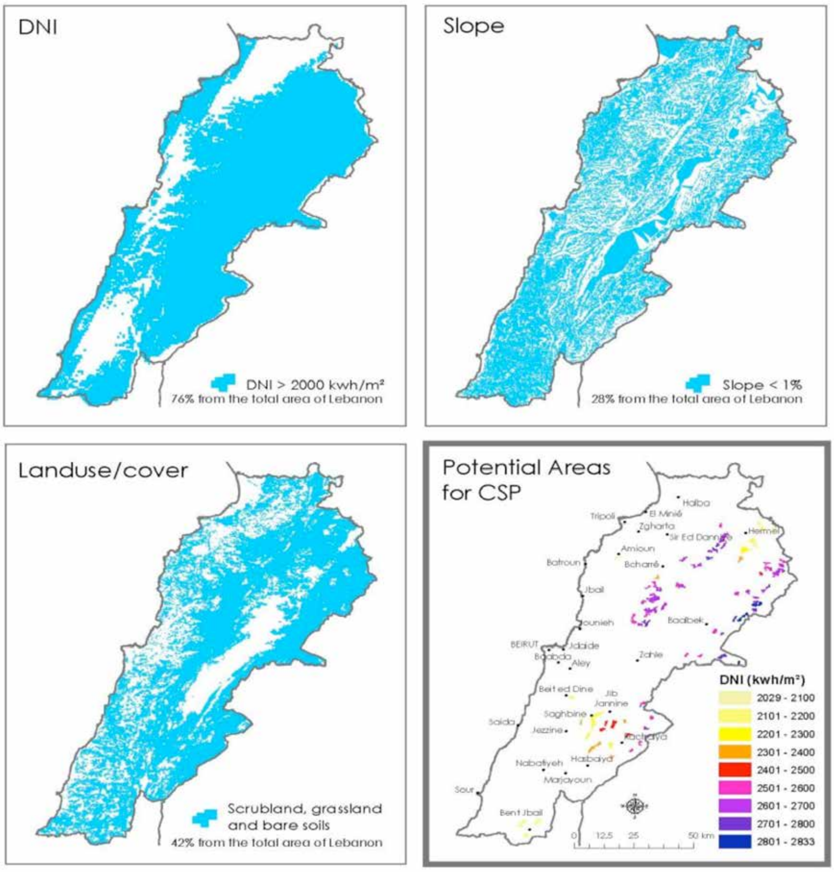


Figure 19. CSP potential maps for Lebanon

Table 17 shows that Lebanon has significant potential that it can tap into for CSP. The assessment is based on a 15% annual average solar-to-electric efficiency and 30% land use factor. If only 15% of the total land area is used, then the potential stands at 1,210 MW of CSP power to be deployed in Lebanon, with a subsequent power supply of 2,741 GWh. Based on the 2010 electricity demand estimations, then CSP, with only 15% land usage, can deliver up to 17.2% of this total demand on aggregate.

Table 17. CSP potential in Lebanon

Direct normal irradiance (kWh/ m^2)	Surface area (km^2)	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**	

By combining CSP with energy storage and/or hybrid natural gas generation or others, the achievable objectives and conditions for the future electricity system in Lebanon can be exceptionally improved in terms of greening the sector while simultaneously safeguarding reliability and diversity. Figure 20 and Table 18 indicate the proximity of the potential CSP sites to the high voltage transmission network in the country.

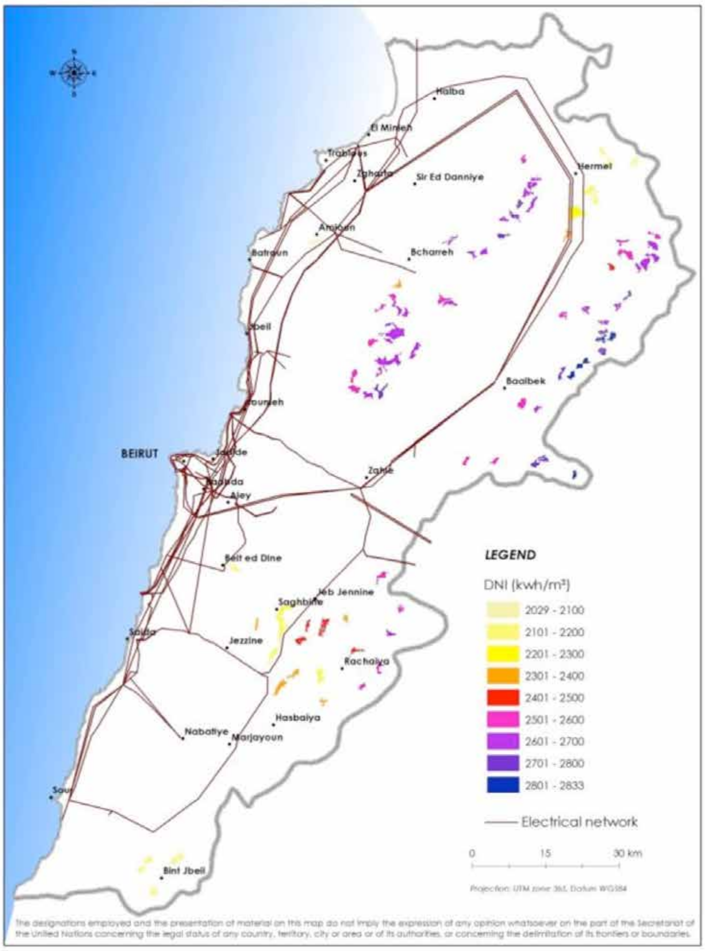


Figure 20. Concentrated solar power potential sites and proximity to power line

Table 18. Potential areas and proximity to power network

	Closest distance to the power network (km)		
Direct normal irradiance (kWh/m²/year)	10	10-20	20-30
2100-2300	95	5	0
2300-2600	67.9	32.1	0
2600-2833	31.7	65.8	2.5

7.3 Financial appraisal of concentrated solar power technology

A detailed financial appraisal for twelve different schemes for CSP in Lebanon can be found in the UNDP-CEDRO (2012) publication. A summary of results can be found in Figure 21.

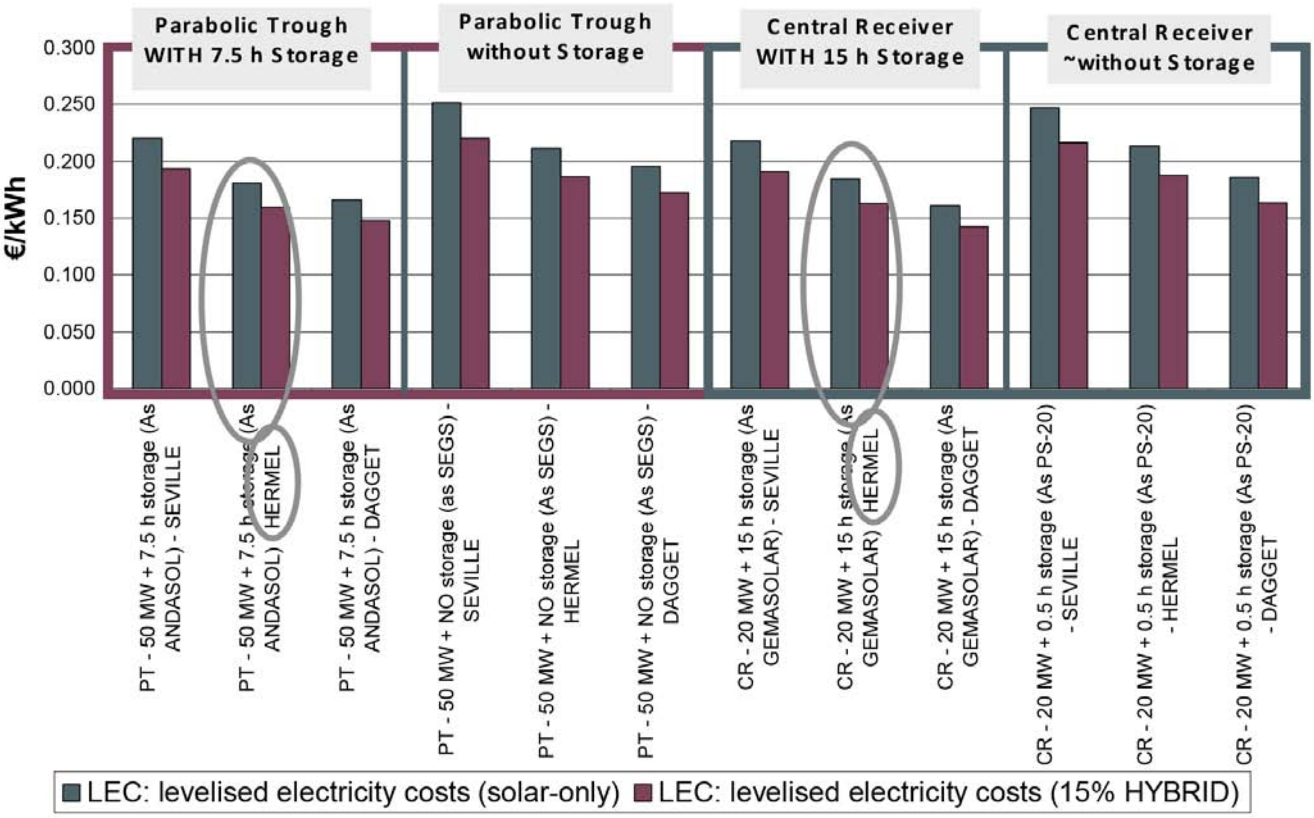


Figure 21. Levelized electricity costs for the 12 concentrated solar power potential sites in Lebanon (UNDP-CEDRO, 2012)

The most cost-effective CSP option shown in Figure 21 is the parabolic trough CSP, particularly 15% hybridized, where the levelized costs reach approximately 16 US cents/kWh for CSP with thermal storage. The estimates in Figure 21 fall within the estimates indicated in the IRENA publication on cost of CSP (IRENA, 2012b).

Indicative costs for CSP in the IRENA publication (2012b) put the range of the LCOE to be between 20 US cents/kWh and 36 US cents/kWh. The more recent REN21 (2014) publication indicated cost ranges for PT and Fresnal between 19 US cents/kWh and 38 US cents/kWh with no storage, 17 US cents/kWh and 37 US cents/kWh with storage, while a more competitive price range of 12.5 US cents/kWh and 16.4 US cents/kWh would be considered for the CSP tower option. Levelized costs are highly impacted by the solar resource variation that is inherent in these figures.

Lebanon is endowed with substantial potential of appropriate areas where CSP plants can be implemented. CSP is not as modular a technology as PV power, and therefore installations happen in bulk where economies of scale play an important role in reducing the overall costs per power output.

The technology is wide spreading due to the drop in costs of CSP. Falling costs will further ensure that CSP technology becomes a prominent source of RE heading into the future. When combined with storage, CSP can be relied on to deliver power in peak periods (usually morning and evening), and can have better dispatching on demand.

CSP in Lebanon has yet to enter the programmatic-making processes. Significant work and assessment must be carried out to gauge the actual direct normal irradiation and other weather characteristics of the regions where such DNI is indicated, through satellite information as high. Other assessments on recent technical progress, associated costs, and contribution to reliability of power supply are needed.

7.4 Target for concentrated solar power

In the case of CSP, this action plan stays conservative due to several immaturities in the development of the technology. However, because of its storage capability, this technology remains attractive when comparing it with other forms of RE. For this reason, the pessimistic scenario does not include any CSP project in Lebanon during the next five years. On the other hand, the realistic scenario considers the most efficient option identified in the previous paragraph, 50 MW parabolic trough in the Hermel area (being a semi-arid region) (see Table 19 and Table 20). As for the optimistic scenario, it is estimated that two similar power plants are to be included in the same region or in two different regions.

Table 19. Target scenarios of concentrated solar power energy for the year 2020

	Optimistic	**Realistic**	**Pessimistic**
Site	Two PT + 7.5 hours storage	Hermel PT + 7.5 hours storage	-
Power (MW)	100	50	-
Energy (GWh)	341.2	170.6	-
Energy (ktoe)	73.7	36.8	-

As for the development of CSP in the country, it is considered that the realistic target could be achieved in 2020, with no further development until 2030. This conservative assumption is taken due to all the uncertainties surrounding this technology.

Table 20. Target of concentrated solar power energy for the years 2010-2030

CSP		-
2010	**-**	-
	-	-
	-	-
2015	**-**	-
	-	-
	-	-
2020	**MW**	50
	GWh	170.6
	ktoe	36.8
2025	**MW**	50
	GWh	170.6
	ktoe	36.8
2030	**MW**	100
	GWh	341.2
	ktoe	73.7

7.5 Budget needed to achieve the 2020 target for concentrated solar power

One of the main reasons for not considering a higher share of CSP in the RE mix is the need for a high investment. The storage capacity it possesses adds the important dimension of stability when compared to the other RE technologies.

Nevertheless, the needed investment for the 50 MW power plant with 7.5 hours of storage remains approximately USD 300 million as estimated by CEDRO in their 2012 publication entitled *Concentrated Solar Power for Lebanon for 2012: A Techno-economic Assessment* (UNDP-CEDRO, 2011). CSP projects have not been implemented yet in Lebanon. However, based on Figure 21, the estimated LCOE for the Hermel 50 MW power plant with 7.5 hours of storage is approximately 16 US cents/kWh (reasonable when compared to the 14 US cents/kWh to 36 US cents/kWh range mentioned by IRENA (2012d) .

In this case, compared to the cost of production of EDL's power plants, the yearly savings would be approximately USD 7.2 million leading to a payback period of approximately 42 years. However, this resource has a major advantage: the ability to store energy for use during peak hours. In the case of Lebanon, the CSP plant would be replacing high cost power plants such as the Tyre and Baalbeck power plants where the cost is close to 32 US cents/kWh. In this case, the yearly savings would be more than USD 27 million and the payback period is very close to 11 years, being a more representative comparison. Finally, the installation of the CSP power plant will supply approximately 50.5 extra hours of electricity in 2020.

7.6 The way forward

The only feasible way to build the 50 MW CSP plant as per the realistic scenario is through the private sector. For the purpose of this NREAP, it is considered that the Lebanese Government will be ready to sign a PPA with private investors to build the CSP plant and connect it to the grid.

Dr. Bassam Frenn, Director General, IRI, MOI, Lebanon

The Industrial Research Institute (IRI), among other activities, is a reference and a leading institution in the inspection, testing and the certification of a wide range of products imported and locally manufactured in Lebanon. Together with LCEC, IRI succeeded in establishing a state-of-art testing facility for solar water heaters in the country, and is currently working on expanding its testing capabilities to include solar PV systems. IRI actually believes that controlling the quality of products and services in Lebanon is the surest way to keep moving forward towards our national objectives. On the other side, since the end of 2015, IRI with the PV system installed on its facilities is producing more than 14% of its electricity peak consumption, exceeding the national goal of 12% in 2020.

| Chapter 8: Solar water heaters

SWH technology is by far the most developed RE technology in Lebanon. Currently, more than 450,000 m^2 of solar collector area is installed in the country. The demand for SWHs is still on the rise.

This positive momentum in the SWH market goes back to 2010. In fact, the *Policy Paper for the Electricity Sector* (2010) commits to "increase the penetration of solar water heaters and devise innovative financing mechanisms in collaboration with the private sector to achieve the slogan 'a solar water heater for every household'" (Bassil, 2010).

This chapter focuses on the development of the SWH market in Lebanon and the potential for 2020 and beyond. As usual, the chapter starts with an outlook on the development of SWHs worldwide, followed by the potential for Lebanon. This chapter will also define the target for 2020 as well as the needed budget to achieve the set target, to be followed by the three possible targets for SWHs according to the three proposed scenarios (realistic, optimistic, and pessimistic).

8.1 Technology global outlook

The current global capacity of SWH is about 406 gigawatts thermal (GWth), which has been estimated to save about 3,036 million in terms of tons of oil equivalents annually equivalent to 444,000 ktoe in heating. Indeed, in sunny regions where electricity is expensive and there is a medium-long heating season, SWHs can have a payback time as short as five years. Global installations of SWHs will probably grow to 600-1,000 GWth by 2020. Cumulative capacity of water collectors reached an estimated 406 GWth by the end of 2014 (with air collectors adding another 2 GWth), providing approximately 341 terawatt-hours (TWh) of heat annually. Figure 22 shows the SWH global installed capacity between 2004 and 2014 (REN21, 2015).

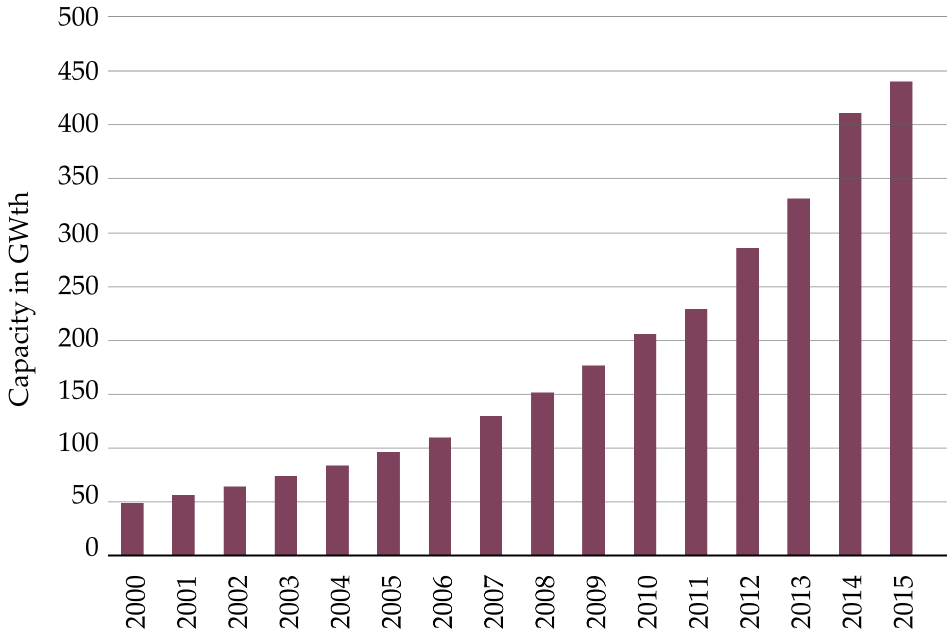


Figure 22. Solar water heating collectors global capacity 2000-2015

China accounted for about 80% of the world market (in terms of investments) for solar water collectors, followed by Turkey, Brazil, India, and Germany. China manufactures approximately three quarters of global SWHs. Regarding the total capacity generated at the end of 2014, the United States comes second, preceded by China and followed by Germany, Turkey, and Brazil. (REN21, 2015)

Large solar water heating systems are being installed in hotels, schools, and other large complexes. An interest in the use of advanced collectors for district heating systems, solar cooling, and industrial applications is growing. In the Middle East, solar hot water is an important resource in many countries. The market is led by three main countries, namely Palestine, Jordan, and Lebanon.

8.2 Potential of solar water heater technology in Lebanon

Solar water heating is already a mature technology in Lebanon. In NEEAP 2011–2015, the fourth initiative aimed at promoting SWHs mainly in the residential sector with an installation target of 190,000 m^2 of solar collectors by 2014 (MEW, 2012). The 2014 objective was achieved and even exceeded. The initial target for 2020 is to reach 1 million m^2 of installed collectors. LCEC believes this target is achievable.

The Global Environment Facility-funded global solar water heating project

In 2009, the UNDP and the United Nations Environment Programme (UNEP) launched a joint programme entitled "Global Solar Water Heating Market Transformation and Strengthening Initiative" (GSWH) with funding from GEF and the International Copper Association (ICA). The GSWH initiative covers six countries, including Lebanon and sets a target of 190,000 m^2 of new installations over a period of five years (2009–2014).

As per Jaoudeh (2015), the first national SWH survey (completed in 2012), which included interviews with several installers, experts and end users, showed continuous growth in the SWH market. The local SWH dealers affirmed that their businesses grew between 10% and 50% as a result of LCEC's initiatives. This study also revealed that the industrial sector is lagging in terms of SWH installations. Actually, SWH installations in this sector represent only 4% of the total installations in Lebanon.

The GSWH initiative and incentives led to installing approximately 186,500 m^2 of SWH collectors between 2011 and 2013. The SWH market is still witnessing steady growth. In 2013, more than 65,000 m^2 of SWHs were installed, 15% higher than in 2012, increasing the total area installed to 186,500 m^2 by the end of 2013. Around 3,557 citizens benefited from interest-free loans offered by the BDL to install SWH.

By the end of 2014, installations of SWH exceeded the set target (Jaoudeh, 2015). Furthermore, Lebanon is now considered among the top 10 markets for SWHs in the world according to Mauthner and Weiss (2014).

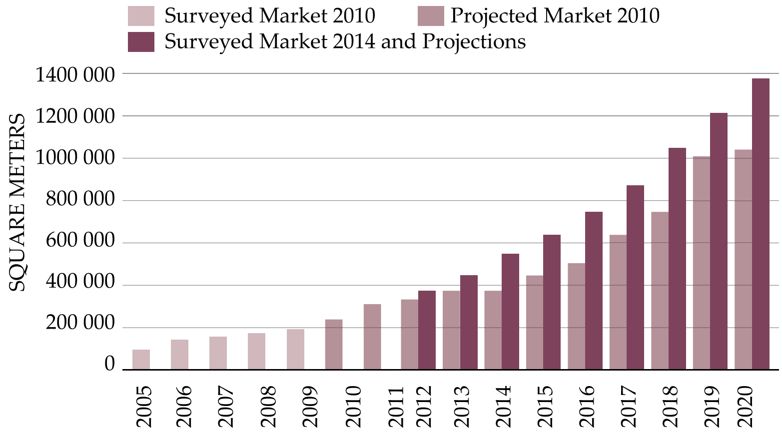


Figure 23. Solar water heater market growth in Lebanon, projected versus surveyed. Reprinted from *Solar water heaters' market evaluations: Case study of Lebanon 2015* (p.49). by E.A. Jaoudeh, 2015, Nairobi, Kenya: United Nations Environment Programme. Copyright 2015 by United Nations Environment Programme.

To get into the technical details, insolation varies widely from country to country, and there can also be significant variation within a specific country. Lebanon is distinguished by a great potential of solar energy with overall yearly average insolation levels varying from 1,500 kWh/m^2/year GHI in the northern parts of the country to over 2,000 kWh/m^2/year in the eastern parts next to the Syrian border as it can be seen in Figure 24. On average, Lebanon has an insolation of 1,947 kWh/m^2/year corresponding to a daily insolation of 5.34 kWh/m^2/day (Jaoudeh, 2015).

It is to be noted that the country's residential hot water consumption is considered to be a major end user with an average annual consumption of 64.5 m^3/household, equivalent to 3,000 kWh of electricity annually. (World Bank, 2009).

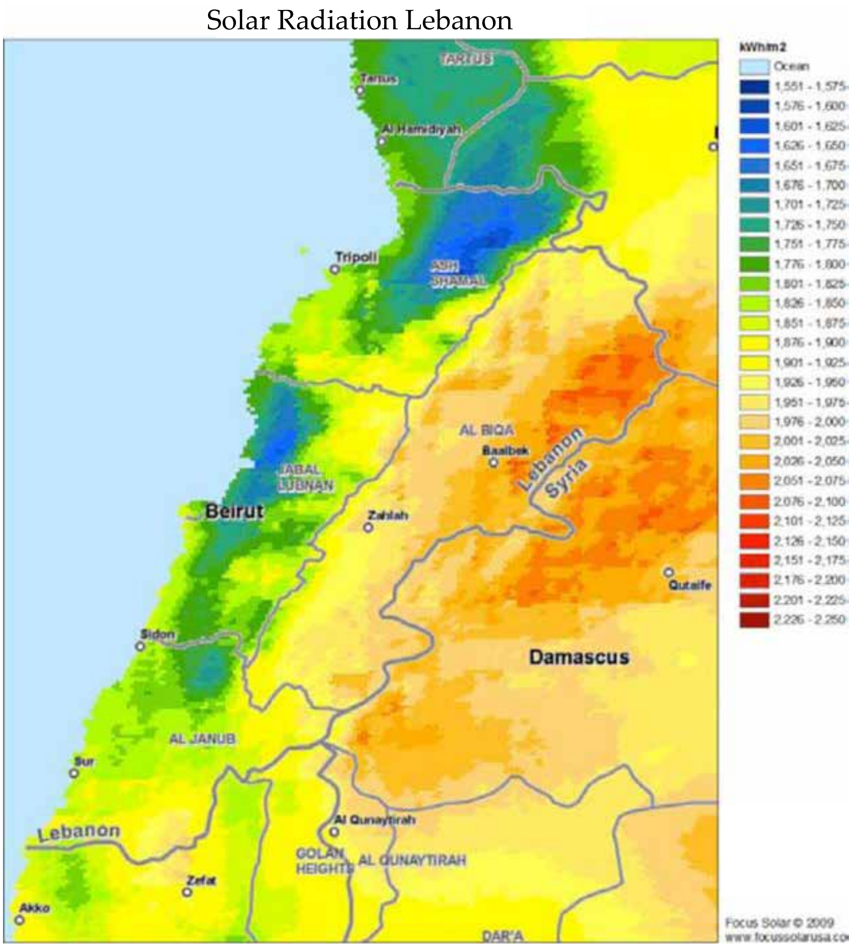


Figure 24. Insolation levels in the Lebanese territory

Qualification of companies working in the solar water heater sector

LCEC initiated a qualification process for SWH systems back in 2009. These systems should be for residential use and not cost more than USD 5,000. Four rounds of qualification are conducted each year. The last round of qualification was conducted in August 2016. The major factors considered in the evaluation criteria are as follows:

- General information (including legal registration, reputation, litigation and arbitration)
- Experience and expertise (engineering experience, other related and nonrelated technical experience, solar energy experience, awards and recognitions, manufacturing experience, installation experience, and list of references)
- Human resources (total number of employees, number of engineers, skilled labor, certificates, and installation experience)
- Equipment (general equipment owned, monitoring equipment, quality of equipment, and depreciation)
- Warranties and after sales (components and operation warranty periods)
- Safety measures (knowledge of safety procedures, and availability of safety tools)
- Technical skills for general manager, project managers, engineers, foremen, and labor (experience, degree, and additional certificates)

Bonus points can be given for companies that are members of the Lebanon Committee of the World Energy Council (WEC), had trainings with LCEC or have tested their systems at the IRI. The IRI is operating the first national solar water heating testing facility. The testing facility allows testing and inspecting the solar water heating systems and granting certifications. Only certified products by the IRI or other international testing laboratories are eligible to be used in the solar water heating subsidization program.

Local products are required to submit a test report from an accredited laboratory. Imported products should be provided with the Solar Keymark certification granted from one of the officially accredited certification bodies.

