Lebanese Republic
Ministry of Energy and Water: MoEW
Électricité du Liban: EDL

DATA COLLECTION SURVEY ON ELECTRICITY SECTOR IN LEBANON

FINAL REPORT

November 2023

Japan International Cooperation Agency
NEWJEC Inc.
Kansai Transmission and Distribution, Inc.

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Data Collection Survey

on

Electricity Sector in Lebanon

FINAL REPORT

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Symbol	Abbreviations
ACC	Arabian Construction Company
AGP	Arab Gas Pipeline
AMI	Advanced Metering Infrastructure
AST	Automatic Switching Equipment
AVR	Automatic Voltage Regulation
BDL	Banque du Liban
BMLWE (EBML)	Beirut & Mount Lebanon Water Establishment
BNSS	Beirut River Solar Snake Project
BUS	BUTEC Utility Services
BWE	Bekaa Water Establishment
CCGT	Combined Cycle Gas Turbine
CCPP	Combined Cycle Power Plant
CoM	Council of Ministers
CSP	Concentrating Solar Power
CT	Current Transformer
DGO	Directorate General of Oil
DRE	Distributed Renewable Energy
DSP	Distribution Service Providers
EBRD	European Bank for Reconstruction and Development
EDF	Électricité de France
EDL	Électricité du Liban
EDZ	Electricite de Zahle
EOI	Expression of Interest
ERA	Electricity Regulatory Authority
FSRU	Floating Storage Regasification Unit
GASYLE	The Lebanese Gas Pipeline
GIS	Geographic Information System
GMS	Global System for Mobile communications
GoL	Government of Lebanon
HFO	Heavy Fuel Oil
HPP	Hydro Power Plant
HRE	High Renewable Energy scenario
HSFO	High Sulfur Fuel Oil
ICE	Internal Combustion Engine

Symbol	Abbreviations
IEA	International Energy Agency
IPP	Independent Power Producer
IRENA	The International Renewable Energy Agency
JICA	Japan International Cooperation Agency
KPI	Key Performance Indicator
KVA	KVA SAL
LBP	Lebanese Pounds
LCEC	Lebanese Center for Energy Conservation
LNG	Liquefied Natural Gas
LOI	Lebanese Oil Installations
LPA	Lebanese Petroleum Administration
LRA	Litani River Authority
LV	Low Voltage
MOA	Ministry of Agriculture
MoD	Ministry of Defense
MoEW	Ministry of Energy and Water
MoI	Ministry of Interior
MoJ	Ministry of Justice
MRAD	MRAD Utility Services
MV	Medium Voltage
NCC	National Control Center
NEEREA	National Energy Efficiency and Renewable Energy Action
NEUC	The National Electrical Utility Company
NG	Natural Gas
NLWE	North Lebanon Water Establishment
NREAP	National Renewable Energy Action Plan
OCGT	Open Cycle Gas Turbine
ODA	Official Development Assistance
OH	Overhead
OJT	On the Job Training
OPGW	Optical Ground Wire
OQ	OQ
PG	Private Generator
PLC	Power Line Communication

Symbol	Abbreviations
PPA	Power Purchase Agreement
PPP	Public Private Partnership
PS	Pump Station
PSS	Power System Stabilizer
PV	Photovoltaic
RE	Renewable Energy
REmap	Renewable Energy Road Map
RFP	Request for Proposals
RoR	Run of River
SAIDI	System Average Interruption Duration Index
SAIFI	System Average Interruption Frequency Index
SCADA	Supervisory Control And Data Acquisition
SLWE	South Lebanon Water Establishment
SOMO	State Oil Marketing Organization
ST	Steam Turbine
TES	Total energy Supply
UG	Underground
UNDP	United Nations Development Programme
USAID	The United States Agency for International Development
VRE	Variable Renewable Energy
VT	Voltage Transformer
WB	World Bank
WE	Water Establishment

CHAPTER 1

INTRODUCTION

CHAPTER 1 INTRODUCTION

1.1 BACKGROUND OF THE SURVEY

Lebanon's Électricité du Liban (EDL), a vertically integrated public utility with exclusivity over electricity generation, transmission and distribution in the country, has been unable to meet prevailing demand in the country for decades. The Lebanese government has tackled strengthening the power sector with annual budget support, but it was mainly focused on fuel and operational expenditures remedying the generation capacity gap.

Currently, Lebanon is under an economic and financial crisis which is compounding the power sector's historical challenges. Although EDL has installed a generation capacity of around 2,300 MW excluding hydropower plants, the utility's ability to meet electricity demand, which was already limited before the crisis, has further deteriorated because of a lack of imported fuel supply.

In response to such a crisis, the Ministry of Electricity and Water (MoEW) finalized its comprehensive 5-years plan (2022-2026) "Setting Lebanon's Electricity Sector on a Sustainable Growth Path", following "Update of the Transmission Master Plan of Lebanon" by Électricité de France (EDF) in 2017, "Emergency Action Plan" by World Bank in 2020, and "Least Cost Generation Plan" by EDF in 2021.

In addition to implement the objectives of this kind of integrated energy master plan, the master plan must be systematically updated every 3-5 years to reflect the change in demand, demographics, technology, environmental standards, and other policy initiatives/priorities. To ensure it, MoEW and EDL need to keep developing the capability of their employees to update the master plan so that valuable institutional memory can be accumulated and planning stability can be secured in a longer term. In addition, streamlined coordination with separate departments/entities within MoEW such as EDL, Lebanese Petroleum Administration (LPA), Lebanese Oil Installations (LOI) and Lebanese Center for Energy Conservation (LCEC) is imperative for the master plan to be more realistic and practical.

In order to achieve the above, an institutional framework must first be established that involves all key stakeholders and redefines their roles at various stages of the planning process, thereby facilitating the MoEW to develop and regularly update an integrated energy master plan. To this end, it is important that the MoEW, EDL, and their related organization take the opportunity to learn about policy making in the Japanese power sector and gain a better understanding of integrated energy infrastructure planning in Japan. In addition, the administrative and technical capacities of the MoEW, EDL, and their related organizations need to be enhanced. Under these circumstances, the request for technical cooperation for the Integrated Electricity Master Plan has been submitted to the Japan International Cooperation Agency (JICA).

1.2 OUTLINE OF THE SURVEY

Items	Contents
Object, Scope of Work	The purpose of this study is to collect and confirm basic information on the current status and issues related to the electricity power sector reform (mainly to strengthen the capacity for the electricity master plan) in response to the Government of Lebanon's policy document and to facilitate discussions and consensus building between the Lebanese sector parties and JICA on the future direction of cooperation. Scope of Work of study are as follows 1) to organize the information on formulating the detail plan of the technical cooperation "Project for Strengthening Institutional Capacity to Develop Integrated Electricity Master Plan", and to facilitate discussions and consensus building between the Lebanese electricity sector stakeholders and JICA on the future direction of cooperation. 2) to collect information on the rehabilitation of the hydropower generation facilities under the MoEW, 3) to collect information on development of a dedicated line to the water treatment facility.
Target Area	Lebanon
Implementation Agency	✓ Ministry of Energy and Water：MoEW ✓ Électricité du Liban：EDL

1.3 IMPLEMENTATION STRUCTURE

1.3.1 Counterpart of Lebanese side

Lebanese side assigned the following members as counterparts for this Preparatory Survey.

Table 1.3-1 Lebanese side Counterpart

<table>
<tr><th>Areas of expertise</th><th>MoEW</th><th>EDL</th></tr>
<tr><td>Chief Consultant ／
Power Development Plan</td><td rowspan="2">Dr. Khaled Nakhle</td><td rowspan="3">Mr. Jihad Ghadieh
Transmission Department
Rabih Daw:
Ramzie Dbaisy
Rabih Daou
Study Directorate
Ghada Shartounieh
Rima Assaf
Raja El-Ali
Ghada Charfouni
Gladys Daru
Eclectic Department
Nabim elabus
Transmission Network Department
Ramzi El Dobeissy</td></tr>
<tr><td>Deputy Chief Consultant /
Power Development Plan</td></tr>
<tr><td>Power Grid System
(Transmission)</td><td></td></tr>
<tr><td>Power Grid System
(Distribution)</td><td></td><td>Beirut division (Distribution)
Tarek Mausow
Regional Distribution
Ghassam Darwich
Distribution (Beirut and ML)
Ibrahim Moussa</td></tr>
<tr><td>Renewable Energy</td><td>Renewable energy project planning is being developed in MoEW</td><td>Generation department
Bshara Etieh
Fadi Abo Khouzam</td></tr>
<tr><td>Hydroelectric Power Generation
(Rehabilitation Planning)</td><td></td><td>Production Department
Bshara Etieh
Fadi Abo Khozam
Hydropower Department
Faoli Bon Khsam</td></tr>
<tr><td>Power Transmission and
Substation (Planning and Design)</td><td>Suzy Howayek</td><td></td></tr>
</table>