Decree 5305 dated October 28, 2010 assigned IRI to test and certify all SWH before introduction to the Lebanese market. This decree states that the following standards are mandatory for all type of SWH:

- NL EN 12975 (Parts 1 & 2)-Thermal solar systems and components (solar collectors)
- NL EN 12976 (Parts 1 & 2)-Thermal solar systems and components (factory made systems)
- NL EN 12977 (Parts 1, 2 & 3)-Thermal solar systems and components (custom build systems)

The qualifications' rating is as follows: not passing, passing, qualified or three-star system. Once rated, check visits are performed by the LCEC team to check the reliability of the installed systems.

These qualifications allow companies to be eligible for two types of financial aid. If the system is qualified or received a three-star rating, it is then eligible for a USD 200 subsidy offered by MEW. Any system, whether qualified or not, can be submitted for a loan with 0% interest over five years. Systems costing more than USD 5,000 can be submitted via the NEEREA financing mechanism supported by the BDL.

8.3 Target for solar water heaters

In 2009, Lebanon set two objectives for SWH installations:

- To achieve 190,000 square meters of installations between 2009 and 2014

- To reach 1,000,000 square meters of installations by 2020

The first objective was achieved and even exceeded in 2014. The 2020 objective is also reachable. For the realistic case, the 2020 objective is 1,000,000 m^2 of SWH installations.

Taking into account the following conversion factors (0.086 toe/MWh as per the baseline detailed earlier and a factor of 0.65 MWh/m^2/year, Shehadeh, 2012), every square meter of SWH collector installed leads to saving approximately 0.06 toe. Considering year 2010 as the baseline year, the total area of SWH installed in Lebanon is approximately 211,988 m^2 leading to 137.8 GWh energy saved per year. The installed area of solar collectors between 2010 and 2013 is approximately 186,000 m^2 (resulting in a total area of approximately 400,000 m^2 which includes 90,000 m^2 of collective SWH systems). Referring to Figure 25, the expected areas of SWHs that would be installed are 413,988 m^2 and 1,053,988 m^2 leading to 269.25 GWh and 685.5 GWh in 2015 and 2020 respectively.

For the optimistic scenario, LCEC considers that the Lebanese Government will enforce the use of solar water heaters as mandatory in all new buildings, leading to an increase of approximately 10% per year for the period 2016-2020. As for the pessimistic case, a small decrease in demand is foreseen, leading to the installation of a total of approximately 600,000 m^2 by 2020.

Regarding the expected area of SWHs installed between years 2020 and 2030, the following scenario is considered. In Figure 25, it is shown that the growth rate between years 2005 and 2020 is approximately 5%. The 2030 scenario assumes a constant yearly growth rate of 5% leading to 1,345,185 m^2 and 1,716,835 m^2 in 2025 and 2030 respectively leading to saving respectively 755.77 GWh and 1,116.61 GWh.

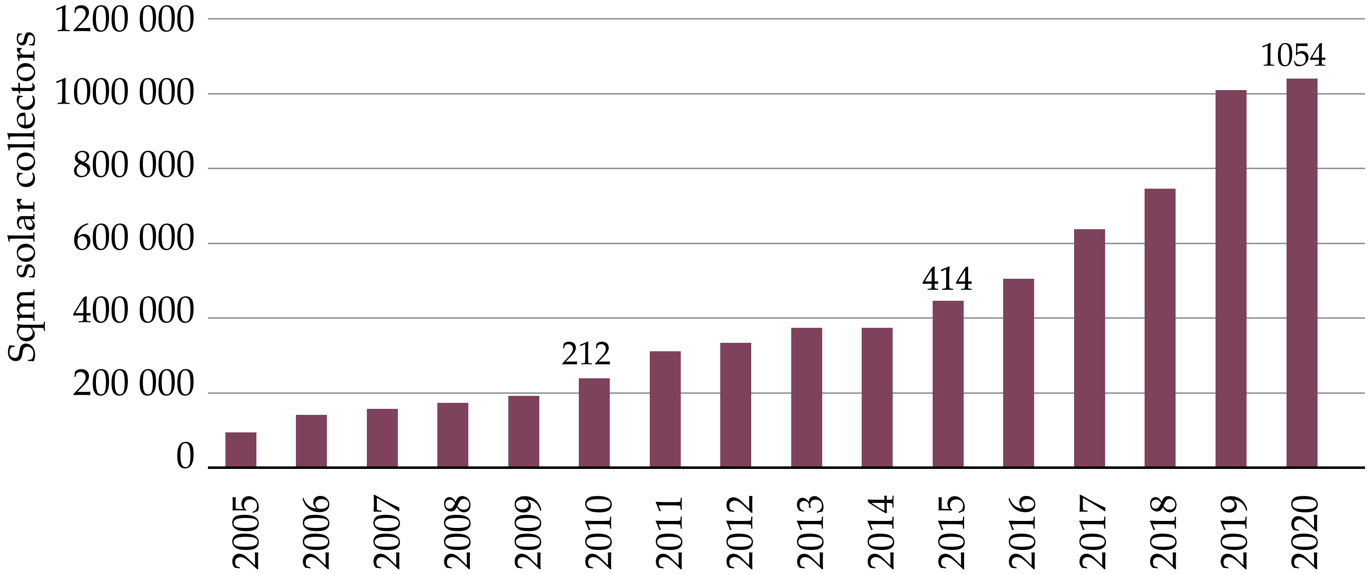


Figure 25. The expected growth of solar water heater market in Lebanon (Khoury, 2013)

The three target scenarios for SWHs development in Lebanon are resumed in Table 21. Whereas, Table 22 describes the evolution of the *realistic* target during the period 2010 to 2030.

Table 21.Target scenarios of solar water heater energy for the year 2020

	Optimistic	Realistic	Pessimistic
Installed surface (m^2)	1,700,000	1,053,988	600,000
Energy (GWh)	1,105	685	390
Energy (ktoe)	238.7	148	84.2

Table 22. Target of solar water heater energy for the years 2010–2030

Solar water heaters		
2010	**m^2**	211,988
	GWh	137.8
	ktoe	30
2015	**m^2**	413,988
	GWh	269.25
	ktoe	58.158
2020	**m^2**	1,053,988
	GWh	685.5
	ktoe	148.068
2025	**m^2**	1,345,185
	GWh	755.77
	ktoe	163.246
2030	**m^2**	1,716,835
	GWh	1,116.61
	ktoe	241.19

8.4 Needed budget to achieve the 2020 target for solar water heaters

Based on the rich experience in the country thanks to the NEEREA mechanism and the USD 200 subsidy program by the MEW, LCEC estimates that a typical SWH of 4 m^2 collector area costs approximately USD 1,200 leading to a cost of USD 300/m^2. The achievement of the target of 1,053,988 m^2 considering an increase of 640,000 m^2 between 2015 and 2020 would cost approximately USD 192 million.

In Lebanon, the savings of SWH can be estimated at approximately 650 kWh/m^2 year. If the lifetime of such systems is approximately 20 years, then combining this with the cost of USD 300/m^2 allows us to estimate the virtual LCOE of SWH in Lebanon to be approximately 2.3 US cents/kWh. The investment for SWH will be completely supplied by the private sector where the payback period would be approximately 2.6 years and the savings from the installations would be equivalent to more than 123 extra hours of electricity in 2020.

A market on the rise

NEEAP 2011–2015 laid out a national financing mechanism specific to the SWH market. The mechanism, initiated by BDL, enables private banks to offer 0% interest loans over five years for residential SWH installations costing less than USD 5,000. Additionally, consumers applying for the loan can benefit from a USD 200 subsidy provided by BDL through a MEW-allocated fund of USD 1.5 million for the sector. The subsidy is only accessible for products qualified by LCEC. For loans greater than USD 5,000, consumers can opt for a NEEREA loan—a subsidized loan for EE and RE projects that offers interest rates as low as 0.6% for up to 14 years including a grace period of 4 years.

Thanks to MED-DESIRE, LCEC conducted a full survey and study in 2016 to assess the performance of policies implemented and in place since 2010.

Results of the data yield a total of 49,565 systems installed in the period 2012–2015, equating to 15,049,487 liters and 219,280 m^2 of installed capacity valued at USD 86,029,660. Thirteen percent (28,732 m^2 of installations were financed via the 0% interest loan, of which a total of 3,393 systems installed in the period benefitted from the additional USD 200 subsidy amounting to USD 678,600. Total installed capacity contributed to 128.52 GWh equivalent of demand-side annual electrical energy, translating to 98,282 tons of reduction in CO_2 emissions equivalent by the national utility EDL with a 14% contribution by installations financed via the subsidized loan. With respect to projected installations, actual installed capacity outperformed estimations by 9.6%, 13.6%, 16% and 14.6% respectively over the four-year period.

Adoption of incentives proved successful with 11,603 approved loan applications estimated at USD 17,672,133 since 2010. By the end of 2015, 5,382 systems were projected to be subsidized amounting to USD 1,076,400 of the total USD 1,500,000 allocated fund.

8.5 The way forward

The culture of SWH installations is well established in Lebanon. To keep boosting the market, the NEEREA financing mechanism will need to continue. On the other hand, LCEC will be launching special initiatives regularly to give the market additional boosts, especially through the USD 200 subsidy program initiated earlier by MEW.

On the other hand, LCEC will be working with all concerned stakeholders towards enforcing the installation of SWH in the country. Namely, the Department of Urban Planning, LIBNOR, IRI, and municipalities are the main players.

Dr. Fadi Comair, Director General,
Directorate of Hydraulic and Electric Resources, MEW

The General Directorate of Hydraulic and Electric Resources has set a 10-year action plan for the development of dams in Lebanon, including the construction of new hydroelectric plants. We have also been the pioneering administration that has launched the Beirut Declaration on the Mediterranean Solar Plan to support RE and EE in the country. Our leadership and commitment will continue with the publishing of this new NREAP 2016–2020 and in accordance with the path set by the last COP meeting in Paris.

Chapter 9: Hydroelectricity

Over the centuries, hydropower has played an important role in providing mechanical energy and more recently electricity, thus supporting economic development for many nations and communities (REN21, 2013). Hydroelectric energy (or hydropower) or simply hydroelectricity is a well-established technology and is already a major contributor to world energy suppliers, producing power reliably and competitively for over a century (Boyle, 2004).

The world's technical potential for hydropower is estimated at 14,000 to 15,000 TWh/year (Boyle, 2004), totaling approximately 61.8%-66% of global electricity production in 2012. Lebanon witnessed extremely successful hydropower projects in the 1950's, with an approximate capacity of 282 MW and a corresponding production of 836.5 GWh in 2010 (resulting in a capacity factor of approximately 33.9%). This represents 6.1% of the total nationally produced electric power in Lebanon for 2010 (percentage of hydro energy production out of the total EDL production is 4.76% during the years 2013-2015 due to scarcity in rainfalls).

An overview of the Litani hydroelectric plants

The Litani River Authority (LRA) is a public institution that was established under the law dated August 14, 1954 (and amended on December 30, 1955). LRA main functions are to implement the Litani irrigation, drinking water, and electricity projects and ensure water monitoring in all Lebanese rivers.

The Litani Basin area is 20% of Lebanon's area (approximately 2,175 km^2). Eighty percent of the basin is located in the Bekaa valley and the other 20% in southern Lebanon. The average level of rainfall feeding the basin is 700 millimetres (mm)/year, or about 764 million m^3 distributed as follows: 543 million m^3 feeding the Qaraoun dam and 221 million m^3 feeding the rest of the dams. The quantity of water discharged from the basin is equivalent to 24% of the net rainfall received by the entire Lebanese territories. This quantity represents more than 40% of the total amount of running water in the internal rivers of Lebanon.

The LRA implemented the hydroelectric plan from 1955 to 1968. The construction of the Qaraoun dam at 800 m above sea level, with a storage capacity of 220 million m^3, included a series of tunnels, basins, and facilities, in addition to three power stations, in Markaba, Awali, and Joun, with a total capacity of 190 MW. Such facilities were operated and still have on average an annual production capacity of 700 million kWh. The general production of 2003 exceeded 1 billion kWh.

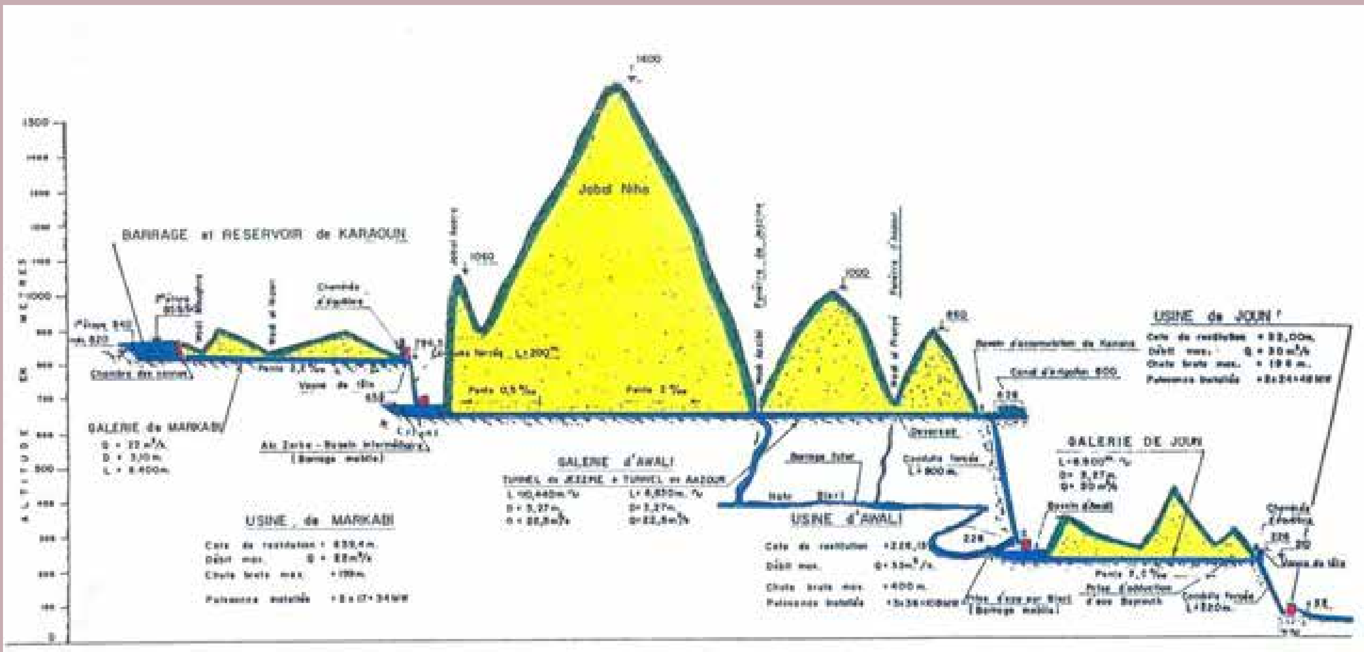


Figure 26. The Litani power plants

The production of hydroelectric power in the Litani stations depends on the amount of annual rainfall in the river basin behind the dam. The water year starts in September and ends in May of each year. During this period, the water is stored in the Qaraoun dam. There are years of abundant precipitations during which the discharged amount of water in the Litani river at the Qaraoun Lake exceeds the capacity of the power stations (approximately 600 million m^3 in 2002–2003), while in dry years this amount would not exceed the 60 million m^3 (like the case of the years 2000–2002).

The main current LRA development projects are the implementation of the first phase of the South irrigation project at an altitude of 800 m above sea level. This project aims at transporting no less than 110 million m^3 of water to irrigate an area of 1500 hectares spread over 12 irrigation sectors located between Kalya in Bekaa and Baraachit in southern Lebanon. It also aims to provide drinking water to 77 villages, mostly located south of the Litani River and stretching to the Lebanese borders (LRA).

As mentioned earlier in this NREAP, hydropower plants produced more than 75% of the Lebanese electricity demand in the 1970's. However, during the Civil War (1975-1990) and even afterwards, the hydropower sector in Lebanon was subject to high levels of negligence (lack of upgrades to infrastructure) and uncertainty (changing snowfall and rainfall patterns due to various climate change scenarios, extensive irrigation projects in the pipeline that diverted water from hydropower, and an ever-increasing need for domestic water usage).

This chapter will present an outlook on the development of hydropower worldwide, followed by the potential of hydropower energy in Lebanon, including the rehabilitation of existing plants, the construction of new hydropower plants, and the micro-hydro and non-river sources plants. Then, the financial appraisal of this technology will be presented, followed by the target for hydropower energy in Lebanon as well as the needed budget to achieve the set target. The chapter will cover the three possible targets for hydropower energy according to the three proposed scenarios (realistic, optimistic, and pessimistic).

9.1 Technology global outlook

An estimated 40 GW of new hydropower capacity was commissioned in 2013, increasing the total global capacity by about 4% to approximately 1,000 GW (REN21, 2014). The global hydropower generation, which varies each year with hydrological and precipitation conditions, was estimated at 3,750 TWh in 2013. Seven countries make up more than 60% of global hydropower capacity, the largest being China, as seen in Figure 27 (REN 21, 2014).

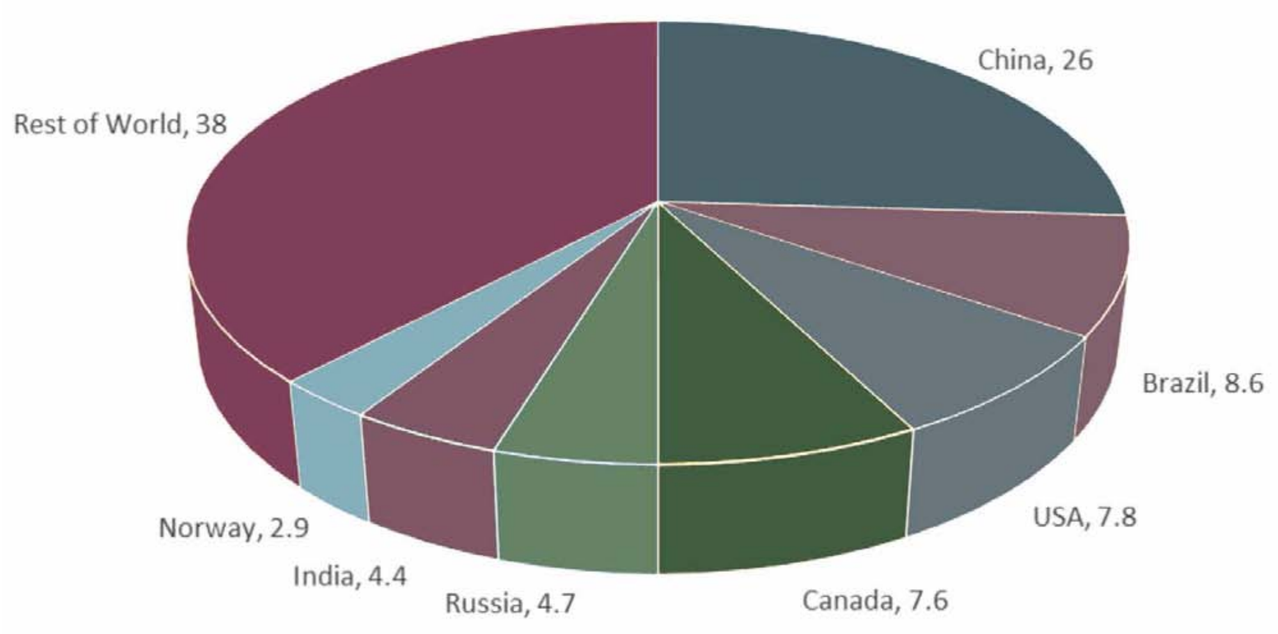


Figure 27. Global distribution of existing hydropower capacity (%) (REN 21, 2014)

9.2 Potential of hydropower technology in Lebanon

Opportunities for the development of hydroelectric power in Lebanon are numerous and range from the rehabilitation and upgrade of existing units, to the installation of new hydro units on the main rivers and streams. Opportunities also include the development of the micro-hydro potential on small streams, and non-river sources such as irrigation storage reservoirs and related channels, water distribution networks, electric plants outfalls, and large wastewater treatment plants (inlets and outfalls). There is also a potential for the development of pumped storage reservoirs when the time-of-use (TOU) tariffs will be introduced in order to allow for a significant differentiation between off-peak and peak tariffs (Osseiran, 2013).

These opportunities are discussed in detail in the following sections as per the following distribution:

- Rehabilitation and upgrade of existing hydropower plants

- New hydropower plants

- Micro-hydro and hydro from non-river sources

Hydrology of Lebanon

Precipitations in Lebanon are typical of a Mediterranean climate. During winter, the cyclonic depressions coming from the Atlantic Ocean cause abundant precipitation, including snow on mountains in the Middle East. During summer, the low pressure over Arabia and Egypt attract air masses that reach the Lebanese shores after having travelled through the Mediterranean too rapidly to be charged with humidity, thereby there is practically no precipitation. Historically, from the analysis of the available precipitation data for Lebanon (more than 100 years), it can be noticed that there was an inflexion in the amount of precipitation during the period 1985–2011 that is characterized by a drop of 8% that seems to be ongoing till the actual period (see Figure 28). Between a return period of 50 dry years and 50 humid years, the annual pluviometry varies from 1 to 2.5 on average on the seaside and between 1 and 5 in the mountains.

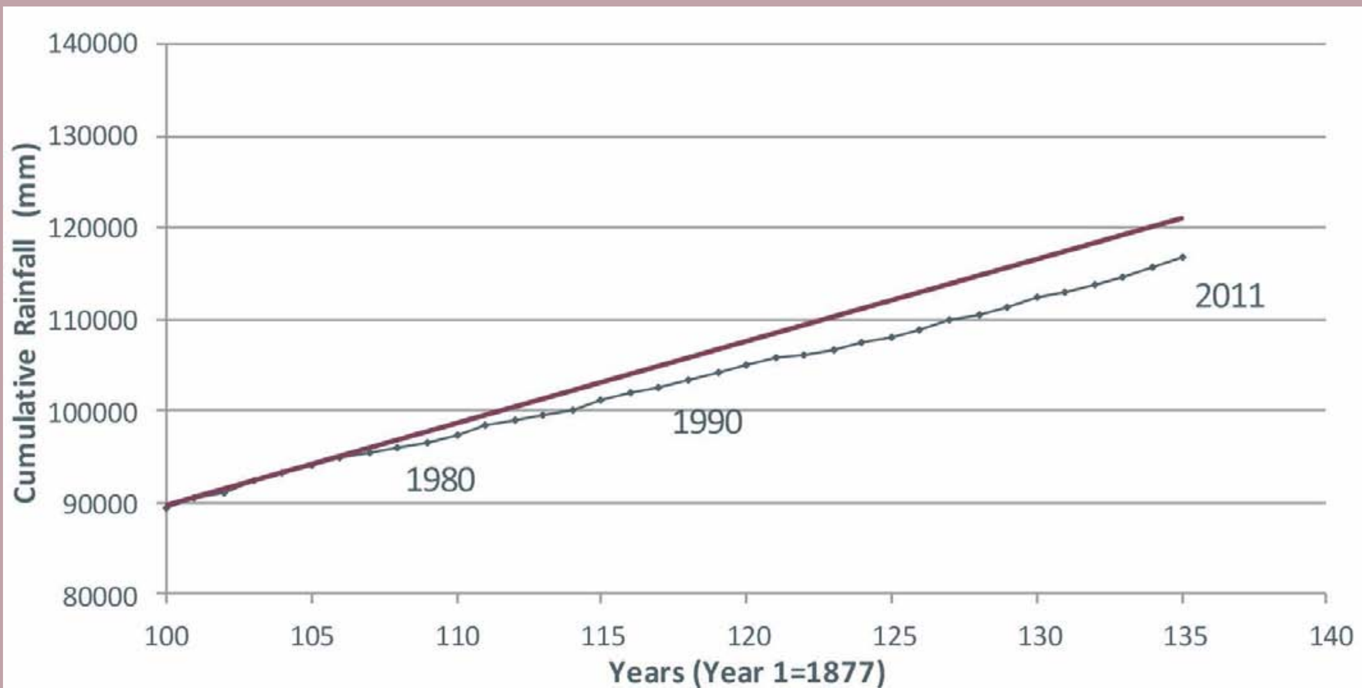


Figure 28. Cumulative rainfall in Beirut for the period 1877 to 2011. Schéma Directeur Hydro-Electrique au Liban, by Sogreah-Artelia, 2012, Beirut, Lebanon: Ministry of Energy and Water. Copyright 2012 by Ministry of Energy and Water.

Throughout a typical year, 80 to 85% of the annual precipitation is observed in the five months between November and March, which is characteristic of the Mediterranean climate (see Figure 29). The distribution of the pluviometry over the year is generally similar in all of the country's areas (seaside, mountains, north or south).

Figure 29. Average monthly rainfall, Beirut International Airport, 1970–2000.

The Lebanese territory is drained by 17 main rivers, 3 of which have their course only partially in Lebanon (El Kebir River, Orontes River, and Hasbani River). Due to the absence of precipitation during the summer period, seasonal variations in the river flows are very important (see Figure 30).

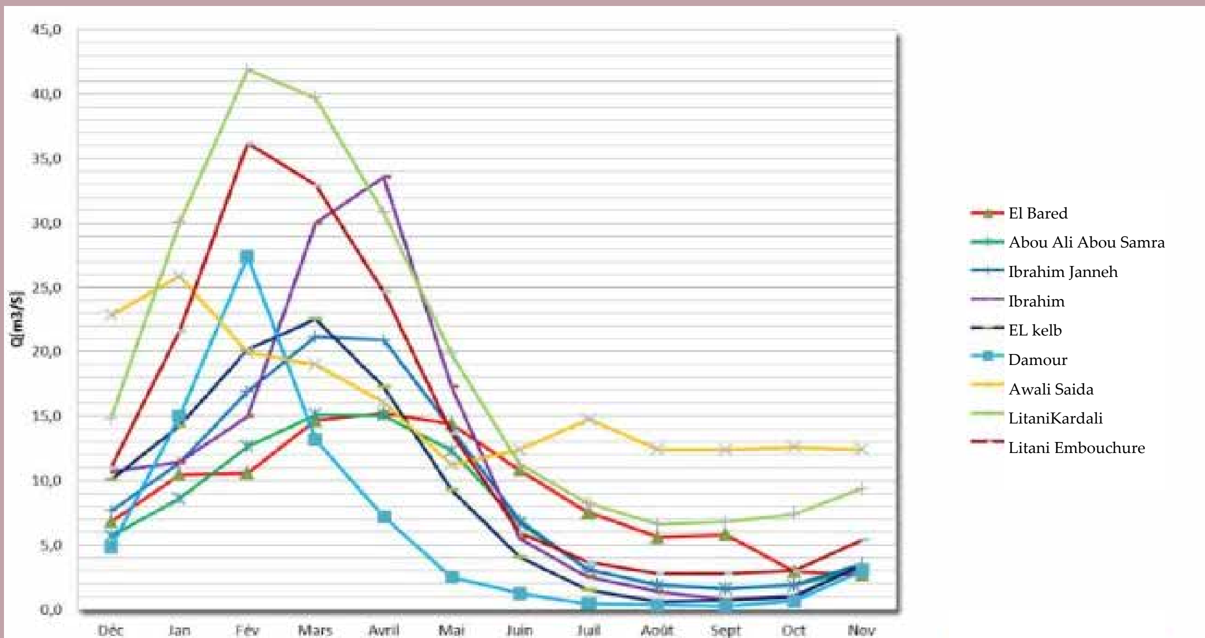


Figure 30. Monthly river flows. Reprinted from Schéma Directeur Hydro-Electrique au Liban, by Sogreah-Artelia, 2012, Beirut, Lebanon: Ministry of Energy and Water. Copyright 2012 by Ministry of Energy and Water.