1.3.2 JICA Study Team Members

This survey was implemented by the following team members (JICA Study Team).

Table 1.3-2 Member of JICA Study Team

Assignment	Name	Organization
Chief Consultant／ Power Development Plan	Kenichiro YAGI	NEWJEC Inc
Deputy Chief Consultant／ Power Development Plan	Sho SHIBATA	NEWJEC Inc
Power Grid System (Transmission)	Kiyotaka UENO	NEWJEC Inc
Power Grid System (Distribution 1)	Kei OTSU	Kansai Transmission and Distribution, Inc
Power Grid System (Distribution 2)	Hiroki BANDO	Kansai Transmission and Distribution, Inc
Power Grid System (Distribution 3)	Keisuke MORITA	Kansai Transmission and Distribution, Inc
Renewable Energy	Takao SARUHASHI	NEWJEC Inc
Economic and Financial Analysis	Fukashi KUMURA	NEWJEC Inc
Hydroelectric Power Generation (Rehabilitation Planning)	Iturou MIYATA	NEWJEC Inc
Power Transmission and Substation (Planning and Design)	Kazuo MURAI	NEWJEC Inc
Environmental and Social Considerations/ Coordinator1	Fumiya SAITO	NEWJEC Inc
Environmental and Social Considerations/ Coordinator2	Hiroki YAMAGUHCI	NEWJEC Inc

CHAPTER 2

CURRENT SITUATION AND ISSUES OF THE POWER ENERGY SECTOR IN LEBANON

CHAPTER 2 CURRENT SITUATION AND ISSUES OF THE POWER ENERGY SECTOR IN LEBANON

2.1 MAJOR POLICIES AND PLANS IN THE ENERGY AND POWER SECTOR WITH LEBANESE GOVERNMENT AND DONOR SUPPORT

2.1.1 Policy and Upper-Level Plans for the Power Sector

In Lebanon, the Ministry of Energy and Water (hereinafter referred to as "MoEW") is responsible for the electricity sector. The largest domestic electricity utility is Électricité du Liban (hereinafter referred to as "EDL"), established in 1964, which owns major power plants and the backbone transmission network, supplying over 90% of the country's electricity consumption. The private sector participation is allowed in power generation, excluding the transmission business. Besides EDL, other power generation companies such as Office National Du Litani, Nahr Ibrahim, Al Bared and others operate. Additionally, the power distribution companies like Électricité de Zahlé (hereinafter referred to as "EDZ") in various cities, as well as Jubaili and Aley are involved (Fig. 2.1-1).

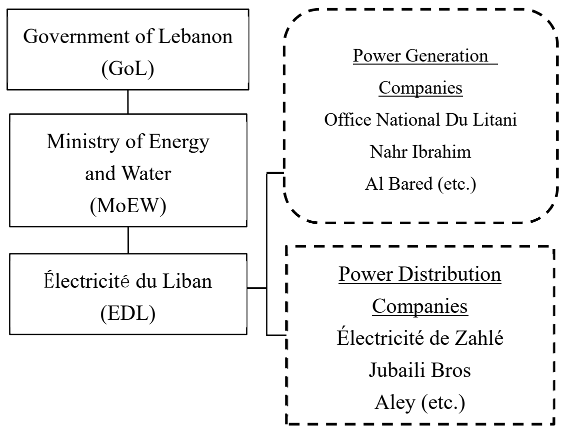


Fig. 2.1-1 Organizations Related to Electricity in Lebanon

Table 2.1-1 Major policies and plans in the energy and power sector with Lebanese government and donor support

	Name	Issuing Authority	Issuance Date	Remarks
1	Setting Lebanon's Electricity Sector on a Sustainable Growth Path	Ministry of Energy and Water	March 2022	Policy document with reform goals such as increase supply of electricity, to achieve 24 hours per day and financial recovery on the EDL.
2	Least Cost Generation Plan	World Bank, Électricité de France	September 2021	Latest demand forecast, power generation development plan, and supply/demand until 2030.
3	Lebanon Power Sector Emergency Action Plan	World Bank	2020	Proposal for emergency measures such as strengthening inter-departmental collaboration and establishing planning departments.
4	Updated Policy Paper for the Electricity Sector	Ministry of Energy and Water	March 2019	Decrease of the transmission and distribution losses. Increase the generation capacity by using Natural Gas
5	Update of the Transmission Master Plan of Lebanon	Électricité de France	May 2017	Proposal for transmission network expansion projects accompanying power generation development and the utilization of renewable energy.
6	The National Renewable Energy Action Plan for the Republic of Lebanon 2016-2020	Lebanese Center for Energy Conservation	November 2016	Proposal for strategic planning to the national renewable energy sector in Lebanon

Among the upper-level plans shown in Table 2.1-1, the policy document "Setting Lebanon's Electricity Sector on a Sustainable Growth Path" is crucial for the reform of the power sector, given the concern about the ongoing situation of limited electricity supply of approximately 3-4 hours per day. The reform framework is based on Électricité de France's (EDF) "Least Cost Generation Plan" and the World Bank's (WB) "Lebanon Power Sector Emergency Action Plan" aiming to achieve 24 hours per day within four years.

To achieve this, proposals include: 1) ~ 4) Development of power generation and distribution facilities for fiscal reconstruction, 5) Governance reform. As part of the fifth governance reform, strengthening the capacity for developing an Integrated Master Plan is suggested, aiming to enhance coordination among energy sector organizations through the value chain and establish planning departments.

Additionally, updating the Master Plan by Lebanese engineers themselves is also necessary.

2.2 POWER SUPPLY AND DEMAND SITUATION, ELECTRIFICATION RATE, POWER LOSS, BLACKOUT TIME AND FREQUENCY, DAILY LOAD CURVE, POWER DEMAND FORECAST, ETC.

2.2.1 Power Demand Forecast and Power Supply and Demand Situation

In 'Least Cost Generation Plan[1] ', power demand is expected to grow at an average annual rate of 2.8% from 3,393 MW in 2022 to 4,232 MW in 2030, as shown in Fig.2.2-1.

Looking at the current state of the power supply side, the current generation capacity (2020) is 2,670 MW (of which, thermal power: 2,381 MW, hydro power: 282 MW, renewable energy: 7 MW), but demand is exceeding it. However, domestic power generation capacity remains at about 70% of peak demand, and long-term rolling blackouts (load shedding) are also being implemented. The Lebanese government has formulated a national strategy and development plan for the development of power sources, mainly thermal power, in order to improve this serious supply-demand gap, but no improvement has been achieved. In order to improve this situation, it is necessary to construct and refurbish power generation facilities in a phased and prompt manner, to secure and transport fuels such as natural gas, and to develop power transmission and distribution line facilities in a timely manner with the expansion of power generation facilities. This is an urgent issue.

Fig.2.2-1 shows the power demand forecast, Fig.2.2-2 shows the power development plan, and Table2.2-1 shows the power demand forecast and supply capacity development plan. Steady power development centered on large-scale combined-cycle thermal power generation is planned in the Least Cost Generation Plan.