Due to the particular geography of Lebanon, the average flow of rivers and capacity factor vary significantly depending on the specific site locations (see Table 23).

Table 23. Average flow of rivers in Lebanon

River	Average flow (m^3/s)		Capacity factor
	Minimum	Maximum	
El Bared	3	4.1	0.62–0.64
Abou Ali	3.3	8.1	0.55
Al Jouz	1.8	1.8	0.49–0.50
Ibrahim	3.4	10.3	0.41–0.58
El Kelb	2.5	6.9	0.25–0.56
Beirut	1.1	3.4	0.38
El Damour	1	6.8	0.47–0.52
Awali	3.9	13.9	0.3–0.68
Litani	0.2	17.2	0.58–0.60

9.3 Rehabilitation and upgrade of existing hydropower plants

The current installed capacity of hydropower plants in Lebanon adds up to approximately 282 MW that are distributed on various river streams and different public establishments or concessions. The main hydropower project in the country is the Litani Project (see Table 24.). However, most of the units have exceeded their expected technical lifetime. Therefore, most of the units are currently either producing only a fraction of their nominal capacity or completely out of service. As a result, the actual generation capacity is limited to nearly 190 MW (Osseiran, 2013). Table 24 summarizes the existing hydropower plants in Lebanon, their respective capacity, their year of initial installation, the number of units, and the operating authority.

Table 24. Summary of current hydroelectric units in Lebanon

River stream	Establishment	Plant name	Year of installation	Number of units	Installed capacity (MW)
Litani- Awali Rivers	Litani Water Authority	Markabi, Awali, Joun	1961, 1964, 1967	7	199
Nahr Ibrahim River	Société Phénicienne des Forces de Nahr Ibrahim des Eaux et Electricité	Chouane, Yahchouch, Fitri	1961, 1955, 1951	8	32
Kadisha Valley	La Kadisha - Société Anonyme d'Electricité du Liban Nord	Bechare, Mar Licha, Blaouza II, Abu-Ali	1924, 1957, 1961, 1932	11	21
Nahr Al Bared	Al Bared Concession	Al Bared 1, Al Bared 2	1936	5	17
Safa Spring	BDL	Richmaya-Safa	1931	3	13
Total installed capacity in MW					**282**
Source: Osseiran (2013)					

In 2010, the share of hydropower in Lebanon, in terms of yearly GWh production, was approximately 6.1% of total electricity production. At least 15% of additional generation is possible from rehabilitating and upgrading hydropower plants, including changing old turbines to increase the working capacity from 190 MW to 282 MW, and then adding new turbines in some selected sites. This would lead to a total increase of approximately 129 GWh per year, thus increasing the average capacity factor of all plants to 42.4% (as compared to 33.9% in 2010). As shown in Table 25, the rehabilitation of all hydro power plants will allow to increase their production from 836.5 GWh in 2010 to approximately 1,047 GWh (leading to an increase of 25.1% in their production capabilities).

Table 25. Summary of energy production after rehabilitation of all hydro power plants

Plant	Rehabilitated plant yearly production (GWh)
Litani	775
Nahr Ibrahim	105
Kadisha	82
Bared	62
Richmaya	23
Total hydro	1,047

9.4 Construction of new hydropower plants

In 2012, MEW prepared, in collaboration with the consultant Sogreah-Artelia, the master plan study for Lebanon's hydroelectric potential along its main river streams. The study identified 32 new sites that have a potential hydroelectric capacity of 263 MW (1,271 GWh/y) in run-of-river schemes and 368 MW (1,363 GWh/y) in peak schemes (i.e., with dam infrastructure). The study mapped these new potential sites against their potential environmental sustainability and their financial viability. Figure 31 shows the new sites multi-criteria feasibility (Sogreah-Artelia, 2012).

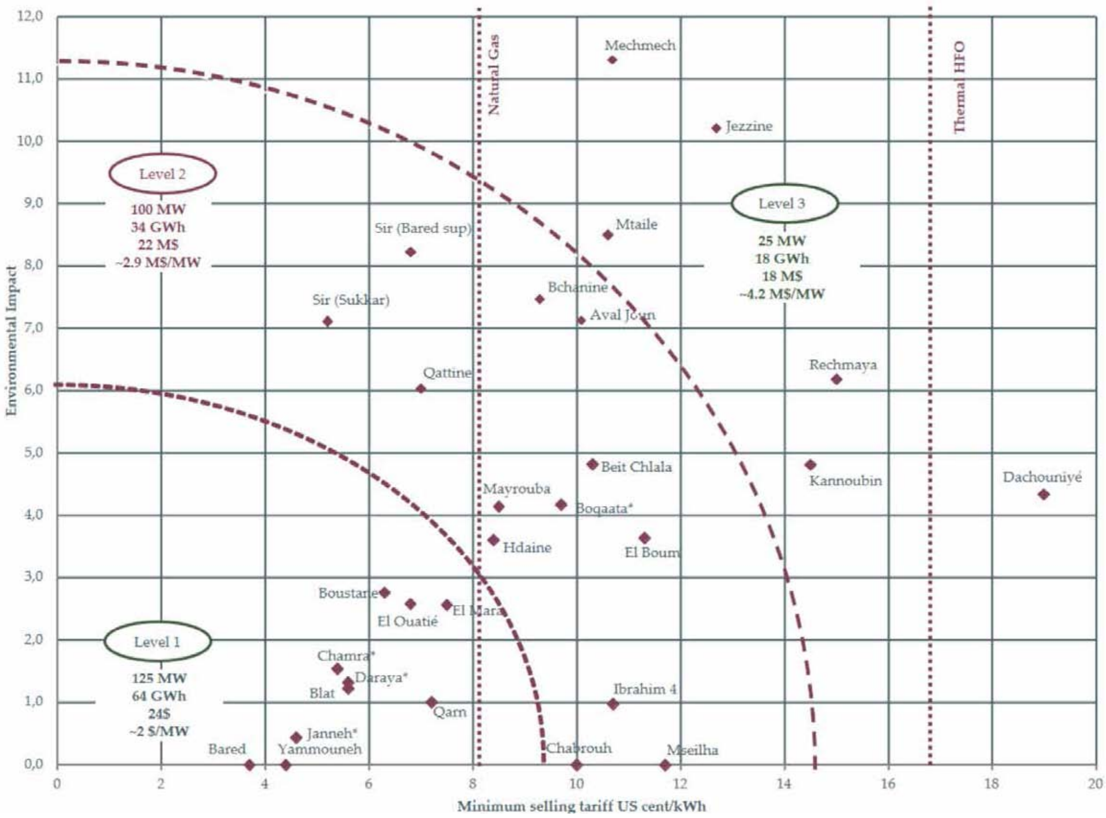


Figure 31. New hydropower plant matrix (Sogreah-Artelia, 2012). Schéma Directeur Hydro-Electrique au Liba, by Sogreah-Artelia, 2012, Beirut, Lebanon: Ministry of Energy and Water. Copyright 2012 by Ministry of Energy

According to Figure 31, the Sogreah-Artelia study identifies three levels of new hydropower plants. Approximately 125 MW of new hydropower supply is viable on exceptionally favorable locations with low environmental impact and relatively low levelized costs. An additional 100 MW are also available and viable, although relatively less favorable than the first trench, while a final 25 MW exists with less favorable conditions. In all three cases, special attention has to be attributed to the environmental impacts of this category of installations.

All three trenches (with the exception of one hydropower plant) have levelized costs lower than the current average EDL generation costs (which is at least 17 US cents/kWh).

9.5 Micro-hydro and hydro from non-river sources

Micro-hydro and mini-hydro power systems are likely to become relatively more important to Lebanon if the country is to preserve and increase its flowing hydro resources. A UNDP-CEDRO (2013) publication entitled *Hydropower from Non-river Sources* focused on a sample of potential sites where hydropower can be utilized, namely hydropower from the cooling systems of near-shore power plants, irrigation channels, water networks, and sewage networks. This UNDP-CEDRO study identified 13 pilot sites with a capacity of approximately 5 MW. However, a bigger potential remains to be identified and tapped into. Table 26 shows a summary of the pilot sites for non-river streams micro hydropower.

Table 26. Summary of micro-hydro pilot sites

Micro-hydro Stream	Public Institution	Number of Studied sites	Potential capacity (MW)
Irrigation channels and conveyors	All water establishments, Ministry of Agriculture (MOA)	4	1.270
Wastewater treatment plant intakes and outfalls	All eater establishments, CDR	1	0.123
Electric power plant outfall channels	EDL electric power plants	5	3.421
Municipal water distribution networks	All water establishments, municipalities	4	0.144
Total capacity			**4.958**

9.6 Financial appraisal of the technology

The economics of hydropower are very site-specific, depending on many characteristics of the sites involved, the civil works necessary, the annual flow of water, and other parameters. A study by IRENA (2012c) shows this wide range of possible economic values, some of which are listed in Table 27.

Table 27. Levelized cost of hydropower

Discount rate (10%)	Installed costs (USD/kW)	O&M costs (%/y of installed costs)	Capacity factor	Levelized cost of electricity (2010 USD/kWh)
Large hydro	1,050-7,650	2-2.5	25 to 90	0.02–0.19
Small hydro	1,300-8,000	1-4	20 to 95	0.02–0.27
Refurbishment	500-1,000	1-6		0.01–0.05

The study on river-sourced hydropower plants in Lebanon, conducted by the Sogreah-Artelia (2012) showed that there are economically viable hydropower plants to be harvested in Lebanon (labeled or trenched as discussed in Table 28 for Levels 1 to 3). Table 28 also shows the number and associated costs for these Lebanese power plants.

Table 28. Economics and tariffs for new hydropower plants in Lebanon

	Level 1	Level 2	Level 3	Total
	Minimum selling tariff < 8.1 US cents/kWh	Minimum selling tariff > 8.1 US cents/kWh and < 12 US cents/kWh	Minimum selling tariff >12 US cents/kWh	
Number of sites	13	12	4	
Power (MW)	139	94	17	29
CAPEX (USD million)	273	287	78	250
Annual production (GWh)	713	413	68	638
Average cost (USD) of installed kW	2,070	3,220	4,310	1,194

Source: Sogreah-Artelia (2012)
Notes: CAPEX (capital expenditure)

As shown in Table 28, new and financially viable hydropower plants in Lebanon can be built to increase the available power at competitive pricing. The most effective hydropower plants are those mentioned in Level 1 in Table 28, followed by Level 2 and Level 3 plants, most of which are financially competitive when compared to the current average generation costs of EDL.

9.7 Target for hydropower

The development of hydropower in Lebanon is extremely complicated due to many factors; the most important among them are the legal and administrative barriers. In addition, the development of large hydropower plants depends solely on the construction of dams, and the subject of dams is of controversial nature. The target for hydropower in Lebanon will be taking all these facts into consideration in the three scenarios for development.

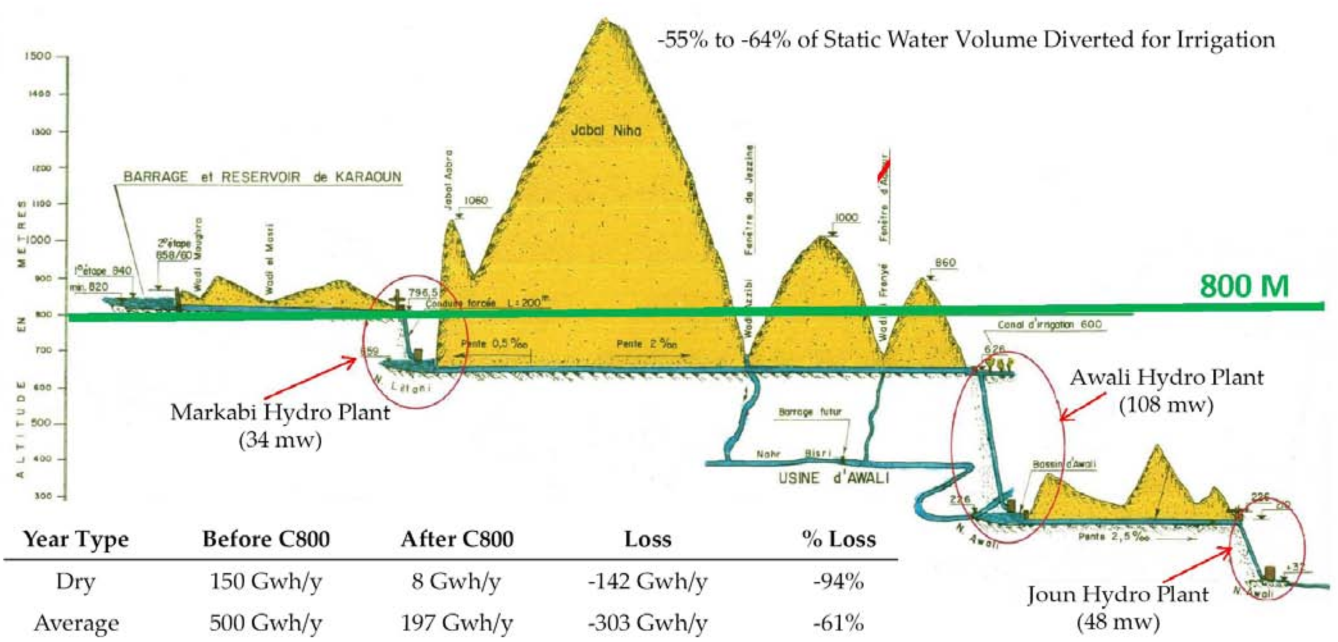
According to the above, the pessimistic scenario considers that no action will be taken in any respect. This could be probable due to the following barriers and challenges:

- Most of the existing hydropower concessions of Bared, Kadisha, Nahr Ibrahim and Litani are close to expiry and are selling the electrical energy produced to EDL at low tariffs.
- The current legal framework gives the exclusive rights on the water resources to the General Directorate of Hydraulic and Electric Resources at MEW while electricity resources production is given to EDL.
- There are other stakeholders involved in the hydropower sector, such as the MOA for the storage basins and irrigation channels and CDR for funded projects.
- The promulgation of the water code is necessary for the creation of a legal framework for the PPPs in the water sector.
- The launching of the independent power producer (IPP) mechanism, as per Law 462 and 181, is necessary in case the development of new projects in the hydropower sector has to be done by the private sector.
- In many cases, the geology of Lebanon is such that the development of hydropower facilities is not feasible unless the costs of a dam's construction are not considered as an integral part of the hydropower investment.
- Introducing the hydro component to a dam, irrigation channel, or other facility, becomes difficult and sometimes not feasible at all if not done at the design stage.
- Water is becoming increasingly scarce over the years, whereas the needs for potable water and irrigation are increasing.

The Conveyor 800 project of the Litani Water Authority

Also known as the Canal 800, the Conveyer 800 project is slated to draw 110 million cubic metres (MCM)/y (50% of the total static water volume) from the Qaraoun reservoir in the Southern Bekaa, to the south of the country. The lion's share of this water, 90 MCM/y is intended for the irrigation of approximately 14,700 hectares of farmland between the 800 m and 400 m levels of the Qaraoun Lake. It will be transported by the 52-km canal to 20 main reservoirs to be distributed among 12 irrigation perimeters across the Cazas of Marjeyoun, Nabatiyeh and South Quasmieh. The remaining 20 MCM/y is destined for the household taps of some 100 southern villages. The Canal 800 is designed to supply irrigation water at the rate of 6,600–7,000 m^3/hectare (ha)/season and will accommodate a 3 MW hydro unit.

Litani Water Authority: Conveyors 800M & 900M



Year Type	Before C800	After C800	Loss	% Loss
Dry	150 Gwh/y	8 Gwh/y	-142 Gwh/y	-94%
Average	500 Gwh/y	197 Gwh/y	-303 Gwh/y	-61%
Rainy	1,000 Gwh/y	705 Gwh/y	-295 Gwh/y	-30%

Figure 32. Impact of conveyors 800 M and 900 M on hydropower production. Schéma Directeur Hydro-Electrique au Liba, by Sogreah-Artelia, 2012, Beirut, Lebanon: Ministry of Energy and Water. Copyright 2012 by Ministry of Energy and Water.

On the other hand, the realistic scenario considers that the rehabilitation of 50% of all existing power plants is completed in addition to the construction of 50% of Level 1 plants and 25% of Level 2 plants.

Finally, for the optimistic scenario, it is considered that the rehabilitation of all existing power plants is completed in addition to the construction of all Level 1 plants and 50% of the Level 2 plants. Table 29 summarizes the three different scenarios in 2020.

Table 29. Target scenarios of the hydropower energy for the year 2020

	Pessimistic	"Realistic"	Optimistic
Rehabilitation and upgrade of existing hydropower plants	Existing hydropower plants with no additions	Existing plants with rehabilitation of 50% of them	All existing plants rehabilitated and upgraded
Effective capacity (MW)	190	236	282
Added generation (GWh)	0	105	210
Added generation (ktoe)	0.0	22.7	45.4
New hydropower plants	No action at all	50% of Level 1 plants (5 sites) and 25% of Level 2 plants (3 sites)	All Level 1 plants (13 sites) and 50% of Level 2 plants (6 sites)
Approximate capacity (MW)	0	93	186
Added generation (GWh)	0.0	459.8	919.5
Added generation (ktoe)	0.0	99.3	198.6
Micro-hydro and hydro from non-river sources	No action at all	Half of the pilot projects implemented	All pilot projects implemented
Capacity (MW)	0	2.5	5
Added generation (GWh)	0.0	7.1	14.3
Added generation (ktoe)	0.0	1.5	3.1
Total power (MW)	**190**	**331.5**	**473**
Total added. generation (GWh)	**0.00**	**571.9**	**1,143.8**
Total added generation (ktoe)	**0.00**	**123.5**	**247.1**

Based on the realistic scenario shown in Table 29, Table 30 shows the development of the hydropower sector between 2010 and 2030.

Table 30. Target of hydropower energy for the years 2010–2030

		Rehabilitation and upgrade of existing hydropower plants	New hydropower plants	Micro-hydro and hydro from non-river sources	Total before C800M*	Total after C800M*
2010	MW	-	-	-	190.0	190.0
	GWh	-	-	-	836.5	836.5
	ktoe	-	-	-	180.7	180.7
2015	MW	-	-	-	190.0	190.0
	GWh				836.5	836.5
	ktoe	-	-	-	180.7	180.7
2020	MW	236.0	93.0	2.5	331.5	331.5
	GWh	941.5	459.8	7.1	1,408.4	961.9
	ktoe	203.4	99.3	1.5	304.2	207.8
2025	MW	259.0	139.5	3.8	402.3	402.3
	GWh	994.0	689.6	10.7	1,694.3	1,391.3
	ktoe	214.7	149.0	2.3	366.0	300.5
2030	MW	282.0	186.0	5.0	473.0	473.0
	GWh	1,046.5	919.5	14.3	1,980.3	1,677.3
	ktoe	226.0	198.6	3.1	427.7	362.3

* Conveyor 800 M (C800M) will induce an average yearly reduction in the electricity output of approximately 446.5 GWh which is equivalent to 96.4 ktoe in 2020.

Italian grant to develop the micro-hydro sector

As part of the cooperation between MEW and the Italian Embassy in Beirut, a mini hydro power plant will be installed for the public hospital in Tannourine. The project is entitled "Integrated Management Plan of the Water resources of the Nahr El Jouz Focusing on the utilization of mini hydro power". The project is a grant from the Italian Cooperation and aims at supporting the development of the capacity of the Lebanese Government and its activities in the field of climate change mitigation (RE), with a special focus on mini-hydro power.

This pilot project is part of a EUR 1.9 million grant offered by the Italian Government to Lebanon. The general objective of this initiative is to contribute to the strengthening of the capacity of MEW in the development of the RE sector and in the mitigation of climate change.

The mini hydro power plant that will be constructed according to the European Standards will provide the electricity for the local public hospital in Tannourine. The hydro power plant is expected to have the potential to produce more than 3 GWh/y.

The utilization of the water for electricity generation shall be such to guarantee a remaining minimum vital flow of the River Nahr El Jouz (calculated according to European Standards I) in order to maintain proper biological conditions sufficient for the life of fish, macro invertebrates, and the flora of the riverbank. The plant has to function with a high efficiency for at least 11 months every year. The month with the lowest water flow shall be utilized in order to carry out the programmed maintenance.

The project will also include the installation of a didactical area related to hydro power and RE. In the Municipality of Tannourine a visitors' area will be installed that offers visitors an insight into the process of generating electrical energy using hydro power. The visitors' area shall be particularly suitable for school classes and tourists. Figure 33 shows how the project shall improve the management capacities of MEW.

Integrated Management Plan of the Water Resources of the Nahr El Jouz focusing on the utilization of Mini Hydro Power	
Financing Type	1,900,000 Euros Grant from the Italian Cooperation
Procurement	To be done by MoEW according to the Italian Law on Procurement and Development Aid Guidelines stated under Annex 2
MOU Duration	18 Months from Entry into Effect/Ratification - Duration subject to extension by mutual agreement
Objectives	Implementation of a Mini Hydro plant at Tannourine Hospital, Awareness Campaign and Capacity Building of the MoEW
Hydro Plant Technical Characteristics	3,000,000 kWh/year Plant Operation with High Efficiency 11 Months/Year 4 Jets Vertical Axis Pelton/ Direct Coupled Generator Generator of Asynchronous Type Forced Conduit 600 mm Diameter/ 2,800 m Length Water Intake at 1,950 m / Hydro Plant at 790m
Beneficiaries	Governmental Hospital of Tannourine / MoEW
Deliverables	Hydro Power Plant at Tannourine/ Awareness Campaign/ Capacity Building

Figure 33. Integrated management plan for the water resources of the Nahr El Jouz focusing on the utilization of mini hydro power

9.8 Needed budget to achieve the 2020 target for hydropower

Considering the cost of installation of new hydropower plants that were described in the master plan study for Lebanon's hydroelectric potential (Sogreah-Artelia, 2012) and cited in Table 28, the needed investment for the construction of the hydropower plants considered in the realistic scenario is approximately USD 219.5 million. The cost of the rehabilitation of the existing power plants can be estimated at approximately USD 33 million. Finally, the cost of micro-hydro and hydro from non-river sources is estimated at approximately USD 11.6 million.

This would lead to a total investment of approximately USD 264.1 million for the additional generation of 571.9 GWh of hydroelectricity. This means that, considering a 20-year lifetime, the LCOE of new hydro power plants is approximately 2.4 US cents/kWh (1.6 US cents/kWh in the case of the rehabilitated power plants and 8.2 US cents/kWh in the case of micro hydro power plants).

The total savings are approximately USD 102.31 million/y for all three types of power plants. Moreover, all these hydro power plants will allow for approximately 170 extra hours of electricity in 2020. The basic budget parameters are summarized in Table 31.

	Needed investment (USD Million)	Levelized cost of energy (US/KWh)	Yearly savings	Payback (Years)	Extra hours
New hydro	219.50	0.0239	81.90	2.68	136.14
Rehabilitated	33.00	0.0157	19.56	1.69	31.09
Micro hydro	11.60	0.0817	0.85	13.58	2.10

Rehabilitation and upgrade of Kadisha hydro plants

MEW has finalized the study needed to rehabilitate the existing Kadisha hydro plants. The rehabilitation includes all civil works, water intakes, penstocks, channels, storage basins, tanks, and others. The study aims at achieving the following objectives:

- Bechare hydro plant-new 1.8 MW unit and rehabilitation of 2 x 0.8 MW units (1924) (+ 0.5 GWh/y)

- Abou Ali hydro plant-new 3 MW unit and rehabilitation of a 2.95 MW unit (1932) (+ 3.5 GWh/y)

- Mar Licha hydro plant-rehabilitation of 2 x 1.1 MW units (1957)

- Blaouza II hydro plant-rehabilitation of 2 x 2.8 MW units (1961).

The overall benefits of the Kadisha hydro plants' rehabilitation will be an increased reliability of the plants and a 7% increase of energy production (equivalent to 4 GWh/y).

Table 32. Basic parameters for both Bchanine and Blaouza rehabilitation projects

	Bchanine	Blaouza
Installed capacity	4.2 to 5.9 MW	2.1 to 2.75 MW
Energy produced	28 GWR/year	10 GWR/year
Project CAPEX	USD 16.5 million	USD 7 million
Levelized cost of energy (12% IRR, 25 years lifetime, 10% interest)	9.3 US cents/kWh	14.5 US cents/kWh

9.9 The way forward

The Sogreah-Artelia (2012) study has identified all the potential for the development of hydro power in Lebanon. Given the complicated administrative and legal barriers, LCEC estimates that the modest realistic scenario allows for some maneuvering in reaching the set target.

In fact, once the Janneh dam is completed, it is estimated to have approximately 100 MW of hydroelectricity by 2020. On the other hand, MEW and LCEC are working with the WB to ensure funding for the rehabilitation of existing hydro power plants. Moreover, many donors including USAID are working with public administrations to upgrade the existing hydro power plants.

Janneh dam hydro plant

The storage capacity of the Janneh dam is 37 MCM, with water height ranging between 350 to 429 meters depending on the water level in the dam. A hydro power plant is expected to be installed using three Pelton multi-jet turbines to adapt easily to variations in water flow, with a base power of 32 MW and a peak power 96 MW. The corresponding CAPEX would be USD 47.8 million and USD 111.5 million respectively (equivalent to a generation of 162 GWh/year and 207 GWh/year respectively).