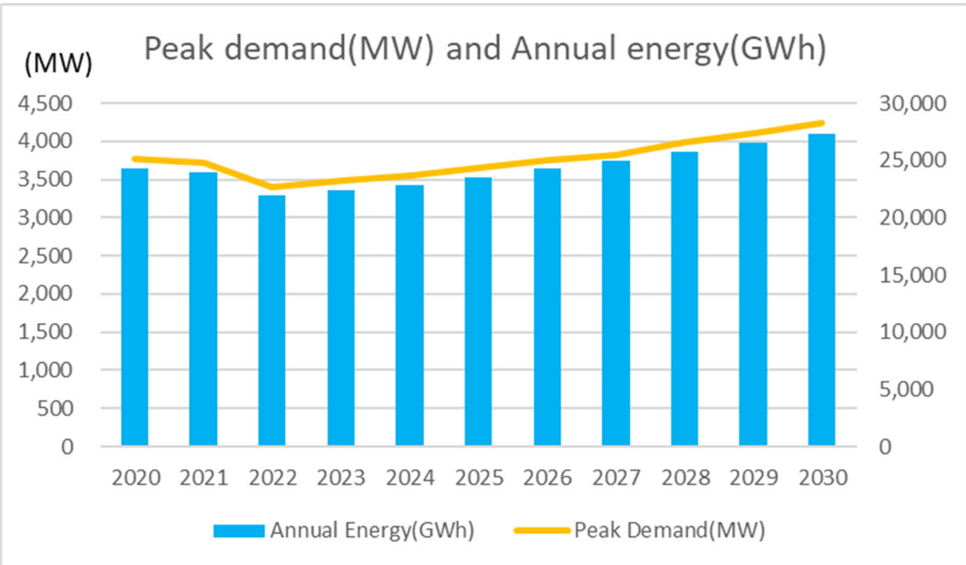


Fig.2.2-1 Power Demand Forecast in Lebanon

[1] Least Cost Generation Plan (WB-EDL-MoEW, September2021)

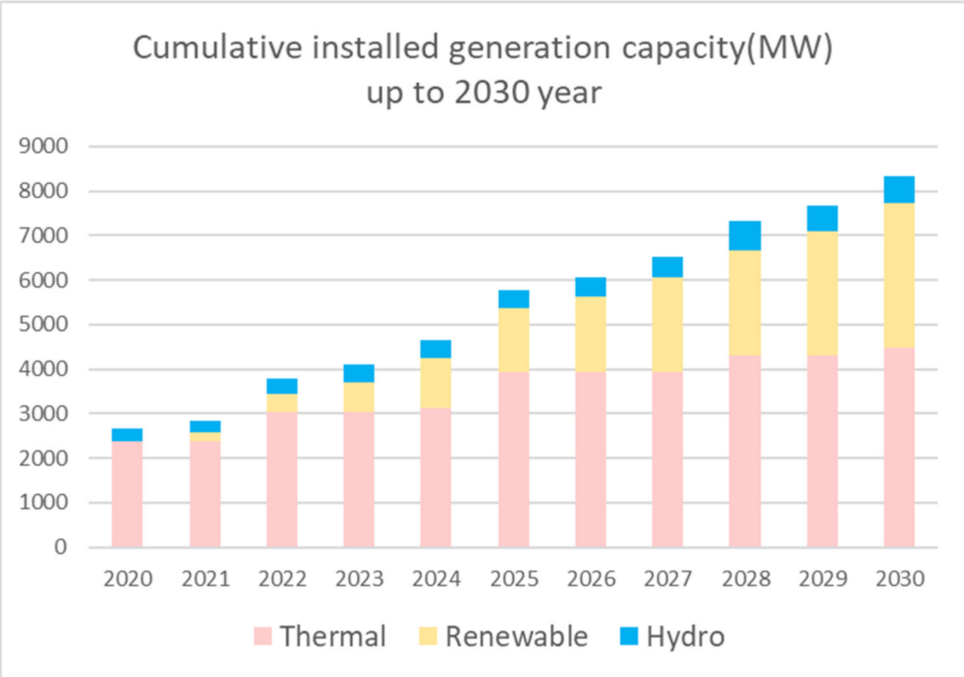


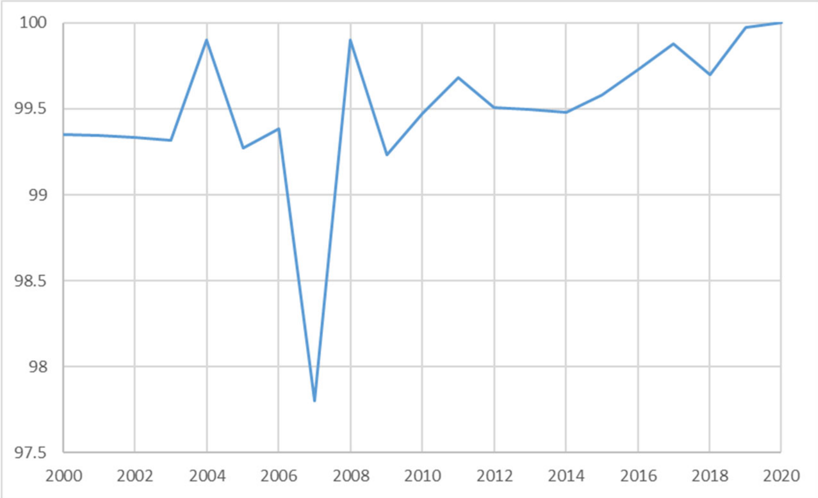
Fig.2.2-2 Power Generation Development Plan in Lebanon

Table2.2-1 Power Demand and Supply Plan in Lebanon

Item		FY										
		2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030
Available capacity(MW)	Thermal	2,015	2,015	2,725	2,725	2,880	3,722	3,722	3,722	4,096	4,096	4,272
	Hydro	28	28	34	39	39	39	43	47	51	55	59
	Renewable	3	19	35	58	94	118	141	177	199	234	270
	Storage	0	0	0	4	4	4	53	53	53	53	53
	Total	2,046	2,062	2,794	2,826	3,017	3,883	3,959	3,999	4,399	4,438	4,654
Peak Demand(MW)		3,773	3,717	3,393	3,477	3,544	3,650	3,760	3,872	3,989	4,108	4,232
Supply capacity shortage(MW)		-1,727	-1,655	-599	-651	-527	233	199	127	410	330	422
Capacity Margin(%)		-46	-45	-18	-19	-15	6	5	3	10	8	10

2.2.2 Electrification Rate

Fig. 2.2-3 shows transition in the electrification rate. According to EDL's transmission department, the current electrification rate is 99%, and the remaining 1% is non-electrified in the village of "Toufail" located in the Middle East, near the border with Syria.



Source: WB data

Fig. 2.2-3 Transition of Electrification Rate

2.2.3 Power Loss

In the power transmission and distribution sector in Lebanon, large power loss is raised as a problem. The total power system loss in 2021 is 40.2%, which is high compared to neighboring countries (Table 2.2-2). This large power loss is causing deterioration of EDL finances, stagnation of capital investment, and further deterioration of distribution services. A 1% reduction in electricity loss will improve EDL's earnings by approximately 20 billion LBP (approximately 18,000,000 yen) in a policy document for the electricity sector, contribute significantly. In recent years, although there has been an improvement trend due to countermeasures against power theft, etc., further improvement is necessary in view of the tight supply and demand situation.

Table 2.2-2 EDL Loss Reduction Plan (EDL Approved Index)

	2019	2020	2021	2022	2023	2024	2025	2026
Transmission Losses	5.7%	5.7%	5.7%	5.7%	5.7%	5.5%	4.8%	4.0%
Distribution Losses	26.8%	32.9%	36.6%	32.2%	29.6%	27.0%	24.3%	22.6%
Technical Losses	13.2%	13.2%	13.2%	13.2%	12.8%	12.4%	12.0%	11.6%
Non-Technical Losses	15.7%	22.7%	26.9%	21.9%	19.3%	16.6%	14.0%	12.4%
Total Network Losses	31.0%	36.7%	40.2%	36.1%	33.6%	31.0%	27.9%	25.7%

Source：Setting Lebanon’s Electricity Sector on a Sustainable Growth Path Policy Statement (MoEW, March 2022)

We have confirmed with EDL's transmission department that the transmission loss of the power loss is currently 5.5%, and that the future target is 4.0% due to the improvement of the transmission voltage due to the expansion of the 220kV system.

On the other hand, the distribution loss will be 36.6% by 2021, which is at an internationally high level, and reduction is an important issue. Looking at distribution losses in detail, technical losses accounted for 13.2% and non-technical losses accounted for 26.9%. For this reason, Lebanon has been promoting the efforts shown in Table 2.2-3 for many years with the aim of reducing non-technical losses, which are among the largest distribution losses, but they have not yet produced significant results.