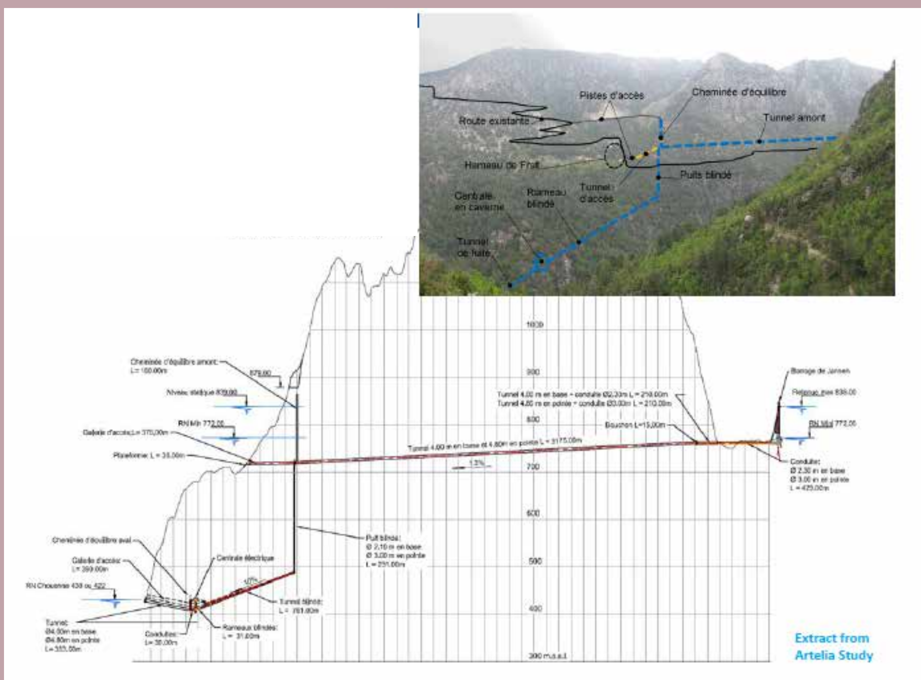


Figure 34. New dams Janneh hydroelectric plant. Reprinted from *Schéma Directeur Hydro-Electrique au Liban,* by Sogreah-Artelia, 2012, Beirut, Lebanon: Ministry of Energy and Water. Copyright 2012 by Ministry of Energy and Water.

Table 33. Comparison of run of river and peak load schemes in the case of Janneh plant

	Janneh run-of-river scheme	Janneh peak load scheme
Installed capacity	54 MW	100 MW
Energy produced	179 GWh/y	199 GWh/y
Project execution time in months	36	40
Project CAPEX	USD 59 million	USD 81 million
Cost of installed Rw	USD 1,100 USD/kW	USD 800 USD/Kw
Selling tariff (16% IRR, 25 years lifetime, 10% Interest)	7 US cents/kWh	8.8 US cents/kWh–peak
LCOE		4.4 US cents/kWh-base

World Bank initiates study on the hydro sector in Lebanon

The WB recently initiated a nationwide study regarding the "assessment of the legal and administrative constraints to the development of the national hydropower market for Lebanon". The study aims to complement national momentum in that regard, and falls within the development of a national sustainable energy strategy and action plan.

The study began early in 2016. The consultant is analyzing the current legal, regulatory, and investment status for the development or rehabilitation of hydropower stations, identifying the barriers for new investments in the hydropower sector, and examining the way hydro energy is fitting into the current conditions of the overall energy market. The study will elaborate a practical action plan for the removal of constraints, including legal agreements between central government and different stakeholders, in such a way as to foster the ability of hydropower to assist in the objective of the Lebanese Government to deliver 12% of its electricity mix through RE sources by 2020.

The ultimate objective of this analysis is how GOL is to attract investments to harness the hydropower potential, both for existing sites to be rehabilitated and for the construction of new sites.

Mr. Philippe Lazzarini, UNDP Resident Representative, UN Resident Coordinator, UNDP Lebanon

The United Nations Development Programme (UNDP) has been working on introducing sustainable energy into the Lebanese market since 2002. With the support of donors, the most recent of which is the European Union and the Global Environment Facility, UNDP has implemented numerous projects in partnership with the Ministry of Energy and Water. This includes the Lebanese Center for Energy Conservation Project that worked on promoting energy efficiency in industries (2002-2009) and solar hot water applications (2010-2013); the CEDRO I-IV and DREG projects (2007-today) that are promoting solar photovoltaics and assessing renewable energy resources. These projects are at the heart of this renewable energy strategy.

Chapter 10: Geothermal energy

The main three pillars of RE development in Lebanon are undoubtedly wind energy, solar energy, and hydro energy. However, other renewable technologies are available and already in use to some extent in the country. Chapters 10–12 deal with these technologies, notably geothermal applications, biomass, and waste-to-energy respectively. It is worth noting that the main reference upon which this chapter is built is the work that was completed by UNDP Lebanon under the CEDRO project.

According to Renewable Energy World, geothermal energy is simply defined as the heat from the Earth, both clean and sustainable. Resources of geothermal energy range from the shallow ground to hot water and hot rock found a few kilometers beneath the Earth's surface, and down even deeper to the extremely high temperatures of molten rock called magma.

Practically, the chapter will start with the geothermal technology global outlook followed by the geothermal potential in Lebanon. Furthermore, the target for geothermal energy will be set and followed by the needed budget to achieve it. The chapter will cover the three possible targets for geothermal according to the three proposed scenarios (realistic, optimistic, and pessimistic).

10.1 Technology global outlook

Geothermal resources provide energy in the form of direct heat, cooling, and electricity, totaling an estimated 167 TWh in 2013, where 76 TWh is expended on electricity (REN 21, 2014). The countries with the largest amounts of installed geothermal electric generating capacity are: (1) the United States (3.4 GW), (2) the Philippines (1.9 GW), (3) Indonesia (1.3 GW), (4) Mexico (1.0 GW), (5) Italy (0.9 GW), (6) New Zealand (0.9 GW), (7) Iceland (0.7 GW), and (8) Japan (0.5 GW) (REN 21, 2014).

Accurate global maps are difficult to find published, as opposed to country specific geothermal mapping. One map published by the Geothermal Education Office, shows roughly that Lebanon falls within the expected areas where geothermal resources are relatively appealing. However, further assessment is required to this end, as discussed in the subsequent sections.

10.2 Potential of geothermal energy in Lebanon

The National Geothermal Resource Assessment, published jointly by the MEW and the UNDP-CEDRO project in 2014, provides preliminary hints to where geothermal resources may be found beneath Lebanon's surface. The geothermal resources have been assessed by collecting all the relevant geological, hydrogeological, structural, and thermal information available on Lebanon. Small-scale temperature measurements in abandoned groundwater wells and laboratory measurements of thermal conductivities on rock samples have also been carried out.

Based on the collected information, a 3D geological and geothermal model of Lebanon has been developed and used to calculate the temperature in its deep underground and Lebanon's geothermal potential. The results are presented in maps that cover the whole territory and that are part of the *Geothermal Atlas of Lebanon*. There are four main factors which could be used to characterize the geothermal potential of a specific target in a broader sense: depth, temperature, stored heat, and recoverable heat.

The depth of the target is an important factor in terms of accessibility and in terms of economics (drilling costs and other factors). Temperature is an important factor since minimum temperatures are required as well for heating purposes as for the production of electricity. In the case of electricity production, a minimum temperature of 100 °C is required. In a more strict sense, geothermal potential is often used as a measure of either the total thermal energy (stored heat) of the target reservoir or as the recoverable heat (defined as the fraction of the stored heat), which could be utilized through current technical means.

The geothermal potential has been estimated for the following target reservoirs:

- Jurassic aquifer
- Cretaceous aquifer
- Depth horizon at 4000 meters below sea level
- Depth horizon at 5000 meters below sea level
- Depth horizon at 6000 meters below sea level
- Depth horizon at 7000 meters below sea level

Cartographic representation of the temperature and recoverable heat category is made for the six target horizons shown in Figure 35, Figure 36, Figure 37, Figure 38, Figure 39, and Figure 40 based on the Badoux, Ollinger, Baujard, and Megel publication (2014).

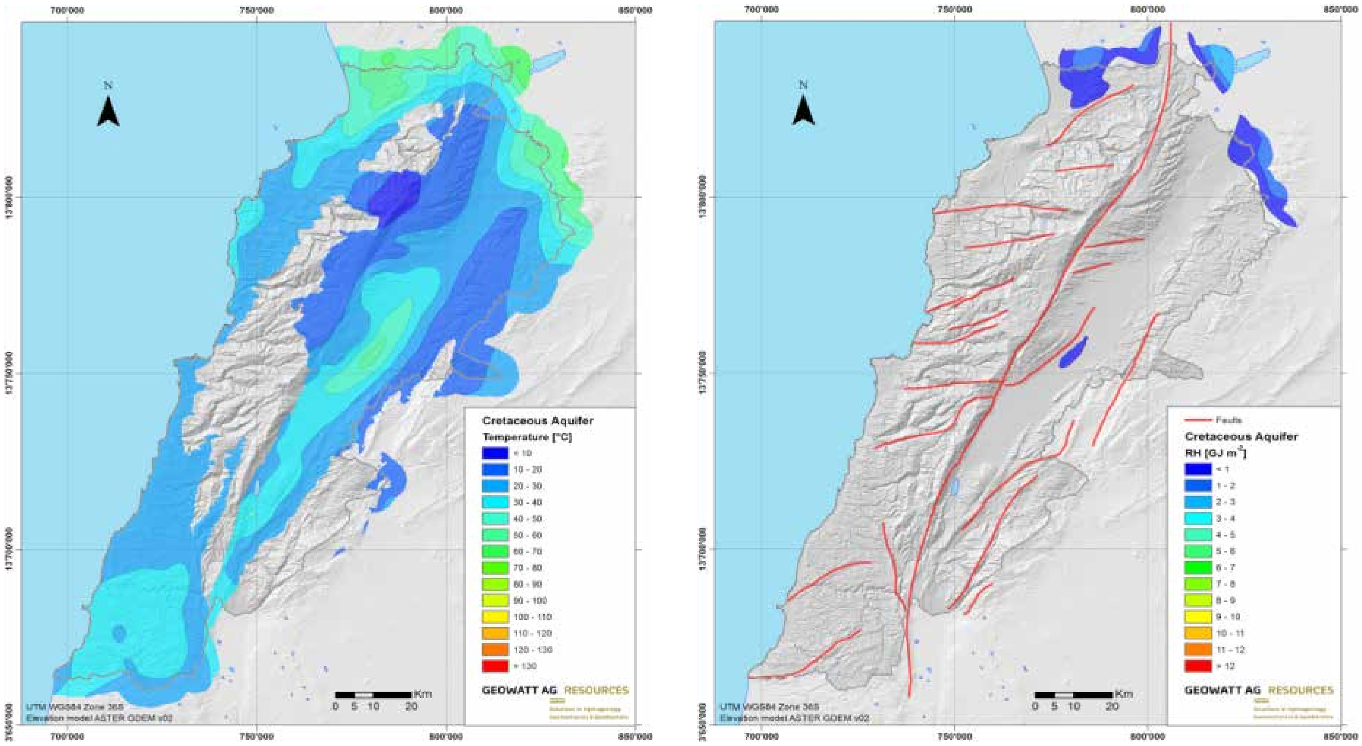


Figure 35. Temperature and recoverable heat for the Jurassic aquifer. Reprinted from *The National Geothermal Resource Assessment of Lebanon* (pp. 113, 121), by V. Badoux, D. Ollinger, C. Baujard, and T. Mégel, 2014, Beirut, Lebanon: United Nations Development Programme-Country Energy Efficiency and Renewable Energy Demonstration Project for the Recovery of Lebanon Copyright 2014 by United Nations Development Programme-Country Energy Efficiency and Renewable Energy Demonstration Project for the Recovery of Lebanon.

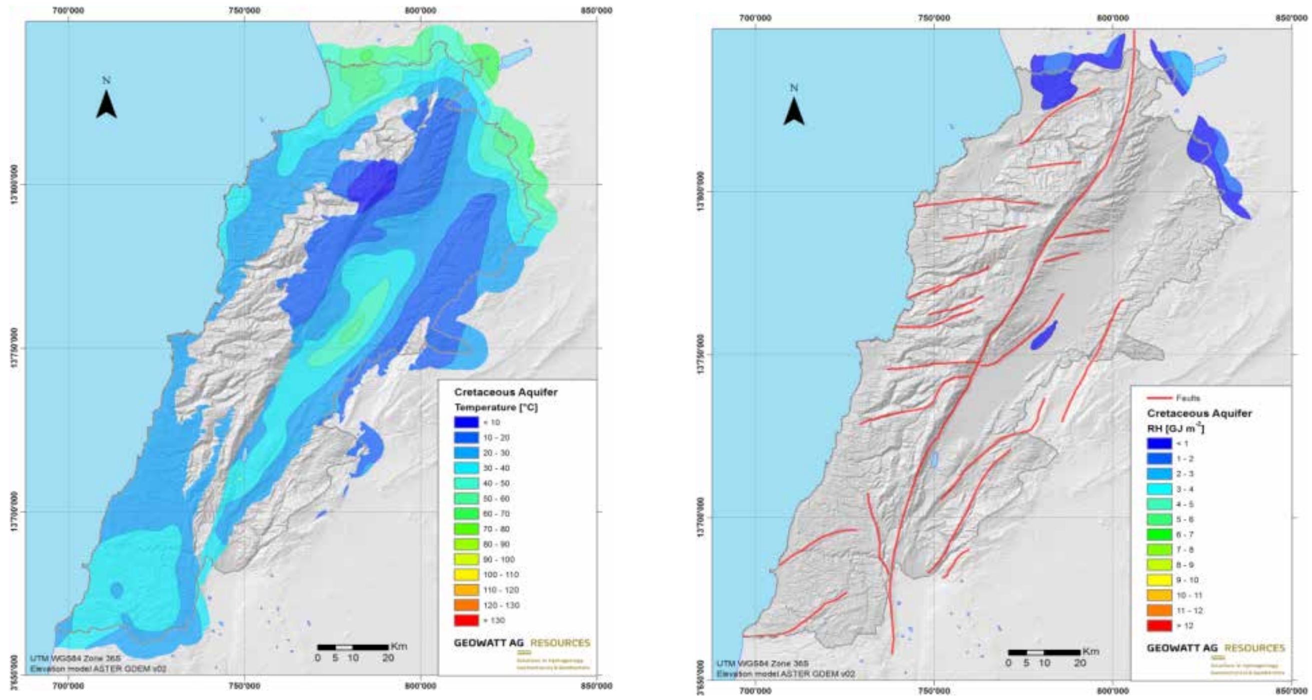


Figure 36. Temperature and recoverable heat for the Cretaceous aquifer. Reprinted from *The National Geothermal Resource Assessment of Lebanon* (pp. 112, 120), by V. Badoux, D. Ollinger, C. Baujard, and T. Mégel, 2014, Beirut, Lebanon: United Nations Development Programme-Country Energy Efficiency and Renewable Energy Demonstration Project for the Recovery of Lebanon Copyright 2014 by United Nations Development Programme-Country Energy Efficiency and Renewable Energy Demonstration Project for the Recovery of Lebanon.

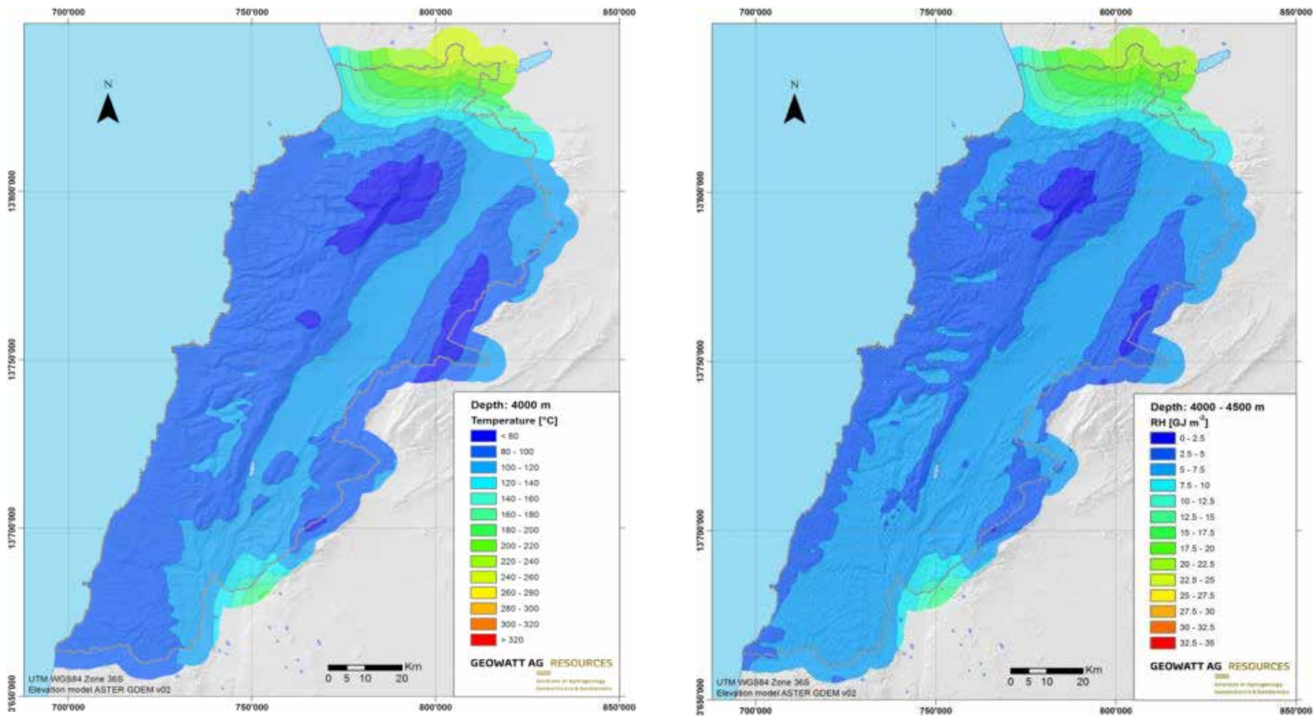


Figure 37. Temperature and recoverable heat for the depth interval 4000-4500 m. Reprinted from *The National Geothermal Resource Assessment of Lebanon* (pp., 125), by V. Badoux, D. Ollinger, C. Baujard, and T. Mégel, 2014, Beirut, Lebanon: United Nations Development Programme-Country Energy Efficiency and Renewable Energy Demonstration Project for the Recovery of Lebanon Copyright 2014 by United Nations Development Programme-Country Energy Efficiency and Renewable Energy Demonstration Project for the Recovery of Lebanon.

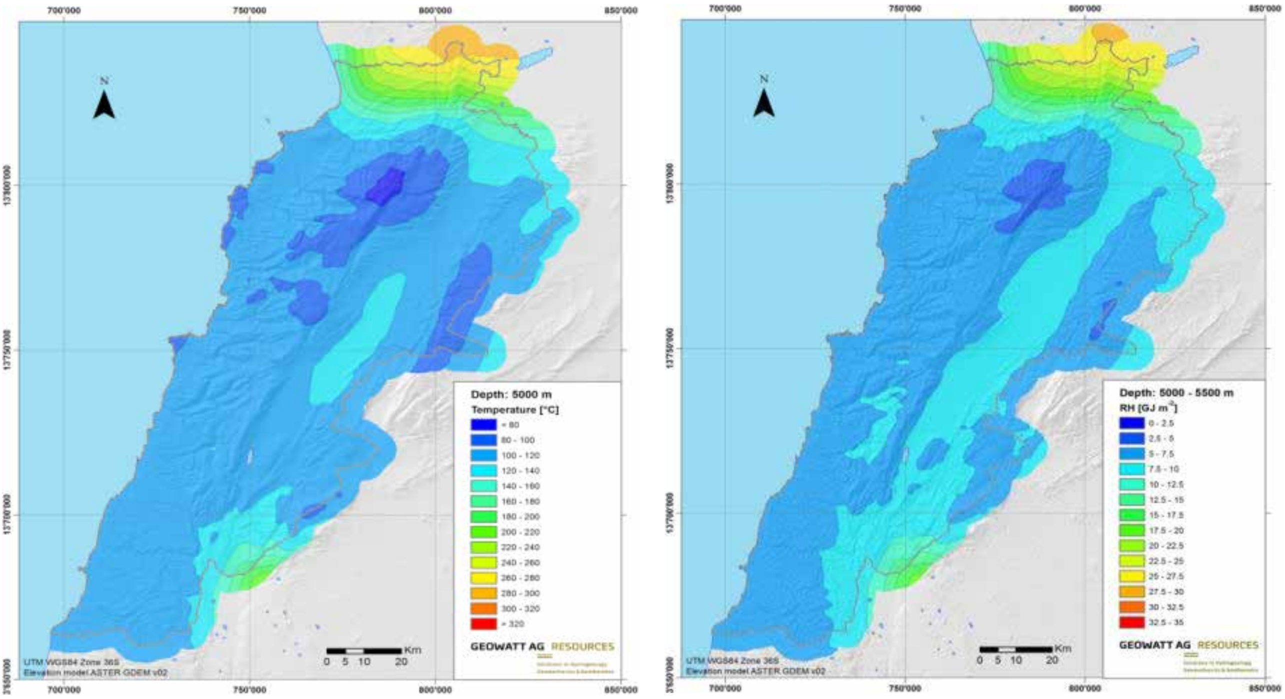


Figure 38. Temperature and recoverable heat for the depth interval 5000-5500 m. Reprinted from *The National Geothermal Resource Assessment of Lebanon* (pp., 126), by V. Badoux, D. Ollinger, C. Baujard, and T. Mégel, 2014, Beirut, Lebanon: United Nations Development Programme-Country Energy Efficiency and Renewable Energy Demonstration Project for the Recovery of Lebanon Copyright 2014 by United Nations Development Programme-Country Energy Efficiency and Renewable Energy Demonstration Project for the Recovery of Lebanon.

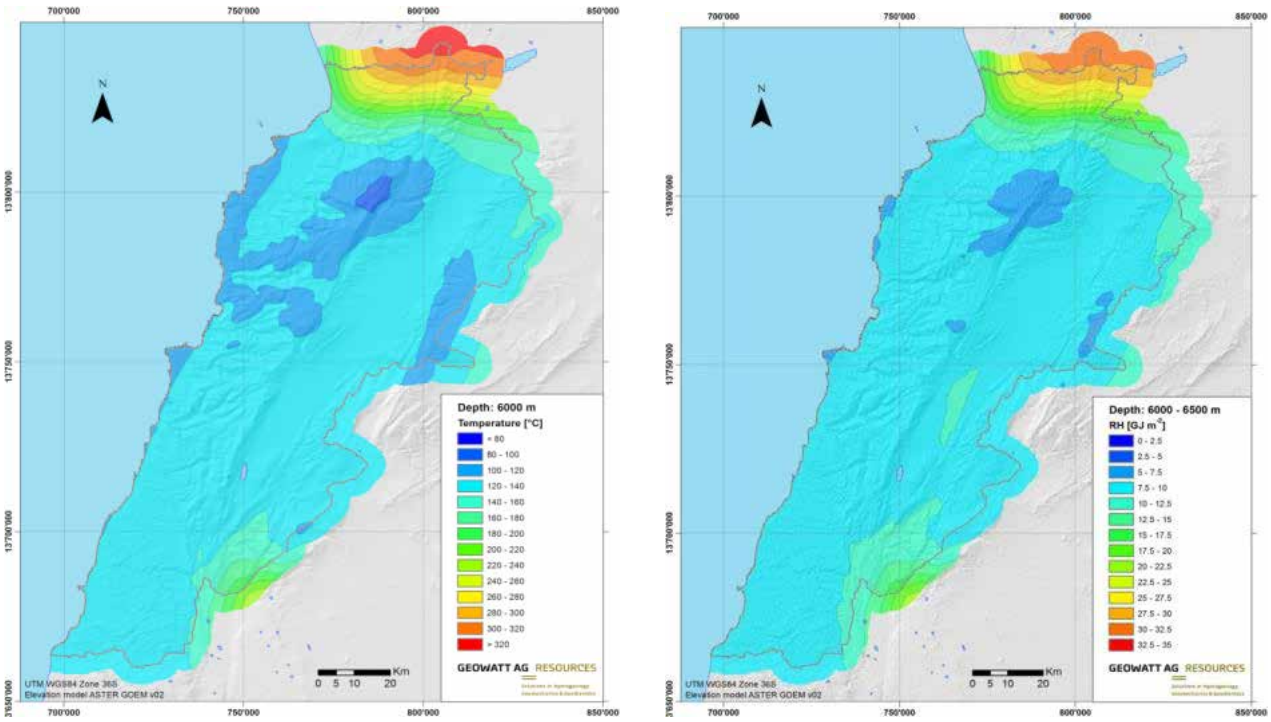


Figure 39. Recoverable heat for the depth interval 6000–6500 m. Reprinted from *The National Geothermal Resource Assessment of Lebanon* (pp 126), by V. Badoux, D. Ollinger, C. Baujard, and T. Mégel, 2014, Beirut, Lebanon: United Nations Development Programme-Country Energy Efficiency and Renewable Energy Demonstration Project for the Recovery of Lebanon Copyright 2014 by United Nations Development Programme-Country Energy Efficiency and Renewable Energy Demonstration Project for the Recovery of Lebanon.

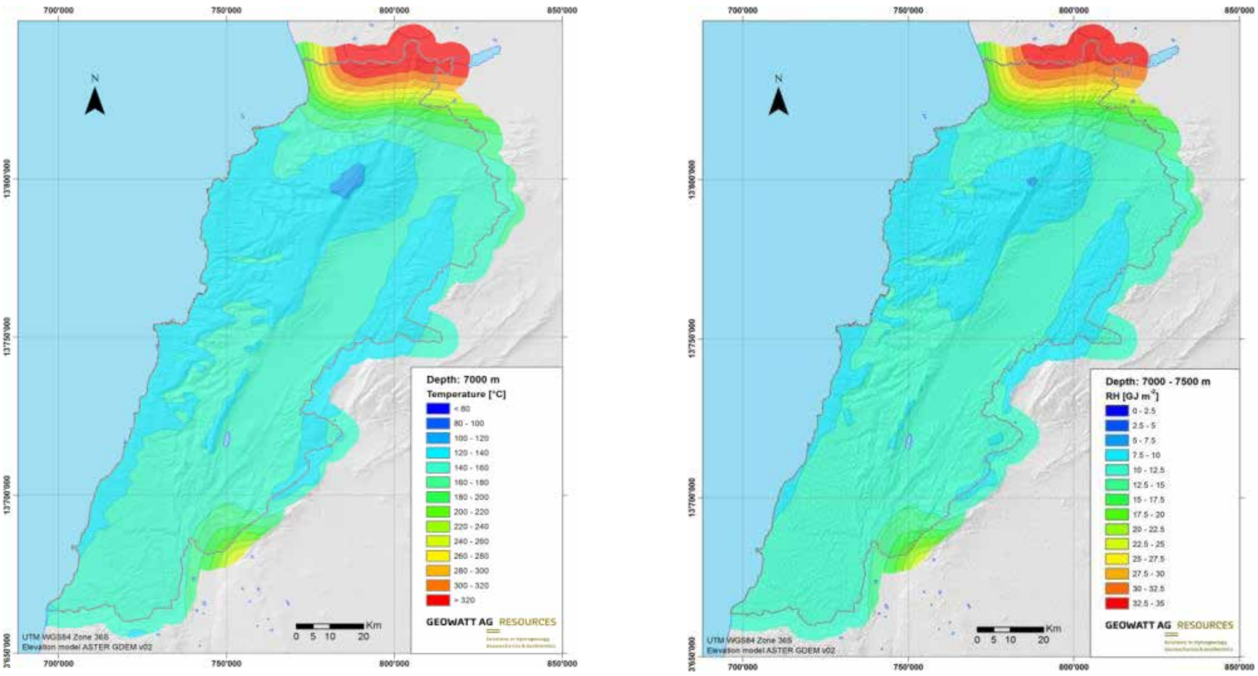


Figure 40. Temperature and recoverable heat for the depth interval 7000-7500 m. Reprinted from *The National Geothermal Resource Assessment of Lebanon* (pp. 126), by V. Badoux, D. Ollinger, C. Baujard, and T. Mégel, 2014, Beirut, Lebanon: United Nations Development Programme-Country Energy Efficiency and Renewable Energy Demonstration Project for the Recovery of Lebanon. Copyright 2014 by United Nations Development Programme-Country Energy Efficiency and Renewable Energy Demonstration Project for the Recovery of Lebanon.