Table 2.2-3 List of issues and major initiatives for non-technical loss reduction in Lebanon

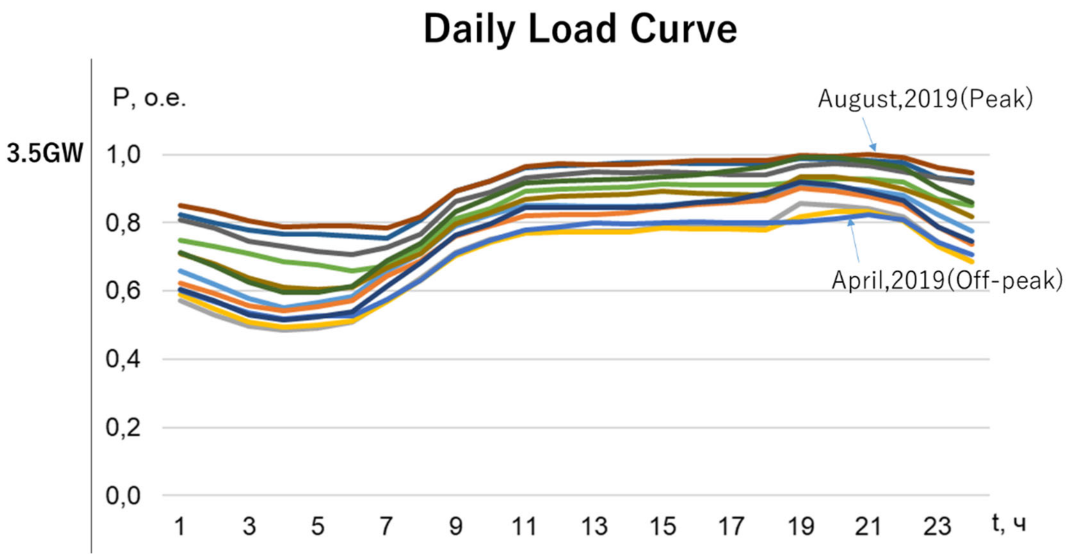
Theme	Efforts	responsibility	Implementation period
(1) Eradication of illegal connections	Illegal connection removal campaign (including protection by security forces and legal backup)	MoI - MoJ - MoD - MoEW - EDL - DSPs	2022-2023
(2) Optimization of electricity bill collection	AMI programs (introduction of smart meters, development of AMI centers, etc.)	MoI - MoJ - MoD - MoEW - EDL - DSPs	2022-2024

2.2.4 Power Outage Time/Frequency

Regarding the average power outage duration (SAIDI) and the number of power outages (SAIFI), we confirmed with EDL's power transmission department that these data are not currently being obtained due to rolling blackouts due to supply shortages. The implementation status of rolling blackouts will be described in Section 4.2, System Operation Situation.

2.2.5 Daily Load Curve

Fig. 2.2-4 shows the daily load curve for 2019 for hourly peak demand transition data (daily load curve). The peak season is August in summer and February in winter, and the off-peak season is April-May and October-November. Also, in a day, peaks occur during the lighting hours from 18:00 to 21:00. The peak demand in 2019 was 3.5GW. Due to the economic collapse that occurred after this year, the supply capacity has decreased significantly, and according to EDL's transmission department, the supply capacity is currently around 400 MW with a constant daily load curve throughout the 24-hour period.

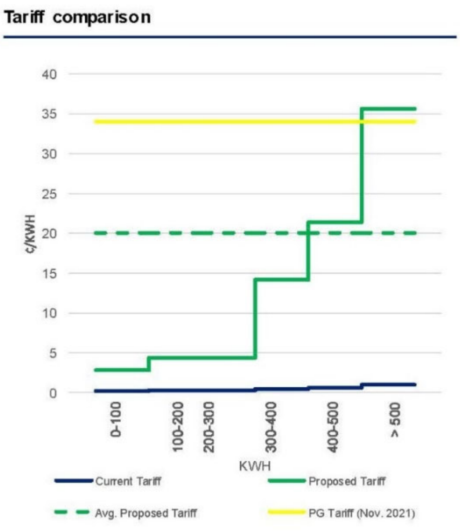


Source：EDL

Fig. 2.2-4　　Daily Load Curve (2019 year)

2.2.6 Tariff

The electricity tariff table is shown in Fig. 2.2-5. A new rate is proposed for the current electricity rate (enacted in 1994). According to this proposal, compared to the 34 cents/kWh electricity bill for private generators (Private Generator), the average electricity bill for EDL can be achieved at 20 cents/kWh, and the burden on households will be reduced.