The temperature maps of both Jurassic and Cretaceous aquifers clearly indicate that the most suitable area is in the Akkar region in the North (due to the local thermal anomaly), followed by the Bekaa Valley, which corresponds to a low syncline structure. The numerical model constitutes a very important milestone for future development of geothermal energy in Lebanon because it allows updating the assessment of the available resource and improving the accuracy of the estimates when more data will be available.

From the preliminary geothermal power assessment, it can be concluded that the gross resource in Lebanon is of 10^9 GWh, the equivalent of approximately 70,000 times the yearly energy demand in Lebanon. The gross resource is defined here as the total energy stored in Lebanon's underground at a temperature high enough to produce electricity (higher than 100°C) and at a depth that could be reached with present drilling technologies (less than 7,000 m below ground level). Since there is no direct measurement of this resource (i.e., absence of measurements from actual deep borehole drillings), the level of confidence is considered as *low* and the resource is categorized as *inferred* (according to the international geothermal reporting code). Furthermore, only a very small part of geothermal heat can be economically exploited considering the present state of the technology.

10.3 Financial appraisal of geothermal energy in Lebanon

Geothermal power plants are capital-intensive, yet have low and predictable running costs (IRENA, 2013). The costs of a deep geothermal power plant project can be divided into investment costs at the beginning of the project and annual costs. The annual costs include the capital annuities (CAPEX) and the operating expenditures (OPEX). The total costs of a geothermal power plant are strongly dominated by the high-risk investment at the very early phase of the project, mainly from drilling costs and the risk of non-discovery. Therefore, financial incentives at the very early stage of the project strongly aid in the overall funding of a geothermal project (Badoux et al., 2014).

Capital investments include the installation/construction of the following elements: well doublet, geothermal fluid cycle (primary), power plant unit (including the secondary fluid cycle), and surface infrastructures.

The National Geothermal Assessment for Lebanon indicated a cost breakdown of four underground environments in Lebanon. Parameters and hypothesis used are listed in Table 34.

Table 34. Parameters and hypothesis for the estimation of the capital and operational costs of the geothermal plant

		Akkar	Bekaa	Beirut	
Parameter	**Unit**	**Hydrothermal**	**Enhanced geothermal system (EGS)**	**Hydrothermal**	**Enhanced geothermal system (EGS)**
Plant capacity factor	-	0.9	0.9	0.9	0.9
Plant lifetime	year	30	30	30	30
Reservoir depth	m	1,500	4,000	2,800	6,000
Production temperature	°C	130	200	130	140
Injection temperature	°C	70	70	70	70
Flow rate	l/s	46	46	46	46
Pump power consumption	kW	577	577	577	577

Some of these parameters are common to the four environments, such as the plant capacity factor, the plant lifetime, the injection temperature, the flow rate, and the pump power consumption. The other parameters are specific to each environment, such as the depth of the reservoir and the production temperature (UNDP-CEDRO, 2014).

The plant capacity factor of a geothermal power plant is higher than 90%, which is the highest of all technologies including nuclear. The summary of the cost breakdown including investment costs, CAPEX, and OPEX, as outlined in *The National Geothermal Assessment*, are outlined in Table 35.

Table 35. Summary of the capital and operating expenditures for four power plant scenarios in Lebanon, and estimation of the net electricity production and the specific costs per kilowatt-hour

	Akkar (hydrothermal)	**Akkar (enhanced geothermal system)**	**Bekka (hydrothermal)**	**Beirut (enhanced geothermal system)**
Heat generation MW_{th}	13	29	13	16
Geothermal power MW_{el}	1.3	2.9	1.3	1.6
Investment costs million USD	24.8	52.5	34.9	68.5
OPEX	0.7	1.1	0.9	1.4
CAPEX	2.1	3.9	2.7	4.9
OPEX/CAPEX %	30	30	30	30
Net electricity production in GWh/year	6.0	18.2	6.0	7.7
Specific cost in US cent/kWh	46	28	60	81
Risk of non-discovery	Medium	Medium	High	Medium
Technical risk	Low	High	Medium	Very high
Time horizon	2020	2025	2020	2030
Source: Badoux et al. (2014)				

The capital costs for the realization of a geothermal power plant in Lebanon are comprised between approximately USD 25 million in the Akkar District and approximately USD 70 million for an enhanced geothermal system (EGS) project in Beirut. Operational costs are similar and are comprised between USD 0.6 million and USD 1.2 million per year.

The difference in terms of costs is clearly related to the depth of the reservoir and the associated drilling costs, which vary from USD 4.7 million in the Akkar region to USD 36 million for the EGS scenario in Beirut (see Table 36).

Depending on geothermal conditions in the reservoir (temperature and transmissivity), the costs are estimated to be comprised between 21 US cents/kWh and USD 1.37/kWh, with an average cost of 46 US cents/kWh. These costs are higher than the actual price of the electricity market in Lebanon.

Table 36. Cost per kilowatt-hour in US dollars for different hydraulic transmissivity and reservoir temperatures of the Jurassic aquifer in the Akkar region

		Transmissivity (square meters per second)		
Temperature (degrees Celsius)		10^{-3}	$3.0 \cdot 10^{-4}$	10^{-4}
120	MW_{el} (gross)	3.5	1.1	0.4
	GWh (net)	13.1	4.2	1.5
	USD/kWh	0.33	0.64	1.42
130	MW_{el} (gross)	4.2	1.3	0.5
	GWh (net)	18.61	5.97	2.12
	USD/kWh	0.25	0.46	1.03
140	MW_{el} (gross)	4.8	1.6	0.6
	GWh (net)	24.1	7.7	2.7
	USD/kWh	0.20	0.37	0.81

10.4 Target for geothermal energy in Lebanon

Badoux et al. (2014) indicates a stepwise scenario for geothermal power usage in Lebanon. In the context of this NREAP, a realistic scenario considers the implementation of one pilot installation of 1.3 MW by 2020. If it succeeds and yields positive results, four additional power plants could be installed before 2025. Considering this scenario, it is concluded, in the study, that total electricity production by 2020 by means of geothermal energy can reach 6 GWh_{el}. By 2025, the total production could be increased to 30 GWh_{el}, which corresponds to about 0.2% of the total energy demand. Combining the different distributed resources, the three possible scenarios for the development of decentralized generation can be considered as per Table 37.

Table 37. Target scenarios of geothermal energy for the year 2020

	Optimistic	**Realistic**	**Pessimistic**
Power (MW)	6.5	1.3	0.0
Electrical Energy (GWh)	30	6	0
Electrical Energy (ktoe)	6.5	1.3	0.0

Based on the 2020 realistic scenario, Table 38 shows the potential progress of geothermal energy until 2030.

Table 38. Target of geothermal energy for the years 2010 - 2030

Geothermal		
2010	MW	0
	GWh	0
	ktoe	0
2015	GWh	0
	MW	0
	ktoe	0
2020	MW	1.3
	GWh	6
	ktoe	1.3
2025	MW	6.5
	GWh	30
	ktoe	6.5
2030	MW	15
	GWh	69.2
	ktoe	15

10.5 Needed budget to achieve the 2020 target and the way forward

Deep geothermal power plants are subject to high upfront capital costs and subsequent levelized costs. This is a major barrier towards geothermal power development in Lebanon. However, levelized costs, as shown in Table 36, can potentially reach 20 US cents/kWh. This falls within the current range of power production by EDL. *The National Geothermal Resource Assessment* estimated the cost of the installations planned for 2020 (1.3 MW) to be USD 5 million (Badoux et al., 2014).

Badoux et al., 2014 suggests beginning with an exploration program specifically dedicated to geothermal energy. The aim of this exploration program is to increase the level of confidence in the geothermal resource in the identified prospective areas and to have them qualified as *indicated* or *measured*. The proposed exploration program includes geophysical surface investigations and the drilling of one geothermal well, which is at the present state of technology, the only method to ascertain the presence of a geothermal resource. Investment costs for this exploration program are estimated to be approximately USD 5 million, and yearly savings are approximately USD 12,000.

The first ground-source heat pump applications in Lebanon: Medrad Medical Center

Grand Source Heat Pump (GSHP) applications in Lebanon have yet to take hold in Lebanon. Only very few applications exist. However, a large GSHP project, with a 1.08 MW capacity, is currently being implemented at Medrad Medical Center (MMC). MMC is a medical center with over 230 beds under construction and located in Choukine, in southern Lebanon.

The GSHP project is co-financed by GOL (through MEW) and the European Union (through the UNDP-CEDRO IV project). The 1.08 MW GSHP consists of 180 boreholes (each 100 metres deep) and will provide cooling, heating, and hot water needs to selected areas in the various complexes within MMC. The system consists of boreholes and distribution pipes, GSHPs, heat and cool buffer tanks, a control and monitoring system, and auxiliary equipment.

The renewable resource used in the GSHP system is widely available and offers high-EE and savings that considerably reduce the CO_2 emissions related to the fossil fuel used for domestic hot water and heating, ventilating and air conditioning (HVAC) when conventional energy sources are used. The ground source heat exchange is done through a closed circuit installed in the ground heat exchanger field. Thus, there is a heat exchange between the fluid (water and anti-freeze) that circulates in a closed loop configuration, and the surrounding ground. The land transfers or takes heat to/from the fluid that is transferred to the GSHP with its compressor. The compressor enables heating the water up to the 60 degrees Celcius (60 ºC) that is stored in the tank for heating purposes, from the condenser side. Simultaneously, the heat pump can produce cold water for cooling from the evaporator side.

The CEDRO IV project, with MEW and LCEC, will be publishing a guideline report on the GSHP technology, including a discussion on which type of institutions best fit this technology. It is hoped that the awareness and capacity building for GSHP will be significantly enhanced through this landmark project that is due to be completed at the beginning of 2017.

The first geothermal project in Lebanon: Four Seasons Hotel

The Four Seasons Hotel in downtown Beirut is currently implementing a geothermal cooling project. The project is financed by the NEEREA financing mechanism. The unofficial application was already submitted to LCEC. This project consists of drilling three wells for closed-loop water circulation which will replace the existing cooling towers on the roofs. As such, the new condenser water cooling system is achieved by geothermal cooling. Wells will be drilled to feed the existing chillers with water cooled by condensers through two exchangers. The water will be returned back to the underground in a closed-pipe system. The system is composed of the three underground wells with two submersible pumps suitable for seawater operation that will supply cold seawater to the heat exchangers. Consequently, the cooling flow rate to condensers will be lower than with the existing system and no water consumption for towers is required.

Several key benefits will result from the implementation of the geothermal cooling project at the Four Seasons Hotel. Energy savings on the fans of the cooling towers and on the condenser pumps will be approximately 415,000 kWh/y. The coefficient of performance of the chillers will increase due to the low temperature of the underground seawater leading to energy consumption reduction and thus remarkable energy savings. Improving the efficiency of the chillers would reduce annually up to 390,000 kWh (approximately USD 40,000). This leads to a reduction in GHG emissions of more than 500 tons of CO_2 per year and promotes the use of RE as a clean energy source.

Additional benefits include water conservation (yearly savings of approximately 26,000 m^3 of water). The full elimination of both the chemicals and water costs will save approximately USD 57,000/year as well.

Chapter 11: Biomass (including waste-to-energy)

Biomass-the fourth largest energy source after coal, oil, and natural gas—is the most important RE option at present that can be used to produce different forms of energy. As a result, biomass is, together with the other RE options, capable of providing all the energy services required in a modern society, both locally and in most parts of the world. Renewability and versatility are, among many other aspects, important advantages of biomass as an energy source. Compared to other renewables, biomass resources are common and widespread across the globe.

Lebanon has a relative abundance availability of bioenergy resources, as approximately one third of the country's land is arable, with the most fertile areas being located along the coastal strip and in the Beqaa Valley. Traditional use of biomass in rural areas is intensive; however, the development of sustainable bioenergy is lagging behind.

This chapter of the NREAP is heavily based on the results of *The National Bioenergy Strategy for Lebanon* developed by UNDP-CEDRO on behalf of MEW. Practically, the chapter will cover the technology global outlook, to be followed by the potential of biomass in Lebanon. Furthermore, the target for biomass energy will be presented (according to the three proposed scenarios (realistic, optimistic, and pessimistic). The chapter then ends with a list of prospects and barriers for technology uptake.

11.1 Technology global outlook

The sustainability potential of global biomass for energy is widely recognized. For example, the annual global primary production of biomass is equivalent to the 4,500 exajoules (EJ) of solar energy captured each year. About 5% of this energy, or 225 EJ, should cover almost 50% of the world's total primary energy demand at present. These 225 EJ are in line with other estimates which assume a sustainable annual bioenergy market of 270 EJ. However, the 50 EJ biomass that contributed to global primary energy demand of 470 EJ in 2007, mainly in the form of traditional non-commercial biomass, is only 10% of the global primary energy demand. The potential for energy from biomass depends in part on land availability. Currently, the amount of land devoted to growing energy crops for biomass fuels is only 0.19% of the world's total land area and only 0.5–1.7% of global agricultural land. Although the large potential of algae as a resource of biomass for energy is not taken into consideration, there are results that demonstrate that algae can, in principle, be used as a RE source. (Ladanai & Vinterbäck, 2009).

Biomass potential for energy production is promising. In most cases, shifting the energy mix from fossil fuels to biomass can now be done using existing technology. Investors in many cases have a reasonably short pay-back because of good availability of low-cost biomass fuels. However, the latter is of course dependant on local incentives. Overall, the future of bioenergy is also to a large extent determined by policy. Thus, an annual bioenergy supply covering global energy demand in 2050, superseding 1,000 EJ, should be possible with sufficient political support.

11.2 Potential of biomass energy in Lebanon

In Lebanon, a total of 23 biomass streams representing a potential resource for energy production have been identified and fully characterized. These streams have been grouped according to their source of origin: forestry, wood and paper industries, agriculture, energy crops, food processing industry, and municipal solid waste and non-hazardous industrial waste.

An overall evaluation of all biomass resources has been performed. This evaluation assessed quantity, energy potential, competition with other uses, accessibility and the current legal framework impacting biomass resource potentials in Lebanon. With this purpose, detailed statistical research has been combined with remote sensing data, on-ground surveys, and key stakeholders interviews. This evaluation has allowed the identification of those biomass streams with the largest potential for development in the country. As a result, the ranking of the 10 most promising bioenergy streams are:

1. Residues from forestry fellings
2. Residues from fruit and olive trees
3. Residues from cereals
4. Energy crops on currently unused land
5. Olive cake by-products
6. Waste wood
7. Municipal sewage sludge
8. Animal fat and slaughterhouse residues
9. Yellow grease
10. Landfill gas recovery (specifically Naameh landfill)

A variety of technology options exist for the conversion of biomass streams of interest into power, heat, and liquid fuels. Many of these options rely on several feedstock alternatives. These options can be implemented from large-scale industrial applications to small-scale and rural end uses. These options are listed below and cover mature and developing technologies:

- Liquid fuels production

- Vegetable oil biodiesel-alternative to fossil diesel fuel, made from plant oils
- First generation bioethanol-alternative to fossil gasoline, made from agricultural crops
- Animal fat and recycled oil biodiesel-alternative to fossil diesel fuel, made from waste fats and oils
- Fischer Tropsch biodiesel-feedstock gasified into syngas then condensed into a diesel replacement

- Biogas production

- Anaerobic co-digestion (manure and agro residues)-feedstocks are converted by bacteria into biogas
- Anaerobic digestion of sewage sludge-sewage sludge is converted into biogas by bacteria
- Slaughterhouse waste biogas-slaughterhouse waste is sterilized, then converted into biogas by bacteria
- Landfill gas-biogas is released by landfills, which can be collected and purified for fuel usage

- Direct combustion

- Waste-to-energy-creating energy by combusting waste
- Combustion combined heat & power (CHP)-simultaneous generation of useful bioenergy
- Combustion boiler-converts biomass into heat
- Co-combustion of biomass and coal-partial substitution of coal by biomass in coal fired power plants

- Pretreatment

- Palletisation-drying and pressing biomass under high pressure into pellets with an improved energy density
- Torrefaction-heating at atmospheric pressure in the absence of oxygen to improve energy density
- Gasification-combined heat power (CHP)-thermal conversion of solid fuel into a combustible gas under oxygen limitation
- Pyrolysis - direct thermal decomposition of biomass into gas, bio-oil and char

- Promising technologies

- Algae options (centered in biodiesel)-simple organisms that use sunlight to grow and produce oil (or other products)
- Salicornia biodiesel-salicornia as a salt tolerant plant that produces oil
- Lignocellulosic ethanol-woody biomass, grasses, or the non-edible parts of plants are broken down into ethanol
- Fuel from municipal solid waste (MSW) - using waste to produce a high quality biofuel

The National Bioenergy Strategy for Lebanon elaborated four scenarios to explore various bioenergy perspectives until 2020. The general characteristics of the four scenarios are shown in Table 39.

Table 39. Considered scenarios for bioenergy in Lebanon

Scenario	Key trends
Scenario I: Well-being and development	Peace in the country and in the region. Strong growing economy. Bioenergy development is promoted. Strict sustainability levels and policies are considered for bioenergy development.
Scenario II: Economic crisis	Peace in the country and in the region, apart from incidental unrest. Economic growth in Lebanon is slow, limiting the possibilities for bioenergy development. Minimum sustainability levels are considered for bioenergy development.
Scenario III: Underdevelopment and poverty	Lebanon is in political turmoil, which affects the economy with increasing socio-economic disparities across Lebanese regions. Bioenergy development has limited to no priority in national strategies. No sustainability levels are considered for bioenergy.
Scenario IV: Political challenges	There is a strong economy; some regions remain underdeveloped due to large political and social unrest. Bioenergy is used for reducing energy deficit and exports. A minimum level of sustainability is considered for bioenergy

Based on the four scenarios, the annual contribution of bioenergy to end uses in 2020 would be as shown in Table 40.

Table 40. Bioenergy scenarios

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

11.3 Target for biomass energy in Lebanon

As part of this NREAP, LCEC bases on the three scenarios II, IV, and III as the optimistic, realistic, and pessimistic scenarios respectively. In fact, 50% of each of the scenarios will be considered when setting up the three scenarios. This would translate as per Table 41.

Table 41. Target scenarios of bioenergy energy for the year 2020

	Optimistic	Realistic	Pessimistic
Energy (GWh)	1,177	771.5	258.5
Energy (ktoe)	254.25	166.65	55.85

Based on the 2020 realistic scenario, Table 42 shows the potential progress of bioenergy until 2030.

Table 42. Target of bioenergy energy for the years 2010–2030

<table>
<tr><th colspan="2">Bioenergy</th><th>Total</th><th>Electricity</th><th>Heat</th></tr>
<tr><td rowspan="3">2010</td><td>MW</td><td>-</td><td>-</td><td>-</td></tr>
<tr><td>GWh</td><td>-</td><td>-</td><td>-</td></tr>
<tr><td>ktoe</td><td>-</td><td>-</td><td>-</td></tr>
<tr><td rowspan="3">2015</td><td>MW</td><td>-</td><td>-</td><td>-</td></tr>
<tr><td>GWh</td><td></td><td></td><td></td></tr>
<tr><td>ktoe</td><td>-</td><td>-</td><td>-</td></tr>
<tr><td rowspan="3">2020</td><td>MW</td><td>-</td><td>-</td><td>-</td></tr>
<tr><td>GWh</td><td>771.5</td><td>261</td><td>510.5</td></tr>
<tr><td>ktoe</td><td>166.6</td><td></td><td></td></tr>
<tr><td rowspan="3">2025</td><td>MW</td><td></td><td></td><td></td></tr>
<tr><td>GWh</td><td>974.3</td><td>368</td><td>606.3</td></tr>
<tr><td>ktoe</td><td>210.4</td><td>-</td><td>-</td></tr>
<tr><td rowspan="3">2030</td><td>MW</td><td>-</td><td>-</td><td>-</td></tr>
<tr><td>GWh</td><td>1,177</td><td>475</td><td>702</td></tr>
<tr><td>ktoe</td><td>254.25</td><td></td><td></td></tr>
</table>

Seven megawatts waste-to-energy electricity in the Naameh Landfill and Waste Management Facility

In 2015, and further to the decision of COM, CDR has assigned the international consultant Mott MacDonald to prepare tender documents for the construction (including operation and maintenance) of a new waste-to-energy power plant up to 6–7 MW of electricity in the Naameh Landfill and Waste Management Facility in Lebanon.

Following the bidding process, the construction contract was awarded to Sukomi-Saker. The power generation plant currently under construction consists of seven containerized generator sets (gensets) powered by GE Jenbacher gas engines. The capacity of each genset is 1,067 kW. The plant will work at N+1 configuration (six gensets running and one genset as standby), plant total capacity is 6.4 MW. The produced electricity will be exported to the national grid for an estimated period of 10 years.

The need for a gas clean up equipment has also been envisaged in order to reduce the levels of siloxane and hydrogen sulfide (H2S) to at least below the maximum levels acceptable by the installed gas engines so as to ensure their long term successful operation, with a minimum of maintenance and down time.

The contract for the construction of the new 7 MW plant was signed on November 4, 2015. The construction is expected to be completed by November 2017. Currently, the project progress is on schedule.

CDR had previously developed, with Sukomi, a landfill gas power plant (0.5 MW) at the facility. The existing entire landfill plant comprises the capped area with the gas wells, five currently operative flares and three in standby, one GE Jenbacher JMS-312GS-LL gas engine, a knock-out pot for gas dewatering, a gas blower with a flare stack, a booster station, associated electrical rooms, and a step-up transformer (480V/5kV). The site of the existing generation unit is a small fenced area of approximately 100 meters long by 70 meters wide. The construction of this landfill gas power plant was completed in 2013.

11.4 Prospects and barriers for technology uptake

The barriers to bioenergy development in Lebanon touch the technological, logistical, legal, economic, financial, and commercial spheres. The main barriers detected are further analyzed to produce recommendations that can help to overcome them. A detailed analysis of the following five bioenergy options is made:

- Combustion-CHP, with a feedstock of residues from forestry felling
- Anaerobic digestion with residues of olive and fruit trees
- Combustion boiler coming from residues of cereals
- Production of lignocellulosic bioethanol from energy crops (giant reed especially recommended) as feedstock
- Anaerobic co-digestion of olive oil cake and other organic wastes

A detailed presentation of the barriers and mitigation options of the bioenergy sources is shown in the annex at the end of this report.

Mr. Pierre El Khoury, President of the Board and Director General, LCEC, MEW, Lebanon

The LCEC team is aware that the achievement of the 12% target by 2020 is not an easy task. Yet, the LCEC will strive to change all the planned activities of this NREAP into concrete realities. Under the leadership of the Minister of Energy and Water, the LCEC team is committed to explore all the available opportunities to develop the different renewable energy technologies with the purpose to reach our national objectives. No efforts will be spared to make Lebanon a positive model for the entire Arab World in the field of sustainable energy.

Chapter 12: Summary of the 2020 expected renewable Energy mix for Lebanon

The previous chapters presented a detailed analysis of the different RE technologies to be developed in Lebanon. The prospects and targets for each technology are developed to the three different scenarios (pessimistic, realistic, and optimistic). In this chapter, a synopsis of the individual targets set for the different technologies is presented. This synopsis is based solely on the realistic scenario.

LCEC considers the compilation of the individual targets according to the realistic scenarios as the main road map for Lebanon to follow. MEW is committed to meeting these targets to reach the 2020 objectives.

At this stage, it is important to clarify the national target once more. As mentioned earlier, the total national electricity and heating demand by 2020 is expected to be approximately 6,389 ktoe, out of which 767 ktoe would be generated by RE sources. The 767 ktoe target represents 12% of the total.

12.1 Prospects and barriers for technology uptake

According to the realistic scenario, a mix of different technologies needs to be developed to reach the 12%. Table 43 summarizes the expected RE mix for Lebanon in 2020 (as per the realistic scenario).

Table 43. RE resources electricity shares

Year	2010			2015			2020		
	MW	GWh	ktoe	MW	GWh	ktoe	MW	GWh	ktoe
Wind	-	-	-	-	-	-	200	595.7	128.7
PC, CPV	-	-	-	-	-	-	150.0	240.0	51.8
Distributed PV	-	-	-	-	-	-	100.0	160.0	34.6
CSP	-	-	-	-	-	-	50.0	170.6	36.8
SWH	211,988 m^2	137.8	12.72	413,988 m^2	269.3	58.2	1,053,988 m^2	685.5	148.1
Total hydro	190.0	836.5	181	190.0	836.5	181	331.5	961.9	207.8
Geothermal	-	-	-	-	-	-	1.3	6.0	1.3
Bioenergy	-	-	-	-	-	-	-	771.5	166.6
Total renewable energy	**-**	**974.3**	**193.72**	**-**	**1,105.8**	**239.2**	**-**	**3,591.2**	**775.7**
Total primary energy demand	**-**	**15,934.0**	**3,438.5**	**-**	**22,324.1**	**4,822.0**	**-**	**29,578.7**	**6,389.0**
Target	**6.1**			**5.0**			**12.1**		

As per Table 43, the RE mix for Lebanon in 2020 is shown in Figure 41. This chart is the main element that summarizes all the work mentioned in this NREAP.

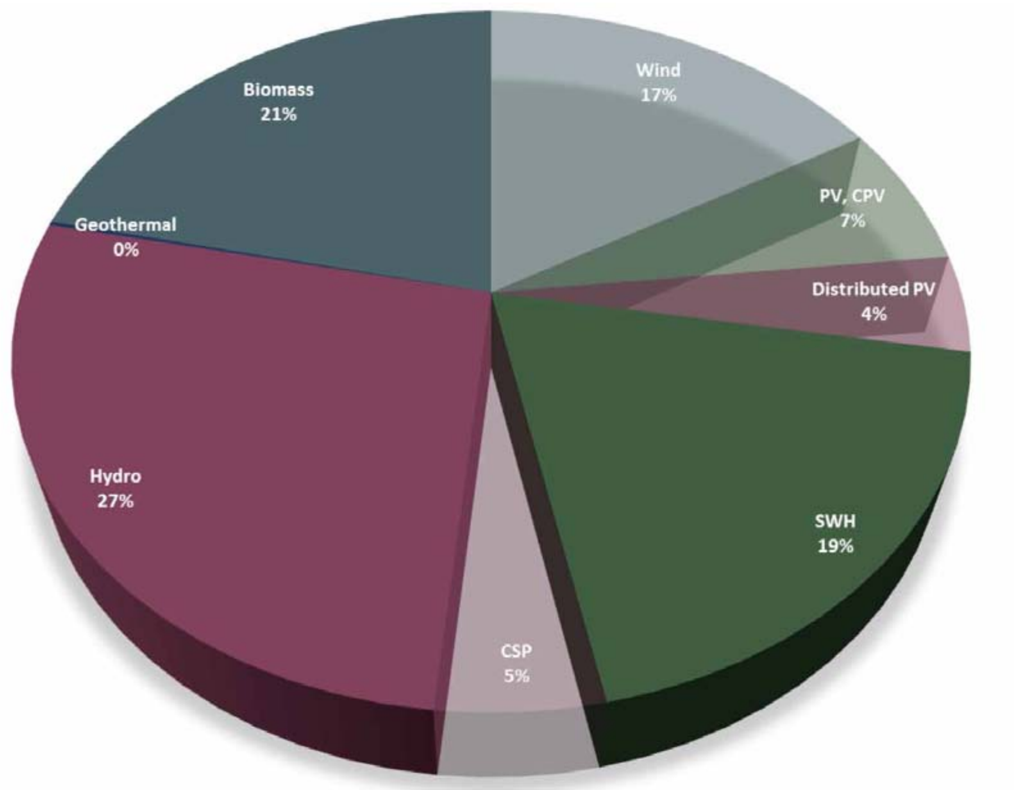


Figure 41. Shares of each resource out of the 12% target

Figure 42 shows the percentage of renewable energies in terms of final energy consumption in 2020 where it can be seen that 67% out of the generated renewable energy will be consumed as electricity whereas, 33% will be consumed for heating purposes.

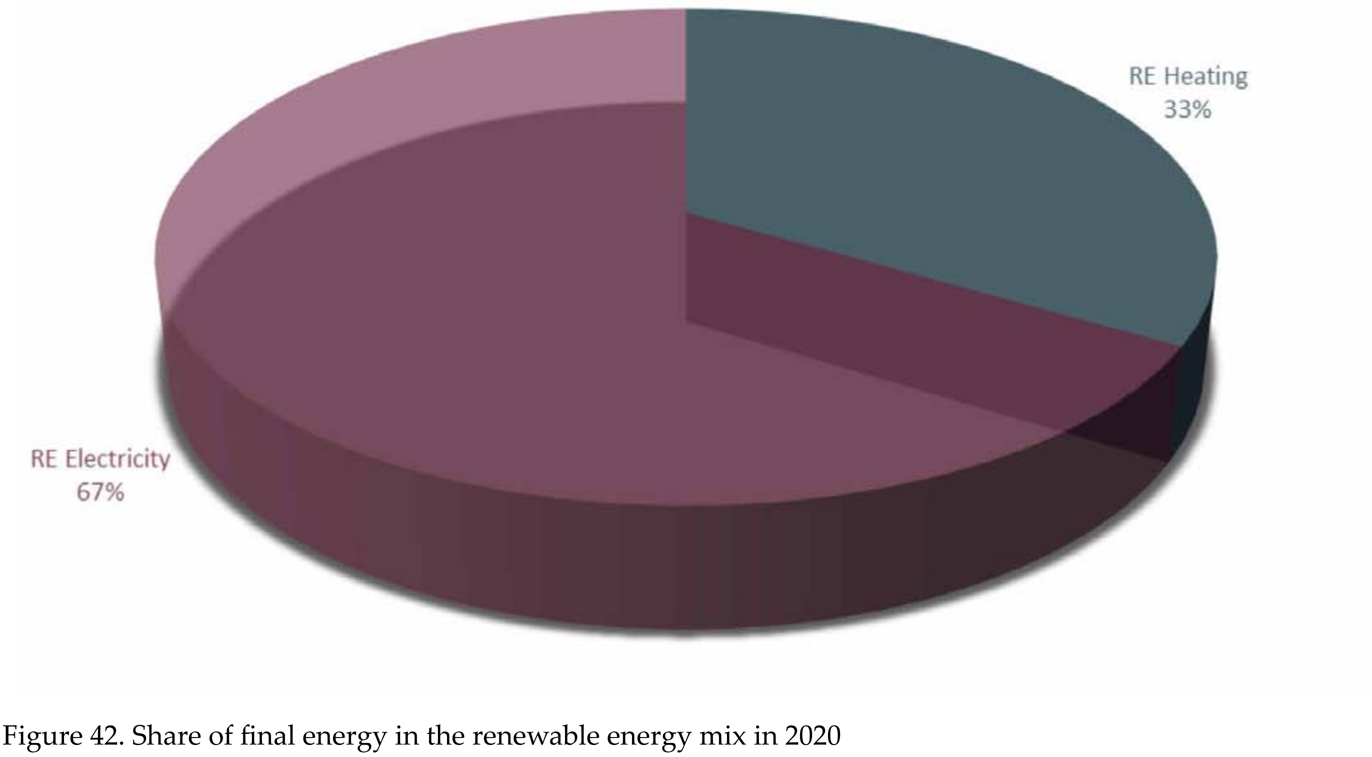


Figure 42. Share of final energy in the renewable energy mix in 2020

12.2 Needed budget and potential benefits

The implementation of the complete phases of NREAP 2016–2020 would need approximately USD 1,737 million in terms of initial investments. Shares of each resource in this total investment are shown in Figure 43.

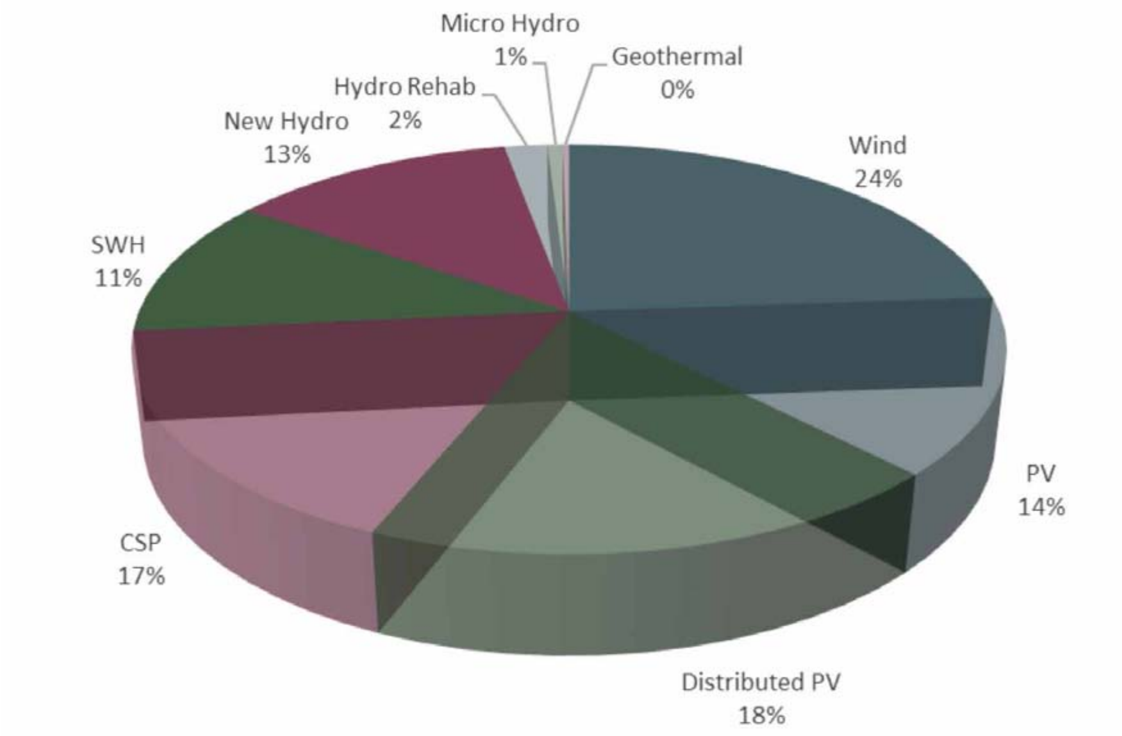


Figure 43. Shares of each resource from the total needed investment

Figure 44 and Figure 45 present the LCOE and payback periods for each of these RE resources

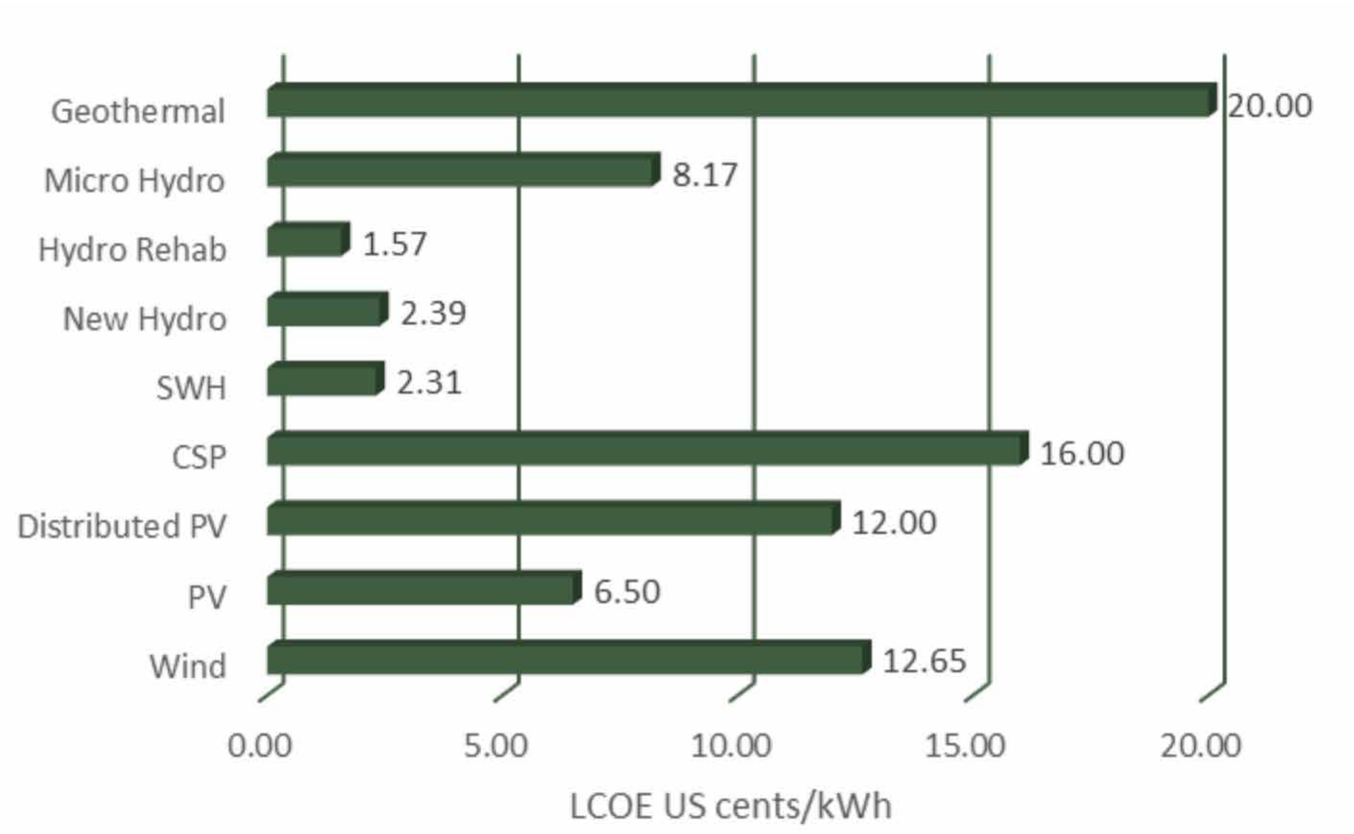


Figure 44. Levelized cost of energy of each of the renewable energy resources in cents of US dollars per kilowatt-hour

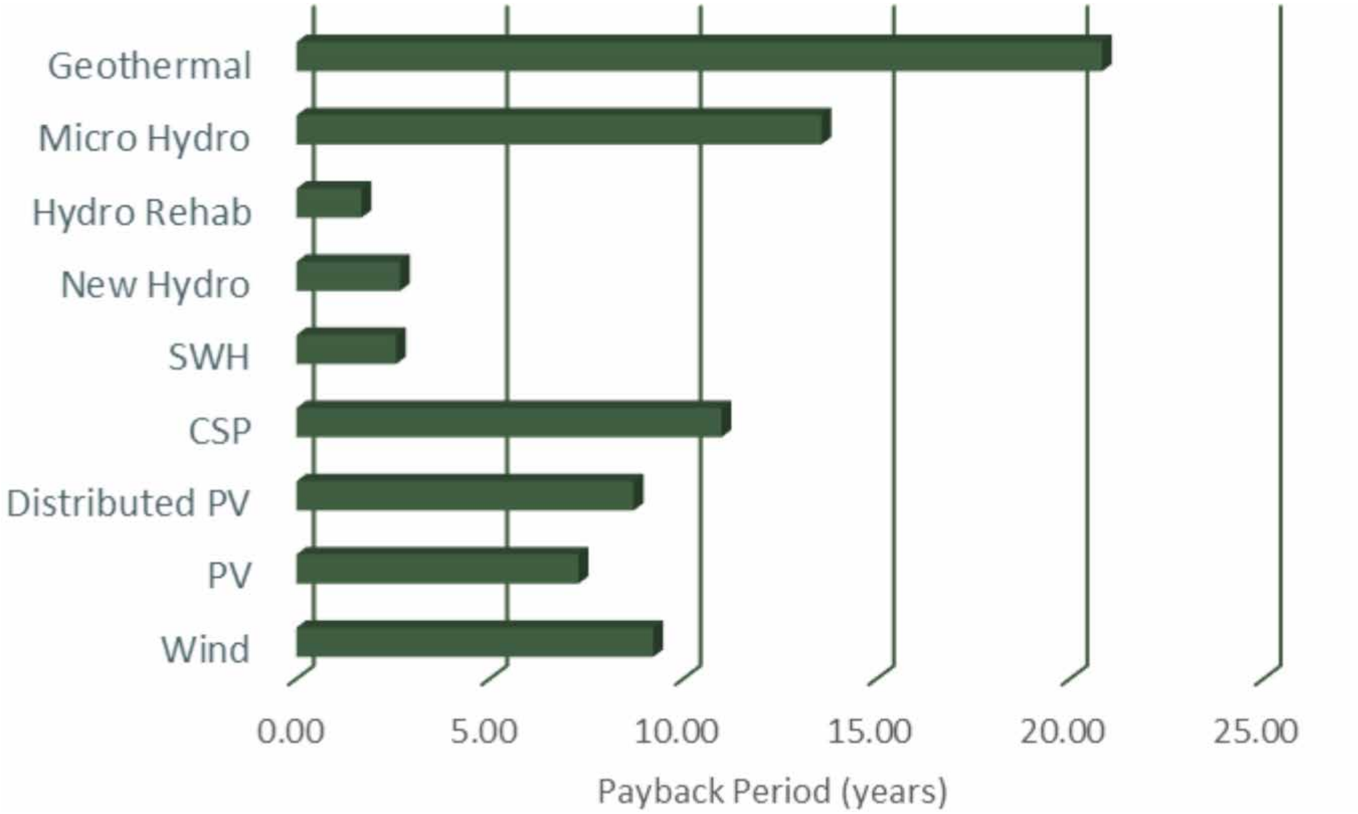


Figure 45. Payback period of each of the renewable energy resources

The introduction of RE in Lebanon will not only profit the Lebanese population in terms of environmental benefits, but will also have an impact from a social perspective. RE technologies will supply extra hours of electricity in a country in need of electricity. The total would add up to more than 640 hours. Figure 46 shows the shares of added electricity in 2020 of each of these resources.

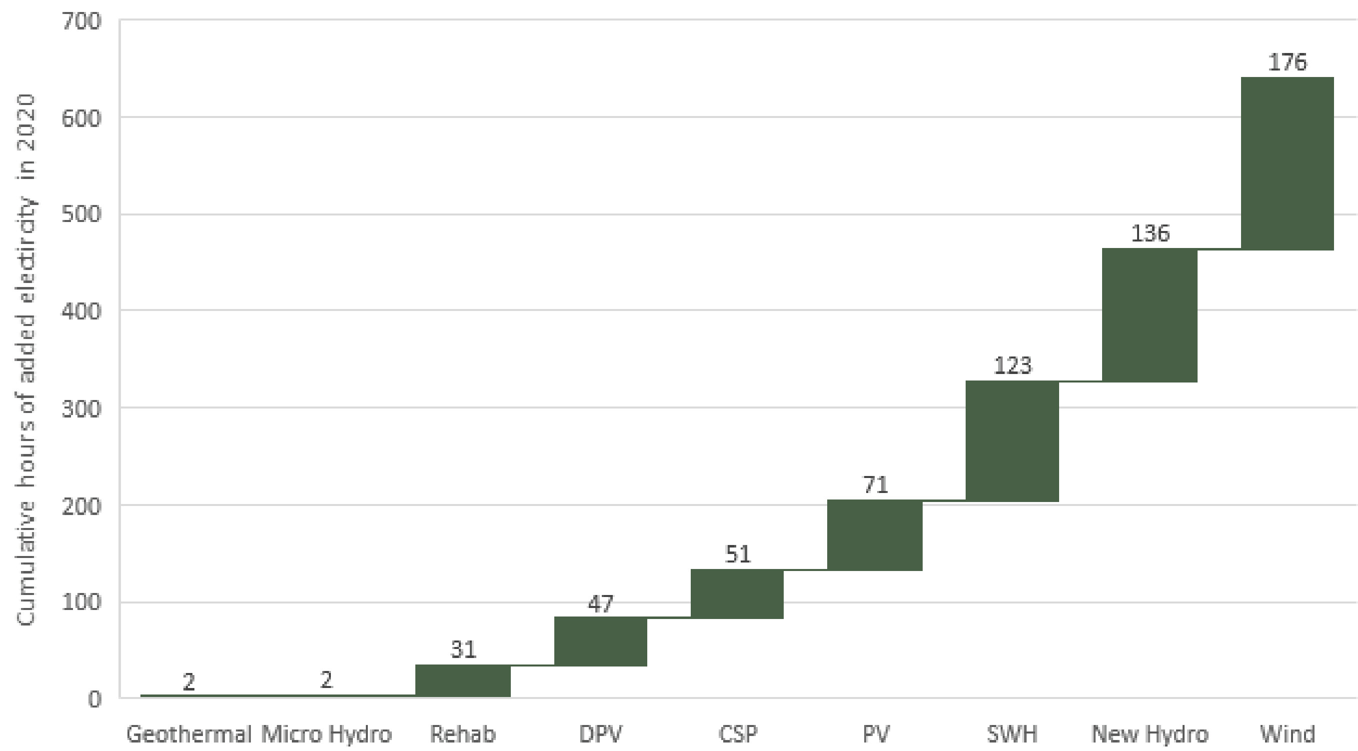


Figure 46. Cumulative extra hours of electricity supplied in 2020 by adding each of the resources

12.3 The national target beyond 2020

Beyond 2020, the analysis is more of a rough estimation. Table 44 shows the proposed development between 2020 and 2030.

Table 44. Renewable energy resources electricity shares beyond 2020

Year	2025			2030		
	MW	GWh	ktoe	MW	GWh	ktoe
Wind	350	1,087.9	235.0	450	1,422.6	307.3
PV, CPV	200.0	320.0	69.1	300.0	480.0	103.7
Distributed PV	125.0	200.0	43.2	150.0	240.0	51.8
SWH	1,345,185 m^2	755.8	163.2	1,716,835 m^2	1,116.6	241.2
CSP	50.0	170.6	36.8	100.0	341.2	73.7
Hydro	402.3	1,391.3	300.5	473.0	1,677.3	362.3
Geothermal	6.5	30	6.5	15	69.2	15
Bioenergy	-	974.3	210.4	-	1,177.0	254.2
Total RE	**-**	**4,929.9**	**1,064.8**	**-**	**6,969.8**	**1,409.2**
Total primary energy demand	**-**	**39,231.5**	**8,474.0**	**-**	**52,032.4**	**11,239.0**
Target %	**12.6**			**12.5**		

To be able to achieve all these targets, the right tools and policies are needed. The leadership of MEW is of prime importance, and the role of EDL is essential in that respect. The next part of the NREAP discusses in details all the parameters that should be available in Lebanon for the country to achieve its objectives.

12.4 The NREAP progress assessment

Like any action plan, the implementation of Lebanon's NREAP 2016–2020 will be monitored through an execution assessment mechanism that includes two major parts: a qualitative assessment and a quantitative assessment. The role of the execution assessment mechanism is to clarify the advancement and progress of the planned steps of the NREAP. The mechanism would be a tool to compare the progress of the implementation versus the stated schedule, noting any modifications or delays.

The qualitative assessment follows up on the execution of the policies already described in the previous chapters. On the other hand, the quantitative assessment follows up on the advancement of implementation of RE projects on a yearly basis. The updates of these tables would include the actual figures corresponding to the year of assessment. All the numbers for the years 2015, 2020, 2025, and 2030 are in this case the revised targets, depending on delays or advancements in the plan execution.

For the purpose of this NREAP, LCEC commits to publish a yearly follow-up report on the progress of implementation (four reports, once every year for the years 2017, 2018, and 2019). The NREAP follow-up reports would identify progress achieved, but also delays, barriers, and changes in the national action plans.

Part C

Policies and tools

Ms. Rola Majdalani, Director, Sustainable Development Policies Division (SDPD), Economic and Social Commission for Western Asia (ESCWA)

The Sustainable Development Policies Division of UN-ESCWA supports the implementation of the NREAP prepared by the Lebanese Centre for Energy Conservation (LCEC). We underline the important role of this policy tool to achieve the 2030 agenda for sustainable developments and command the efforts exerted by the Republic of Lebanon to face the multi-layered challenges to achieve the target of 12% of energy needs from Renewable Energy by 2020. This can only be sustained through an integrated approach that equally prioritizes energy efficiency and access of energy to all delivered through a well-functioning and transparent governance structure.

Chapter 13: A suitable legal and legislative framework

Undoubtedly, the rapid development of RE anywhere in the world needs a suitable legal and legislative framework. Lebanon is no exception. This chapter of NREAP 2016-2020 covers the steps needed to ensure a smooth and focused development of RE technologies in the country as per the targets set in the previous chapters.

It is important to keep in mind that NREAP 2016-2020 aims to develop RE projects according to two main paths: the development of RE projects by the public sector and then the development of RE by the private sector.

The aim of this chapter is to highlight the status of the legislative and legal framework regarding RE development, the initiatives implemented so far, and the challenges facing a wider scope of deployment. Most importantly, the chapter proposes a plan of action to be followed to reach the national objectives by 2020.

13.1 National outlook

One of the main barriers towards a more systematic, calculated, and profuse penetration of RE systems into the Lebanese power network is the absence of an appropriate and clear regulatory framework underpinning this sector. Such a regulatory framework will enable a quicker development and utilization of RE resources, more investments in RE sources, and an indigenous capacity in technology and employment for RE sources.

MEW is the main public party responsible for the country's electricity sector in terms of strategy, policy, and planning. EDL, on the other side, being a public institution under the supervision of MEW, is tasked with the management of the sector.

The Policy Paper for the Electricity Sector in Lebanon, prepared by MEW in 2010 and endorsed by COM at its meeting on June 21, 2010, reaffirms the target to deploy RE technologies with a share that should reach 12% of generated electric power by the year 2020. Most importantly, the *Policy Paper* calls on the private sector to finance RE projects. This document commits to launching, supporting, and reinforcing all public, private, and individual initiatives to utilize RE.

Regulatory initiatives and plans were to be performed by an electricity regulatory authority (ERA), which would have technical, administrative, and financial autonomy and would issue permits and licenses for all activities mandated under Law 462 dated September 2, 2002. The Lebanese Parliament has ratified Law 462, however to date it has yet to be implemented.

The legal provisions to reform the sector structure were promulgated in Law 462 in 2002. This Law sets out the responsibilities of the main actors in the sector and recognizes IPPs to participate in electricity generation in Lebanon. Article 1 of the law defines the term *production* as the production of electricity through thermal resources, water, RE or other resources. Article 3 states the principle of independence of each of the activities of production, transmission, and distribution of electricity-a significant reform of decree 16878 issued in 1964. Article 7 provides for the establishment of an ERA. According to the capability that Law 462 grants the ERA, this entity is eligible to determine and classify the various types of electricity production in Lebanon.

According to the law, the ERA has the ability to grant, renew, suspend, amend, or cancel licenses or permits for power generation. As soon as a license is delivered, it enables companies to benefit from a concession that will last for no longer than fifty years. The concession involves the establishment, processing, development, management, or marketing of devices within the scope of public services used in the areas of production, transport, and distribution of more than 10 MW or the right to use the devices listed in a form of leasing. The ERA, once established, has the ability to issue licenses for a maximum of fifty years in accordance with the following:

- Public Tenders for production capabilities exceeding 25 MW

- Call for bids for production capabilities of 25 MW and below

Although Law 462 has been in force since 2002, it was never actually implemented. Accordingly, there is no regulatory body to issue licenses for new generation. From 1999 to 2002 the emphasis was on privatization; but after 2002, the emphasis shifted towards public-private partnerships and corporatization, leaving the law somewhat behind the change in consensus.

Law 462 does not include any articles on RE, nor does it include any policies for their promotion on a national scale. However, it allows private power production for personal use. It allows up to 1.5 MW of private generation, any private generation greater than 1.5 MW requires a permit from ERA, and any plant greater than 10 MW requires a license from ERA.

Various amendments to the Law 462 have been proposed to make it more applicable to current Lebanese conditions and to stimulate the widespread use of renewable resources. According to these amendments, any new law is expected to make provisions for the feed-in tariff (FIT) for co-generation and should call for the introduction of a transition period during which the corporatization of EDL will take place. It shall also call for the gradual introduction of the private sector into EDL through a service provider law and new IPP.

Law 775 (dated November 11, 2006) introduced an amendment to Article 7 of Law 462. Law 775 provides that temporarily, for a duration of one year, and until the ERA is officially created and its members are appointed, licenses and permits to produce electricity are granted by a decision from COM based upon the proposal of MEW.

Law 775 expired in 2007 with no licenses or permits issued for power generation.

13.2 Current status

Law 288 (dated April 30, 2014), further sidelined Law 462 by indicating that for a period extending two years (i.e., from April 2014 to April 2016), COM, upon joint proposals from MEW and MOF, can grant permits and licences to IPPs. Law 288 literally indicates that "temporarily and for a duration of two years and until the ERA members are appointed and until it could assume its mandate, permits and licenses are granted by a decision from the Council of Ministers based upon a proposal from the Minister of Energy and Water and the Minister of Finance". Furthermore, the Lebanese Parliament approved law 54 (dated October 24, 2015) extending the duration of Law 288 until April 2018. The mechanism and tendering capacities and procedures for the joint proposals from MEW and MOF were not indicated nor clarified.

MEW initiated one exercise towards the implementation of these laws and that is the wind farms tender. The current wind farm tender (reaching as high as 200 MW) is an example that is structured through LCEC. In other words, MEW, through LCEC, opened the possibility of wind farms in Lebanon requiring a tender, organizing, therefore, private sector participation. The evaluation committee includes representatives from all concerned ministries, including mainly a representative from MOF. Both ministries would need to forward the outcome of this tender, jointly, to COM for a decision on licensing.

13.3 The proposed plan of action

The proposed plan of action relies on the application of the laws 288 (2014) and 54 (2015) to allow the private sector to generate electricity in the RE sector solely and exclusively. This would mean allowing the private sector to produce electricity and export electricity to the national grid following the approval of the COM and based on the proposal of MEW and MOF.

It is crucial to note that the proposed plan of action applies exclusively to electricity production from RE sources, namely solar PV, solar CSP, hydro, and wind. This plan of action does not apply to any other technology of electricity production. This plan of action does not apply to traditional sources of power (fuel-based or diesel-based). In the case of traditional sources of power, there is a clear need for a transaction advisor to complete all the needed tasks.

According to this current NREAP, the following procedure will be followed to reach our national objectives:

1. Announcement of the call for proposals by MEW

2. Submittal of project proposals by the private sector

3. Technical evaluation by MEW and the LCEC team

4. Financial appraisal by MEW

5. Coordination and approval of MOF

6. Submittal of selected bidders with best pricing to COM

7. Decision by COM to give licenses to selected bidders

The mentioned procedure takes the following points into consideration:

- Request for proposals-based on the national objectives set in this current NREAP 2016-2020, MEW will be announcing a call for projects by the private sector.

- The objective of the request for proposals (RFP) is for MEW to procure RE utilizing a PPA.

- The private sector entity will finance, develop, acquire land, design, build, own, operate, and maintain the RE plant. The RE farm will deliver electricity to the EDL network/grid.

- EDL with approval of MEW will contract to purchase the electrical energy for a period of 20 years subject to terms and conditions defined in the PPA. MEW or EDL does not intend to purchase the RE assets.

- The contractor will deliver electricity to a location that is mutually agreed to by the contractor and MEW/EDL. The contractor will build the feeder line, substation (or upgrade an existing substation), and all other infrastructure required to deliver energy into an existing transmission line.

- The delivered energy will meet the quality standards and requirements as per the grid code (see next chapter).

- The contractor will provide real-time energy production and related data to EDL's national control center/dispatch center.

- Bidder shall submit unit price for each kilowatt-hour of electricity in USD, annual amount of minimum, average and maximum kilowatt-hours delivered to the grid, date of full operation of the RE plant, and other requested information.

- Along with proposal, all bidders shall provide a bid security as bank guarantee. The bid security amount will be returned to bidders that are not selected.

- The selected bidder shall also provide a performance bond. The bidder shall forfeit the performance bond for non-compliance-inability to successfully commission and put into production the entire project in the proposed timeframe.

- In each region of Lebanon, the minimum power capacity of one given solar farm is 10 MW and the maximum power capacity is 15 MW.

- According to the previous point, a maximum of three solar farms per region could be selected.

- In the same region, and in case of more than three offers pass the technical evaluation, the three bids offering the lowest price per kWh will be automatically selected.

- The proposed PPAs will be based on the lowest price received from the lowest bidder in all Lebanon.

- The call for proposals will cover all regions of Lebanon as per the following distribution for solar PV farms:

    - Mount Lebanon-a targeted minimum of 30 MW and a maximum of 45 MW

    - North-a targeted minimum of 30 MW and a maximum of 45 MW

    - South-a targeted minimum of 30 MW and a maximum of 45 MW

    - Bekaa-a targeted minimum of 30 MW and a maximum of 45 MW

Introducing permitting schemes for RE technologies and setting platforms for fruitful collaboration between governmental entities, and with private sector participation, is essential to reach our national objectives. 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. This current NREAP provides a long-term strategy for RE integration into the national grid.

The previous procedure described in detail for solar PV farms would be eventually applied for CSP and hydro power.

13.4 The energy conservation law

The draft energy conservation law more recently labeled “the renewable energy and energy efficiency law” is currently under final review by the legal team of LCEC. The contents of this draft law deal with EE and RE. For the sake of this current NREAP, the following parts of the law are of importance to the development of RE:

- Adoption of the NREAP

- Permitting and licensing

- Grid code development

- Use of land for RE use

Other parts of the proposed law deal with the mandatory building code, standards and labels, and encouraging investments.

This law has undertaken a regulatory impact assessment study in collaboration with the Office of the Minister of State for Administrative Reform (OMSAR) and the Support for Improvement in Governance and Management (SIGMA), a joint initiative of the Organisation for Economic Co-operation and Dvelopment (OECD) and the European Union.

Ms. Jamila Matar, Director of the Energy Department, League of Arab States (LAS), Egypt

It is a real pleasure to see that the NREAP 2016-2020 of Lebanon is following the Arab Renewable Energy Framework (AREF) developed by the Energy Department at the League of Arab States in partnership with RCREEE. Our concern has always been to have a harmonized cooperation among the member countries of the Arab World, and it is a pride that Lebanon is the first Arab country to develop its NREAP as per the requirements of the League of Arab States.

Chapter 14: Setup of a national grid code

This chapter of NREAP 2016–2020 focuses on the setup of a suitable grid code to integrate RE projects to the existing electrical networks. First, a description of the current overview is presented to be followed by the steps taken to develop a suitable grid code for the country.

It is worth noting that EDL is currently working with Électricité de France on developing a new master plan for the transmission network. The master plan would include all the planned RE projects expected between 2016 and 2020.

When developing a national grid code, several aspects related to the integration of RE must be taken into consideration, mainly the advantages offered to investors for RE connections along with any problems restricting connections of new projects.

In addition, one major challenge is to highlight any dispatching priorities for RE electricity or any access guarantees clarifying the access to the grid priorities between different RE resources and real time dispatching possibilities with any type of extra tariffs charged to the usage of the distribution and transmission grids.

14.1 Access to and operation of the grids

The integration of various renewable resources to the national power grid in Lebanon provides opportunities to improve the power sector in the country. However, it is well known that in order to ensure a reliable power system that incorporates variable renewable power resources, conventional generation will need to become more flexible, and there will be a need for additional automation and voltage and frequency regulation at the distribution level.

Furthermore, distributed, controllable generation and storage will need to be deployed to match the fluctuating levels of RE generation units. Using data networks in real time, smart grids can intelligently and automatically control these increasingly complex power systems (ABB, n.d.).

More explicitly, there are a few reasons for establishing a grid code for renewable generation as early as possible:

- The grid code describes the time response of renewable generation, which helps avoid malfunctioning.

- The grid code provides a general standardization of the most relevant electrical characteristics of the systems.

- Wind turbine generators and PV inverters are mass-produced, and any deviation from the standardized models implies additional costs.

In Lebanon, there is no text that specifies the exact requirements of connection of renewable energies to the grid. LCEC and UNDP-CEDRO have worked with EDL to develop within the net metering scheme a certain set of requirements for the connection of decentralized PV systems to the grid. On the other hand, the preparation of requirements of connection of large scale projects to the grid is still in its early stages despite the efforts done by LAS, RCREEE, LCEC, UNDP-CEDRO and UNDP-DREG. In fact, a clear and well-formulated grid code is essential in order to successfully integrate variable renewable into the grid and to guarantee the security of the electrical power system.

The grid code defines the operating procedures and principles governing the relationship between the system operator and all users (consumers, generators, distribution network operators). It affects all the elements of the electrical power system. It specifies all relevant procedures for both planning and operation stages under normal and exceptional circumstances.

The grid code should permit the development, maintenance, and operation of a safe, secure, and economically-feasible system for generation, transmission, and delivery of electrical energy. Moreover, it should be non-discriminatory and promote fair competition between the different electricity providers (ReGrid, n.d.).

14.2 Development of a grid code for renewable energy in Lebanon

When developing a grid code for renewable generation for the first time, two different approaches could be followed, knowing that each has its own advantages and disadvantages:

- A good approach is to incorporate renewable generation into already existing grid codes, because it allows better integration of renewables. In this case, aspects common to conventional and renewable generation, such as frequency levels, are not treated separately. Only aspects specific to renewable generation are defined additionally.

- A quicker option is to develop an independent grid code specifically for renewable generation. In this case, due to the similarities between PV and wind farms, it is possible to consider them together in one grid code. Renewable generation based on thermal processes (biomass, biogas) can be integrated into the existing grid codes for conventional generation.

In the Lebanese case, most of renewable thermal generation was considered in the scope of this NREAP for heat generation. Moreover, because EDL was and still is the sole official electricity producer there is no clear text for a conventional grid code. In the light of all what have been cited, the NREAP for Lebanon recommends development of a separate grid code for renewable electricity production.

In order to ensure an efficient development of this grid code the following elements should be integrated:

- Planning requirements-describe the information exchange between the system users and the system operator

- Connection condition requirements-contain the minimum technical requirements to be compiled by the system operator and the system users at all connection sites

- Operating requirements-technical specifications for the system operator on demand forecast, outage planning process, system security, isolation and earthing during maintenance operations, reporting and documentation of system faults

- Data registration requirements-necessary information that the system operator has to provide to the system user and vice versa (ReGrid, n.d.)

On the other hand, the main criterion of connection conditions is to minimize the cost of integrating renewable generation (including grid connection and electricity distribution) while maintaining system security. The connection conditions should also describe the active and reactive power capabilities, as well as further voltage control modes and the requirements for voltage recovery. The connection conditions specify the voltage levels at the point of connection over which disconnection is not allowed. The low-voltage ride-through capability (or fault ride through) means that a renewable generator is not allowed to disconnect in the case of a short-term voltage drop. On the other hand, high-voltage ride through means that a generator cannot disconnect if a short-term voltage rise has occurred.

Because most RE sources are intermittent, a renewable power plant cannot always deliver the rated power. Therefore, the grid code should always distinguish between rated capacity and maximum available power. The latter is the maximum power a renewable generation plant can deliver at a specific time. Figure 47 summarizes the basic parameters to be included in the future RE grid code.

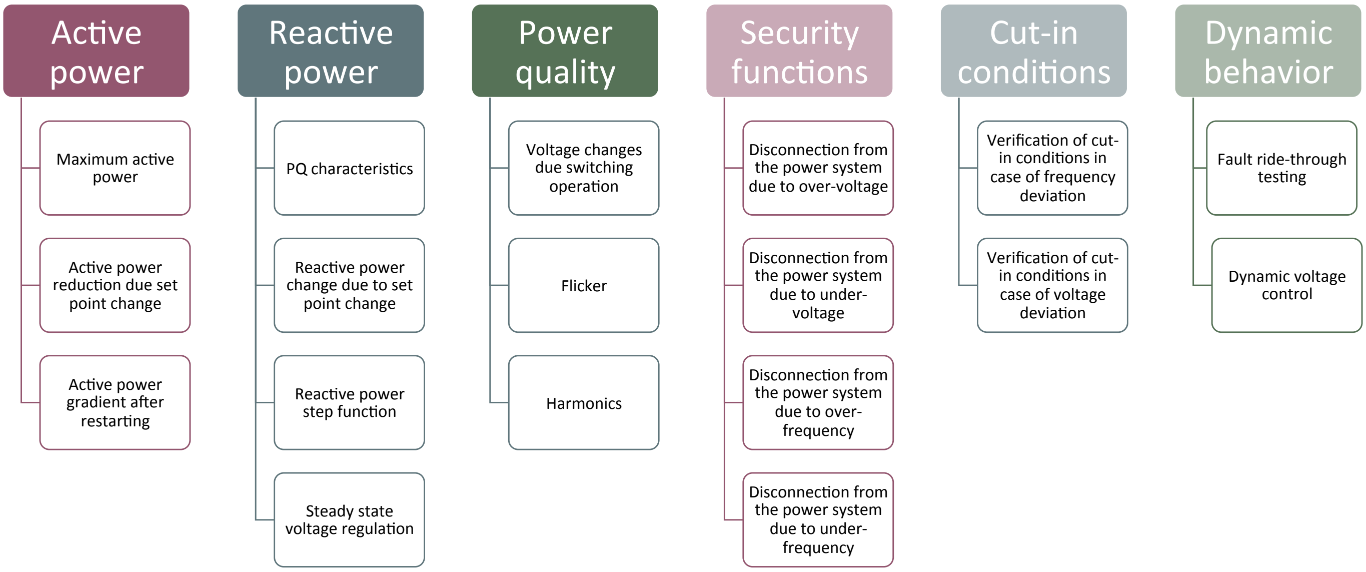


Figure 47. Grid code parameters

14.3 Grid code compliance

Grid codes specify all relevant procedures for both planning and operation phases under normal and exceptional circumstances. In this context, a grid code compliance study or compliance check ensures the security of the system by testing or verifying that all installations meet the grid code requirements. Additionally, it is highly recommended for large projects to conduct certified tests. In the case of non-compliance, reasonable sanctions should be imposed (ReGrid, n.d.).

Generally, the grid code compliance process has to be adapted to the overall size and cost of each project. Otherwise, there is a considerable risk that small projects will become economically unfeasible. With respect to small projects, a highly standardized procedure is essential to streamline the process for both grid operators and renewable generation operators/owners.

The grid code compliance tests are conducted at the different stages of the plant's development:

- Development and production of generating units (prototype testing and verifying of mathematical models describing the electrical behavior of the units).

- Planning stage-At this stage, it is essential for the plant planner to get verified mathematical models of the renewable generation and results of prototype testing. A compliance confirmation from the grid operator is also necessary. The reason being is that once the plant has started working, it is very difficult to add or modify components (e.g., reactive power compensation units). Very often this confirmation is also necessary for the bankability report (ReGrid, n.d.).

- Commissioning-Commissioning tests are crucial for the system operator to guarantee that everything works according to the concept and the connection conditions (ReGrid, n.d.).

The grid code is definitely one essential backbone for the introduction of large-scale RE power plants to the grid. In that respect, the role of EDL is of prime importance in ensuring the coordination among traditional power plants and the planned RE plants. These efforts need to be complemented by other national support policies and financing schemes, which will be presented in the next chapter.

Mr. Wael Hamdan, Director, Head of the Financing Unit, BDL, Lebanon

BDL has issued a large number of circulars offering subsidized loans to boost the national economy in Lebanon, with main focus on sustainable energy issues. The NEEREA financing mechanism issued by BDL has proven to be a very successful initiative, leading to more than USD 450 million of loans in a period of four years. The BDL is keen to keep this momentum towards a greener future for Lebanon.

Chapter 15: Support policies and financial schemes

The implementation of NREAP 2016-2020 requires a set of support policies and financial schemes. This current chapter is divided into two main parts. The first part is dedicated to the existing policies and schemes, and which are planned to continue until 2020 (net metering and the NEEREA financing mechanism). The second part includes a list of the potential policies that could be adopted and a description of what LCEC considers as a main prerequisite for the NREAP implementation.

It is important to note that list of policies is based on LAS requirements as mentioned in the Arab Renewable Energy Framework issued by RCREEE.

15.1 Net metering

The net-metering mechanism refers to the meter measuring electricity consumption and such a mechanism is mostly applied in the promotion of decentralized solar electricity. Net metering is a service to an electric consumer under which electric energy generated by that electric consumer from an eligible on-site generating facility and delivered to the local distribution facilities may be used to offset electric energy provided by the electric utility to the electric consumer during the applicable billing period. If the consumer has produced more electricity than the electricity consumed before, the local grid or distribution operator has to pay for the net production at the end of a fixed period at a fixed price.

Net metering has been applied to Australia, Denmark, Italy, Japan, Mexico, Spain, Thailand, Tunisia, and a number of US states. Examples of successful net-metering schemes are those developed in California and New Jersey. Some 23,000 solar systems were installed under these schemes by 2008. It is worth mentioning that net metering has been primarily developed to support the decentralization of solar generated electricity but it could be utilized also for other RE technologies. In Lebanon, net metering was launched by the MEW to be adopted by EDL in December 2011 based on a proposal by the UNDP-CEDRO project. However, EDL does not pay for the net production as defined above, This net production is credited to the next billing period and reset at the end of the year.

There are numerous advantages in net-metering schemes. In particular, the solar PV is usually produced during the daytime; therefore, there is availability of energy during the demand peak time. The combination of the scheme with flexible tariffs, according to the time-of-day during which the energy is consumed by the consumers, can generate a significant income for consumers. It is very easily manageable, transparent and, when purchasing prices of net production are appropriately fixed and revised, not particularly costly for governments.

Recently, EDL added a new dimension to net metering called community net metering allowing communities to apply to this scheme. Currently, all operational procedures to apply community net metering are under preparation. Community net metering is expected to give a huge push to decentralized RE generation.

15.2 The National Energy Efficiency and Renewable Energy Action support mechanism

NEEREA is an ongoing financing mechanism that was initiated by BDL in collaboration with MEW and LCEC. NEEREA's goal will always be to finance private projects where RE is the key. These projects may vary from existing buildings, new buildings, industrial projects, or agricultural ones. It offers soft loans with a grace period and very low interest rate.

The concept of having a national action called NEEREA was introduced in NEEAP 2011-2015. NEEREA is one of the 14 initiatives of the first NEEAP of Lebanon. It is worth noting that COM approved NEEAP 2011-2015 on November 10, 2011 (Decision No. 26).

It is undisputable that financing mechanisms are an extremely effective way to boost EE, RE, and green buildings in a country. Fortunately, Lebanon is characterized by one of the best financing mechanisms in the region. On November 25, 2010, BDL issued Circular No. 236 setting the conditions of application for green loans under the NEEREA financing mechanism. NEEREA is dedicated to support the financing of new and existing environmental projects, including EE, RE, and green buildings implementations.

NEEREA allows private sector entities (individuals, SMEs, or corporate bodies) to apply for subsidized loans for any type of EE and/or RE projects. Loans are available to all subsidized (industrial, agricultural, tourism, information technology, and research) and non-subsidized sectors (residential, commercial, non-profit organizations). NEEREA finances new environmentally friendly projects as well as enhancing the conditions of existing projects to become environmentally sound.

Another extremely important characteristic of NEEREA is that greens loans are provided through any of the Lebanese commercial banks to directly reach the end user. To date, more than 17 Lebanese banks are involved in the NEEREA mechanism. Still, the most important aspect of NEEREA is that it is a fully national mechanism, meaning that the incentives of NEEREA are based on incentives created and offered by BDL.

As part of this NREAP 2016-2020, LCEC expects that NEEREA would continue for at least the next five years (until 2020). NEEREA has proved its success as an innovative financing mechanism. The current available fund for subsidized loans by BDL, including NEEREA, is approximately USD 1 billion per year. NEEREA will be boosted by a new credit line by the European Investment Bank (EIB) and Agence Française de Développement (AFD) with a total value of EUR 80 million.

LCEC considers that the effect of NEEREA is and will continue to be a huge market driver for RE development, especially decentralized RE systems (mainly decentralized solar PV and biomass applications). NEEREA could be also used to finance larger RE projects.

At this stage, it is important to clarify that the work of LCEC does not include any other financial support mechanism except NEEREA. All other types of support like subsidies, capital grant, tax exemption, tax reduction, or tax refunds are not part of the work of LCEC and will not be considered in this NREAP.

Around the world, a mix of regulatory policies, fiscal incentives, and public financing mechanisms including Feed-in-tariff (FIT) policies, renewable portfolio standards (RPS), net metering, tax reductions or exemptions, grants, low-interest loans, and public competitive bidding /tendering continue to be adopted to promote increased renewable power capacity or generation (REN21, 2014). This section explains a number of RE support policies from all over the world while addressing the applicability of each of them within the Lebanese context.

15.3 Support policies for large-scale renewable energy projects

Around the world, a mix of regulatory policies, fiscal incentives, and public financing mechanisms (including FIT policies, RPS, net metering, tax reductions or exemptions, grants, low-interest loans, and public competitive bidding, tendering) continue to be adopted to promote increased renewable power capacity or generation (REN21, 2014).

The Arab Renewable Energy Framework (issued by LAS and RCREEE) lists a number of support policies needed for large-scale RE projects, including:

- Renewable energy targets
- FIT/premium payment
- Electric utility quota obligation
- Tradable renewable energy credits

- Tendering
- Heat obligation/mandate
- Capital subsidy or rebate
- Investment or production tax credits
- Reductions in sales, energy, CO_2, VAT, or other taxes/public investment, loans or grants

This section presents the potential RE support policies, offering first a general worldwide review, and then addressing the applicability of each of them within the Lebanese context.

15.3.1 Renewable energy targets

By early 2014, at least 144 countries had RE targets and 138 countries had RE support policies in place (REN21, 2014). Developing and emerging economies have led the expansion in recent years and account for ninety-five of the countries with support policies, up from fifteen in 2005 (REN21, 2014). Lebanon is one of the countries that declared their national targets during COP 15 to the UNFCCC in December 2009.

15.3.2 Feed-in tariff premium payment

From a historic and international perspective, the FIT is one of the most commonly used cost-based incentive tools (Gifford, Grace, & Rickerson, 2011). A FIT policy states that utilities must purchase all renewable power for sale and in return receive a premium- the government sets prices (tariffs) through long-term contracts (Huang & Wu, 2011). Premium payments or a feed-in premium (FIP) is a type of feed-in policy, where producers of electricity from renewable sources sell electricity at market prices, and a premium is added to the market price to compensate for higher costs and thus to mitigate financial risks of renewables production (REN21, 2014).

However, during the last years, several drawbacks were encountered by FIT all over the world, especially in Spain, when it comes to keeping up with contracts with high costs of electricity combined with decreasing prices of oil, causing thereby major financial losses.

LCEC believes FIT is not a wise option for Lebanon. Given the high costs of electricity generation by EDL, most tariffs adopted for RE would be lower than the average cost of EDL.

15.3.3 Electric utility quota obligation

Electric utility quota obligations, generally called RPS, require electric utilities to provide renewable electricity to their customers, typically as a percentage of total energy use (Cory, Couture, & Kreycik, 2009). It is important to note the main differences between FIT and RPS policies to understand their potential relationship with each other. RPS mandates prescribe how much customer demand must be met with renewables, while properly structured FIT policies attempt to support new supply development by providing investor certainty (Cory et al., 2009).

In the Lebanese context, the restrictions of having a stable investment environment and reliable government revenue streams to have an effective FIT policy do not exist for an RPS. However, RPS policies may encounter several other challenges, such as uncertainties with project financing, high contract failure rates, and little local and community-scale involvement in RE development (Cory et al., 2009).

After adoption of the NREAP by the Lebanese Government, this latter will specify the share of RE projects to be developed through national funds; especially that adopting RE as a substitute of conventional energy will lead to major economic benefits in most of the cases.

15.3.4 Tradable renewable energy credits

Renewable energy credits are certificates that represent the value of a specific amount of renewable electricity that has been generated, and are typically amassed in units that represent 1 MWh of electricity, equivalent to 1,000 kWh. Electric utilities purchase such credits to help meet requirements that they produce a certain percentage of electricity from renewable sources (ETC Green, n.d.).

A tradable scheme in Lebanon could be designed to promote price parity by allowing entities to participate in each other's auctions, rather than the expectation of significant transfer of allowances on the secondary market. Several questions should be addressed by such a mechanism especially when dealing with the real emission reduction value of those credits. Given that Lebanon is not a major trading partner with regional superpowers, such a mechanism is not a priority for development in Lebanon (Phillips, 2015).

15.3.5 Tendering

Public competitive bidding, or tendering, continues to gain prominence, with the number of countries turning to public auctions increasing from 9 in 2009 to 55 by early 2014 (REN21, 2014). Central and South American countries continue to be global leaders in RE tenders (REN21, 2014).

In Lebanon, this is one of the most promising financing tools for large-scale RE projects for several reasons. This policy echoes the methodology proposed for the implementation of laws 288 (2014) and 54 (2015) described in the previous chapter.

15.3.6 Heat obligation/mandate

This is a measure that requires designated parties (consumers, suppliers, generators) to meet a minimum, and often gradually increasing, target for RE, such as a percentage of total supply or a stated amount of capacity (REN21, 2014). Costs are generally borne by consumers. Mandates can include RPS, building codes or obligations that require the installation of renewable heat or power technologies (often in combination with EE investments), renewable heat purchase requirements, and requirements for blending biofuels into transport fuel (REN21, 2014).

Given the inexistent market of large-scale independent energy producers in the national grid, combined with the absence of community heating networks, having a heat obligation/mandate in Lebanon is still not viable.

15.3.7 Capital subsidy or rebate

Capital subsidies and rebates reduce the installed cost of a RE project. Capital subsidies are often paid in lump sum payments, while rebates are frequently determined on a USD/kW basis. This can have a very good potential in Lebanon, especially based on grants from international donors like the one that was included for small scale projects by the European Union-funded grant for SMEs providing some grants and limited subsidies for newly developed RE projects.

15.3.8 Investment or production tax credits

Governments can provide tax credits, refundable tax credits, and cash grants for investment in or production of RE that either allow the taxpayer to subtract a certain portion of the cost from the amount of taxes owed on a dollar-for-dollar basis or provide a refund if the credit exceeds the amount of gross tax owed.

The taxation system in Lebanon consists of scheduler income taxes, which mainly include corporate tax on profits, tax on wages and salaries, and tax on income from movable capital. Other taxes include a VAT, stamp and customs duties, social security contribution, and property tax.

An exemption from the 10% VAT tax (sales tax) or the 5% custom duties, or both, for the import of RE products, for example, would require an amendment of the respective laws and thus would require Parliament's ratification but would present a very good incentive for RE projects. LCEC does not consider that investment or production tax credits are a priority in the context of this current NREAP.

15.3.9 Reductions in sales, energy, CO_2, VAT, or other taxes/public investment, loans, or grants

Fiscal incentives, such as loans, grants, and tax reductions, have been used successfully by many countries in their off-grid renewable electricity programs to address the barrier of high upfront costs (REN21, 2014).

Taxation of GHG emissions from the combustion of energy effectively starts to put a price on emitting carbon and may be a natural progression after the removal of fossil fuel subsidies in the country. However, taxing fossil fuels is not as economically efficient as developing an emissions trading scheme and it has three main drawbacks (Phillips, 2015):

- A tax does not guarantee the achievement of a particular level of performance since those who want to emit more can do so simply by paying more
- Consequently the level of the tax is difficult to justify
- Taxes are traditionally a political auction, which aspiring political parties often pledge to reduce in an attempt to win votes-this undermines the long-term price signals, which are needed to encourage emitters to switch to low carbon technologies

The other problem with taxes is that they tend to be regressive in nature, penalizing low-income groups and certain sectors of the economy more than others. In order to reduce the negative impacts of taxation, it is necessary to design and implement effective redistribution strategies so that those worst affected can be relieved of the burden whilst those who are most able to pay can continue to do so (Phillips, 2015). Again, LCEC does not consider this issue as a priority in the context of this current NREAP.

As a conclusion, a healthy fiscal policy is required in order to introduce various measures enabling the RE market in Lebanon. Fossil-fuel subsidies in the Lebanese electricity sector, as stated, are in the form of direct cash transfers to EDL. Therefore, there needs to be a fossil fuel subsidy reform plan put in place that has to end up with a gradual phasing-out of these subsidies (Clements et al., 2013). The following table resumes all the studied policies in the scope of this document all along with their status.

Table 45 shows a synthesis of the different policies for large scale renewable energy projects in Lebanon.

Table 45. Support policies for large scale renewable energy projects

Name of the policy/measure	NREAP recommendation
Renewable energy targets	To be updated regularly
FIT/FIP	Not considered
Electric utility quota obligation	Not considered
Tradable renewable energy credits	Not considered
Tendering	Mandatory
Heat obligation/mandate	Not considered
Capital subsidy or rebate	Mandatory
Investment or production tax credits	Not considered
Reductions in sales, energy, CO_2, VAT, or other taxes/ public investment, loans, or grants	Not considered

One final note: On research and development, emerging technologies, and accompanying activities

The national path of Lebanon towards its 2020 objectives rely heavily on mature and well developed RE sources, namely wind, solar, and hydro. These three main pillars are fundamental in reaching the 767 ktoe target by 2020. However, and on a parallel path, other “emerging” RE technologies could play an effective role in the future.

The development of the new emerging technologies relies heavily on universities, research and development centers, and pioneering initiatives in the country. The purpose of this chapter is to highlight few emerging RE technologies that could have a more important role in the future energy mix of Lebanon. In addition, it is important to note that the role of universities and research centers is central in boosting the sustainable energy sector.

Looking more closely to the implementation of the NREAP 2016-2020, a lot of activities need to be carried out in order to ensure a suitable national framework. The following indicators are essential in that respect:

- Institutional participation to capitalization and dissemination activities (from both central administration and local administration)
- Number of capacity building seminars and workshops
- Number of training initiatives on sustainable energy
- Number of web activities and downloads related to training material
- Number of pilot training initiatives on new financial and market stimulus instruments
- Number of training activities for public administrations involved in the sustainable energy sector
- Number and mix of participants to project dissemination activities at local level.

Annex- Summary of barriers and mitigation options for bioenergy

Annex Table 1. Summary of barriers and mitigation options-Combustion-combined heat power, with a feedstock of residues from forestry felling

Barriers	Mitigation options
Pre-treatments required	Selection of most feasible alternative according to the heat source
	Financial support
Corrosion due to extreme operational conditions and sensitivity of alkali	Usage of feedstock with low contents of potassium and chlorine with this technology. Using the residues from felling as feedstock
Lack of current collection practices	Implementation of collection activities into governmental fire-fighting and forestry cleaning initiatives
Lack of technology suppliers in Lebanon	Research of suppliers overseas with closer headquarters and study of market prices
	Establishment and stimulation of technological industry in Lebanon
	Stimulation of technological industry in Lebanon
	Importing exemptions for equipment
Lack of accessibility of raw material	Analysis of the strategic location of the combustion-CHP plant
	Recollection regulation, best agricultural practices
	Proper development and maintenance of road infrastructure
Consumption of water	The treatment processes of forestry residues will be optimized to reduce the consumption of water to the minimum possible. The global water footprint related to fibers and vegetal origin biomass is 3537 m^2 per ton of biomass treated (Mekonnen & Hoekstra, 2010). This figure results from the following additional data found about consumption of water: The blue water footprint is 163 m^3/ton and the green water footprint is 3375 m^3/ton.. No gray water footprint is considered for forestry fellings.

Annex Table 2. Summary of barriers and mitigation options: Anaerobic digestion from olive and fruit trees residues

Barriers	Mitigation options
Variety in the quality of feedstock	Forestry management
Land, supply, and storage availability	Enforcement of regulation frameworks (Law 462 and Law 85)
Labor and staff expertise	Capacity building
	Memorandum of Understanding between BDL and UNDP for technical cooperation
	Awareness raising and promotion of social acceptance
Local conditions of the production chain	Flexibility in raw materials
	Improvement of logistics for distribution
High investment costs	Grants for clean energy development
	Tax exemptions of imported bioenergy equipment
Legislative policy framework	Regulation frameworks (Law 462 & Law 85)
	Coordination between ministries
Technology maturity in Lebanon	Investigating technology feasibility
	Set up of small-scale pilot plants
	Stimulation of technological industry in Lebanon

Barriers	Mitigation options
Consumption of water	The treatment processes of residues from olive and fruit trees will be optimized to reduce the consumption of water to the minimum possible.
	The water footprint related to residues from fruit depends on the specific sort of fruit: however, some general data found about cereals points to a global water footprint of 967 m^2 per ton of biomass treated (Mekonnen & Hoekstra, 2010). This figure results from the following additional data found about consumption of water: 727 m^3/ton which is the green water footprint for this biomass, 147 m^3/ton is the blue water footprint and 93 m^3/ton the grey water footprint.
	As for residues from olive trees, the total water footprint reaches 3,015 m^3/ton and the equivalent additional data is as follows (Mekonnen & Hoekstra, 2010): 2,470 m^3/ton of green water footprint, 499 m^3/ton of blue water footprint and 45 m^3/ton of grey water footprint.

Annex Table 3. Summary of barriers and mitigation options - Bioethanol from lignocellulosic energy crops

Barriers	Mitigation options
Additional transportation costs	Development /improvement and proper maintenance of road infrastructure
	Analysis of the strategic location of the plant
	Improvement of connecting roads infrastructure
Competition of residues from cereals with other end users	Research of the accurate percentage of feedstock available with energy purposes (collection trials of the feedstock left on the ground and the biomass directly burned)
Small-scale size limitations	Dissemination of the environmental advantages of using combustion/boiler technologies instead of burning the biomass directly
	Governmental subsidies, incentives and financial mechanisms to cover combustion / boiler expenses and make its use affordable on the domestic level
	Capacity building by workshops, trainings and provision of benchmark information
Lack of technology suppliers in Lebanon	Research of suppliers overseas with closer headquarters with consideration of market prices and rural population's purchasing power
Consumption of water	The treatment processes of residues from cereals will be optimized to reduce the consumption of water to the minimum possible. General data found about cereals points a global water footprint of 1644 m^3 per ton of biomass treated (Mekonnen & Hoekstra, 2010). This figure results from the following additional data found about consumption of water: 1,232 m^3/ton which is the green water footprint of this biomass, 228 m^3/ton is the blue water footprint and 184 m^3/ton the grey one.
Competition with other end uses	Choosing a feedstock that with the least competing end uses and highest sustainability criteria
Additional collection, handling and transportation activities	Improvement of transportation networks between available and suitable agricultural areas where energy crops would be cultivated
	Identification of a strategic location for the establishment of the lignocellulosic ethanol plant
Identification and negotiation of grasslands, unused lands and cannabis plantations	Identification of most adequate and accessible lands (administratively and geographically)
	Awareness rising within the farming communities of rural areas, namely in Nabatiyeh
	Capacity building
Intensive physical and chemical pretreatment	Governmental subsidies, incentives and financial mechanisms to cover plant expenses and make commercially profitable the bioethanol production
Water consumption with irrigation purposes	Choosing a feedstock with little water requirements and highest sustainability criteria. Perennial grasses and other lignocellulosic crops are a viable option under adapted technology
Lack of technology suppliers in Lebanon	Research of suppliers overseas with closer headquarter with consideration of market prices and rural population's purchasing power

Annex Table 3. Summary of barriers and mitigation options - Bioethanol from lignocellulosic energy crops

<table>
<tr><th>Barriers</th><th>Mitigation options</th></tr>
<tr><td>Consumption of water</td><td>The treatment processes of lignocellulosic energy crops will be optimized to reduce the consumption of water to the minimum possible. Depending on the type of energy crops studied, the water consumption of their treatment varies. In general terms, it is found a total water footprint of 1193 m3 per ton of biomass treated (Mekonnen & Hoekstra, 2010): 982 m^3/ton which is the green water footprint, 109 m^3/ton corresponds to blue water footprint and 102 m^3/ton to the grey one. The figures provided on this section have been calculated according to the average values of all energy crops suggested (Mekonnen & Hoekstra, 2010)</td></tr>
</table>

Annex Table 4. Summary of barriers and mitigation options - Anaerobic co-digestion of olive oil cake and other organic residues

<table>
<tr><th>Barriers</th><th>Mitigation options</th></tr>
<tr><td>Feedstock accessibility and variety of quality</td><td>Stimulate collection of residues in cooperatives with the help of subsidies, grants or funds</td></tr>
<tr><td rowspan="2">Land availability, supply, and storage</td><td>Storage of raw materials in cooperatives</td></tr>
<tr><td>Provide distribution lines</td></tr>
<tr><td>Local use of feedstock</td><td>Promote not only global distribution but also personal uses</td></tr>
<tr><td rowspan="2">Labor and staff</td><td>Capacity building: workshops, training, benchmark information</td></tr>
<tr><td>Promoting public acceptance in renewable energies</td></tr>
<tr><td>Local conditions production chain</td><td>Flexibility in raw materials as there are different feedstock</td></tr>
<tr><td>High investment cost</td><td>Financial incentives and regulations for RE</td></tr>
<tr><td rowspan="3">Legislative policy framework</td><td>Provide incentives for bioenergy</td></tr>
<tr><td>Define tariff regulations for electricity</td></tr>
<tr><td>Legal policy to support market</td></tr>
<tr><td rowspan="2">Technology maturity in Lebanon</td><td>Small scale units or pilot plants</td></tr>
<tr><td>Investment and development of local technology</td></tr>
<tr><td rowspan="3">Market absence</td><td>Legal framework to ensure entrance in the energy grid</td></tr>
<tr><td>Legal opening of the market to privatization</td></tr>
<tr><td>FITs for bioenergy options</td></tr>
<tr><td rowspan="4">Lack of a Master Plan specifically for organic municipal waste</td><td>Building and controlling of landfills</td></tr>
<tr><td>Municipal collection waste system</td></tr>
<tr><td>Implementation of a free to get rid of waste in order to maintain the collection system and landfills installations</td></tr>
<tr><td>Workshops and public training about the importance of the correct management of waste in areas where there have not been previous habits of controlled dumping</td></tr>
<tr><td>Consumption of water</td><td>The treatment processes of this biomass stream will be optimized to reduce the consumption of water to the minimum possible. The water footprint associated to olive oil cake depends on the production of olive oil as the cake is a by-product of this process. The total water footprint reaches 14,431 m^3/ton of virgin olive oil produced (14,726 m^3/ton for refined olive oil) (Mekonnen & Hoekstra, 2010). From these quantities: 11,826 m^3/ton corresponds to green water footprint (12,067 m^3/ton for refined olive oil), 2,388 m^3/ton to blue water footprint (2,437 m^3/ton for refined olive oil) and 217 m^3/ton to the grey one (221 for refined olive oil)</td></tr>
</table>

| References

ABB. (n.d.) ABB's smart grid technologies. Retrieved from ABB website: http://new.abb.com/smartgrids/smart-grid-technologies

Badoux, V., Ollinger, D., Baujard, C., & Mégel, T. (2014). *The National Geothermal Resource Assessment of Lebanon*. Retrieved from United Nations Development Programme-Country Energy Efficiency and Renewable Energy Demonstration Project for the Recovery of Lebanon website:http://cedro-undp.org/content/uploads/publication/141003044245906~The%20National%20Geothermal%20Resource%20Assessment%20of%20Lebanon.pdf

Bassil, G. (2010). *Policy Paper for the Electricity Sector***.** Lebanese Republic Ministry of Energy and Water. Retrieved from http://climatechange.moe.gov.lb/viewfile.aspx?id=121

Boyle, G. (2004). *Renewable energy: Power for a sustainable future.* Location: Oxford University Press.

Central Administration of Statistics. (2005). *Census of Buildings and Dwellings and Establishments 2004.*

Chaaban, F.B., Chedid, R., & Ginzarly, R. (2014). Design aspects of low-speed small-scale wind power permanent magnet generators. *Global Science and Technology Journal,* 2(1), 1–12.

Clements, B., Coady, D., Fabrizio, S., Gupta, S., Serge, T., Alleyne, C., & Sdralevich, C. (2013). *Energy subsidy reforms: Lessons and implications.* Washington, D.C.: International Monetary Fund.

Cory, K., Couture, T., & Kreycik, C. (2009). *Feed-in tariff policy: Design, implementation and RPS policy interactions* (NREL/TP-6A2-45549). Retrieved from National Renewable Energy Lab website: http://www.nrel.gov/docs/fy09osti/45549.pdf

El Khoury, P.T. (2006). *The use of natural gas for power generation in Lebanon: analysis of the proposed solutions for the Beddawi and Zahrani power plants* (master's thesis). American University of Beirut, Beirut, Lebanon.

ETC Green. No date, www.etcgreen.com.

Gifford, J.S., Grace, R.C., & Rickerson, W.H. (2011). *Renewable energy cost modeling: a toolkit for establishing cost-based incentives in the United States* (NREL/SR-6A20-51093). Retrieved from National Renewable Energy Lab website: http://www.nrel.gov/docs/fy11osti/51093.pdf

Global Wind Energy Council. (2012). www.gwec.net

Goodrich, A., James, T., & Woodhouse, M. (2012). *Residential, commercial and utility-scale photovoltaic (PV) system prices in the United States: Current drivers and cost-reduction opportunties* (NREL/TP-6A20-53347). Retrieved from National Renewable Energy Lab website: http://www.nrel.gov/docs/fy12osti/53347.pdf

Hassan, G. (2011). *The National Wind Atlas of Lebanon.* Retrieved from United Nations Development Programme-Country Energy Efficiency and Renewable Energy Demonstration Project for the Recovery of Lebanon website: http://cedro-undp.org/content/uploads/publication/141003044317718~The%20National%20wind%20Atlas%20for%20Lebanon.pdf

Huang, Y.H., & Wu, J.H. (2011). Assessment of the feed-in tariff mechanism for renewable energies in Taiwan. *Energy Policy*, 39(12), 8106–8115.

International Energy Agency. (2015). Unit converter. Retrieved from http://www.iea.org/statistics/resources/unitconverter/

International Renewable Energy Agency. (2012a). *Renewable energy technologies: Cost analysis series-Biomass for power generation, 1*(1/5). Retrieved from http://www.irena.org/DocumentDownloads/Publications/RE_Technologies_Cost_Analysis-BIOMASS.pdf

International Renewable Energy Agency. (2012b). *Renewable energy technologies: Cost analysis series-Concentrating solar power, 1*(2/5). Retrieved from http://www.irena.org/documentdownloads/publications/re_technologies_cost_analysis-csp.pdf

International Renewable Energy Agency. (2012c). *Renewable energy technologies: Cost analysis series-Hydropower, 1*(3/5). Retrieved from http://www.irena.org/DocumentDownloads/Publications/RE_Technologies_Cost_Analysis-HYDROPOWER.pdf

International Renewable Energy Agency. (2012d). *Renewable energy technologies: Cost analysis series-Solar photovoltaics, 1*(4/5). Retrieved from http://www.irena.org/DocumentDownloads/Publications/RE_Technologies_Cost_Analysis-SOLAR_PV.pdf

International Renewable Energy Agency. (2012e). *Renewable energy technologies: Cost analysis series-Wind power, 1*(5/5). Retrieved from http://www.irena.org/DocumentDownloads/Publications/RE_Technologies_Cost_Analysis-WIND_POWER.pdf

International Renewable Energy Agency. (2013). *Renewable power generation costs in 2012: An overview.* Retrieved from http://www.irena.org/DocumentDownloads/Publications/Overview_Renewable%20Power%20Generation%20Costs%20in%202012.pdf

International Renewable Energy Agency. 2015). *Renewable power generation costs in 2014.* Retrieved from http://www.irena.org/DocumentDownloads/Publications/IRENA_RE_Power_Costs_2014_report.pdf

Jaoudeh, E.A. (2015). *Solar water heaters' market evaluations: Case study of Lebanon 2015.* Nairobi, Kenya: United Nations Environment Programme.

Osseiran, K. (2013, February). Hydropower in Lebanon; History and prospects. *Cedro Exchange Issue Number 4.* Retrieved from http://cedro-undp.org/content/uploads/Publication/141009092113199~Exchange%204.pdf

Khoury, P. E. (2013). The Solar Water Heaters Market From 2009 to 2013 and the Way Beyond. *Beirut Energy Forum.* Beirut.

Ladanai, S. & Vinterbäck, J. (2009). *Global Potential of Sustainable: Bioenergy for Energy* (Report 013). Retrieved from Swedish University of Agricultural Sciences, Department of Energy and Technology website: http://www.worldbioenergy.org/sites/default/files/WBA_Global%20Potential.pdf

Lebanese Center for Energy Conservation. (2011). *The National Energy Efficiency Action Plan for Lebanon.*

Mauthner, F., & Weiss, W. (2014). Solar heat worldwide: Markets and contribution to the energy supply 2012. Retrieved from the International Energy Agency-Solar Heating and Cooling Programme website: http://www.iea-shc.org/data/sites/1/publications/Solar-Heat-Worldwide-2014.pdf

Mekonnen, M.M., & Hoekstra, A.Y., (2010). *The green, blue and grey water footprint of crops and derived crop products* (Value of Water Research Report Series Number 47). Delft, The Netherlands: UNESCO-IHE Institute of Water Education. Retrieved from http://waterfootprint.org/media/downloads/Report47-WaterFootprintCrops-Vol1.pdf

Ministry of Energy and Water. (2012). *The National Energy Efficiency Action Plan for the Republic of Lebanon-NEEAP 2011-2015*. Beirut, Lebanon: Ministry of Energy and Water and Lebanese Center for Energy Conservation.

Ministry of Energy and Water. (2016). *The Second National Energy Efficiency Action Plan for the Republic of Lebanon-NEEAP 2016-2020.* Beirut, Lebanon: Ministry of Energy and Water and Lebanese Center for Energy Conservation.

Phillips, G. (2015). *Opportunities for climate change policies and climate finance in Lebanon.* Unpublished manuscript.

ReGrid program, 2010-2014, . Capacity Building on Integration of Large Amounts of Renewable Energy into the Electricity Grids, Renac Germany.

Renewable Energy Policy Network for the 21st Century. (2013). *Renewables 2013 Global Status Report.* Retrieved from http://www.ren21.net/Portals/0/documents/Resources/GSR/2013/GSR2013_lowres.pdf

Renewable Energy Policy Network for the 21st Century. (2014). *Renewables 2014 Global Status Report.* Retrieved from http://www.ren21.net/Portals/0/documents/Resources/GSR/2014/GSR2014_full%20report_low%20res.pdf

Renewable Energy Policy Network for the 21st Century. (2015). *Renewables 2015 Global Status Report.* Retrieved from http://www.ren21.net/wp-content/uploads/2015/07/REN12-GSR2015_Onlinebook_low1.pdf

Shawon, M.J., El Chaar, L., & Lamont, L.A. (2013). Overview of wind energy and its cost in the Middle East. *Sustainable Energy Technologies and Assessments*, 2, 1-11.

Shehadeh, N. H. (2012). *The residential solar water heaters market in Lebanon in 2011: How can sound governmental policies boost a green economy.* Beirut, Lebanon: United Nations Development Programme and Global Environment Facility. Retrieved from http://www.greengrowthknowledge.org/sites/default/files/downloads/resource/the_residential_solar_water_heaters_market_lebanon_GEF.pdf

Sogreah-Artelia. (2012). S*chema Directeur Hydroelectrique du Liban.* Beirut, Lebanon: Ministry of Energy and Water.

Taylor, D., (2004). Wind Energy. In Boyle, G., Renewable Energy; Power for a Sustainable

Téllez, F., Obeid, J., & Karam, C. (2013, May). Concentrated Solar Plants. *Cedro Exchange Issue Number 7.* Retrieved from http://cedro-undp.org/content/uploads/Publication/141009092328246~exchange%207.pdf

United Nations Development Programme-Country Energy Efficiency and Renewable Energy Demonstration Project for the Recovery of Lebanon. (2011). *Concentrated Solar Power for Lebanon for 2012: A Techno-economic Assessment.* Retrieved from http://cedro-undp.org/content/uploads/publication/141008090642765~Concentrated%20Solar%20Power%20for%20Lebanon.pdf

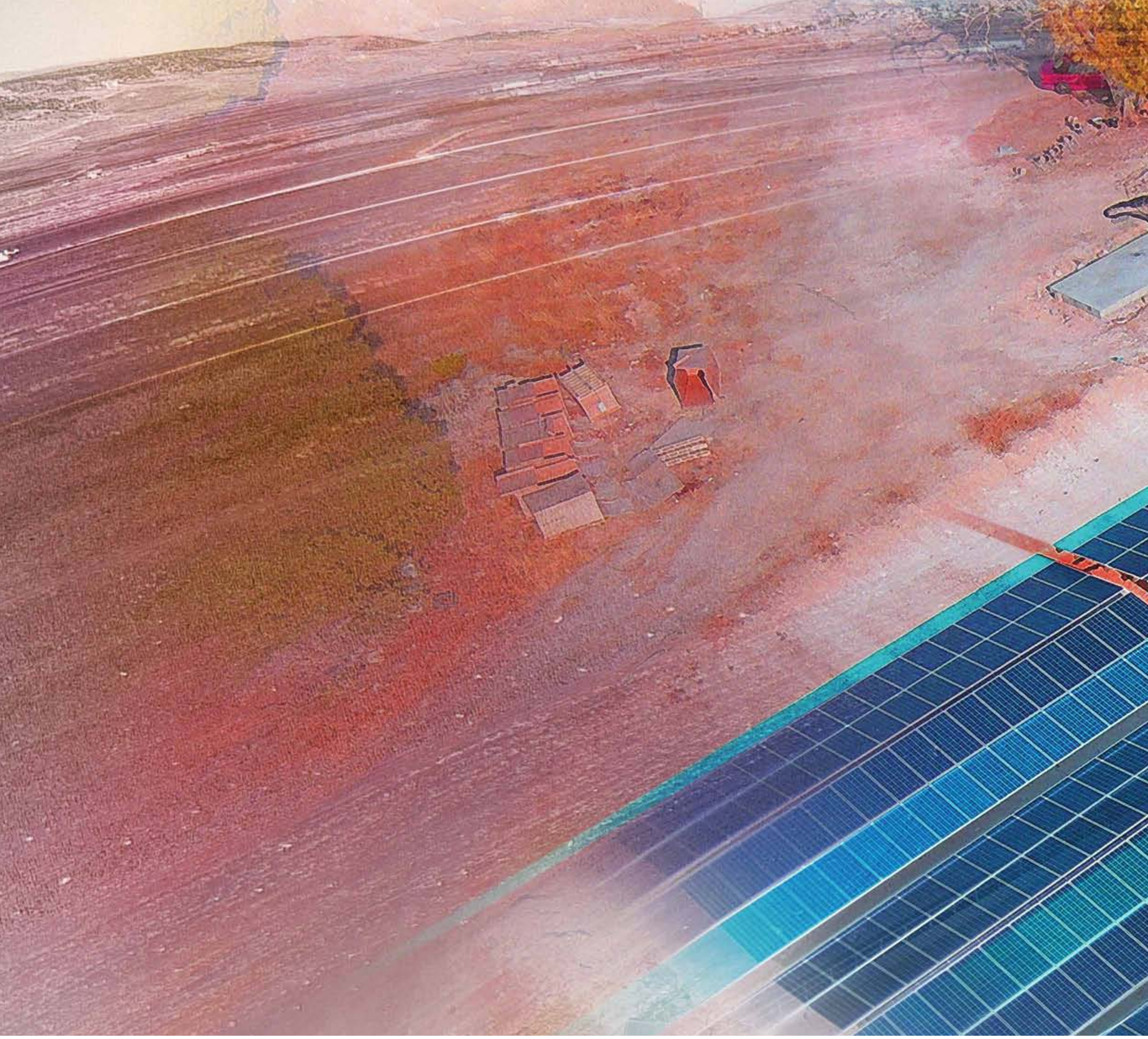
United Nations Development Programme-Country Energy Efficiency and Renewable Energy Demonstration Project for the Recovery of Lebanon. (2012). *The National Bioenergy Strategy for Lebanon.* Retrieved from http://cedro-undp.org/content/uploads/publication/141003043844453~The%20National%20Bioenergy%20Strategy%20for%20Lebanon.pdf

United Nations Development Programme-Country Energy Efficiency and Renewable Energy Demonstration Project for the Recovery of Lebanon. (2013). *Hydropower from non-river sources; The potential in Lebanon.* Retrieved from http://climatechange.moe.gov.lb/viewfile.aspx?id=55

United Nations Development Programme-Country Energy Efficiency and Renewable Energy Demonstration Project for the Recovery of Lebanon. (2014). *National Geothermal Resource Assessment.*

United Nations Development Programme-Country Energy Efficiency and Renewable Energy Demonstration Project for the Recovery of Lebanon. (2015). *Large-Scale Renewable Energy for Lebanon; Background Information on Resources, Economics, Grid Integration, Regulatory Requirements and Fiscal Incentives.* Beirut, Lebanon: United Nations Development Programme-Country Energy Efficiency and Renewable Energy Demonstration Project for the Recovery of Lebanon.

World Bank (2009). *Lebanon-Energy efficiency study in Lebanon.* Retrieved from http://documents.worldbank.org/curated/en/863271468055739324/pdf/703020ESW0P1130al0version00912180WB.pdf



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