Low voltage tariff brackets

Bracket [KWH]	Current tariff LL	Current tariff USC[1]	→	Proposed tariff LL	Proposed tariff USC[1]
0-100	35	0.18	x16	566	2.83
100-200	55	0.28	x16	889	4.44
200-300	55	0.28	x16	889	4.44
300-400	80	0.4	x36	2844	14.22
400-500	120	0.6	x36	4267	21.33
> 500	200	1	x36	7111	35.56
Fixed Charges[2]	9,800	49	x29	287,467	1,437
Industrial/ Agricultural	115	0.58	x36	4,089	20.4
Public Admin./ Public Estab./ Water Estab.	140	0.7	x36	4,978	24.9

(1) At the rate of 20,000 LL per USD
(2) 20[A] meter subscription

Source：EDL

Fig. 2.2-5　　EDL Electricity Tariffs (Current and Proposed)

2.3 ORGANIZATION AND OPERATION OF THE LEBANESE ELECTRICITY SECTOR

2.3.1 Principal entities

As mentioned in sub-section 2.1.1, MoEW exercise major jurisdiction over a power sector in Lebanon. EDL, a vertically integrated and state-owned electricity utility, takes an essential role in the electricity sector.

MoEW was originally established by Law No. 20 in 1966 as Ministry of Water and Electricity Resources and reorganized by Law No. 247 in 2000, and is responsible for the overall strategic planning and policy development of the electricity, water and iol sectors. Organizational structure of MoEW is illustrated in the below Fig. 2.3-1. EDL falls under the tutelage of the General Directorate of Exploitation, which was formerly known as the General Directorate of Exploitation, within MoEW.

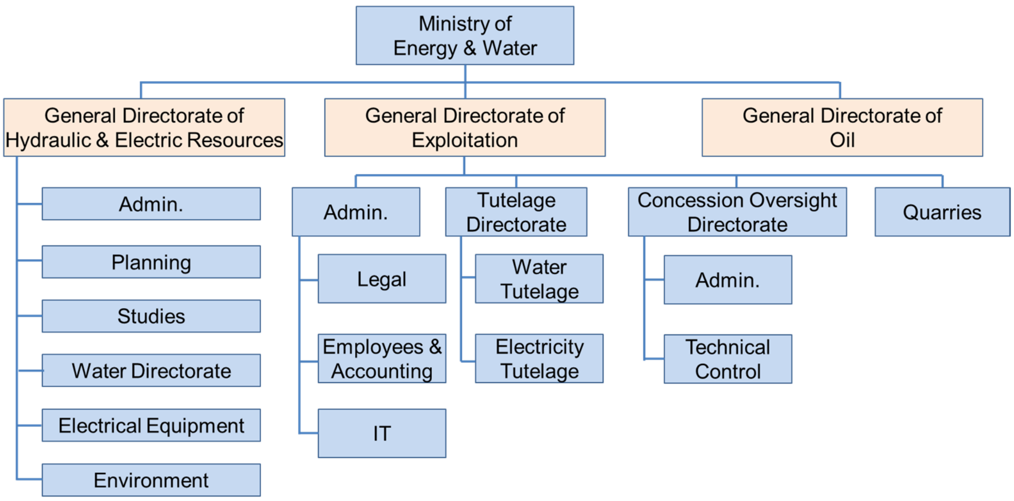


Fig. 2.3-1 MoEW Organizational Chart

EDL was established by Decree No. 16878 in 1964 as a public institution serving as Lebanon's electric utility with administrative and financial autonomy. A number of governmental entities reportedly retain oversight over EDL, despite its autonomy. The Ministry of Finance has financial oversight over EDL. Other governmental entities exercising control over EDL include the Court of Audit, the Civil Service Board, and the Central Inspection Board. Fig. 2.3-2 below portrays EDL's simplified organizational structure which is composed of a board of directors and ten directorates.

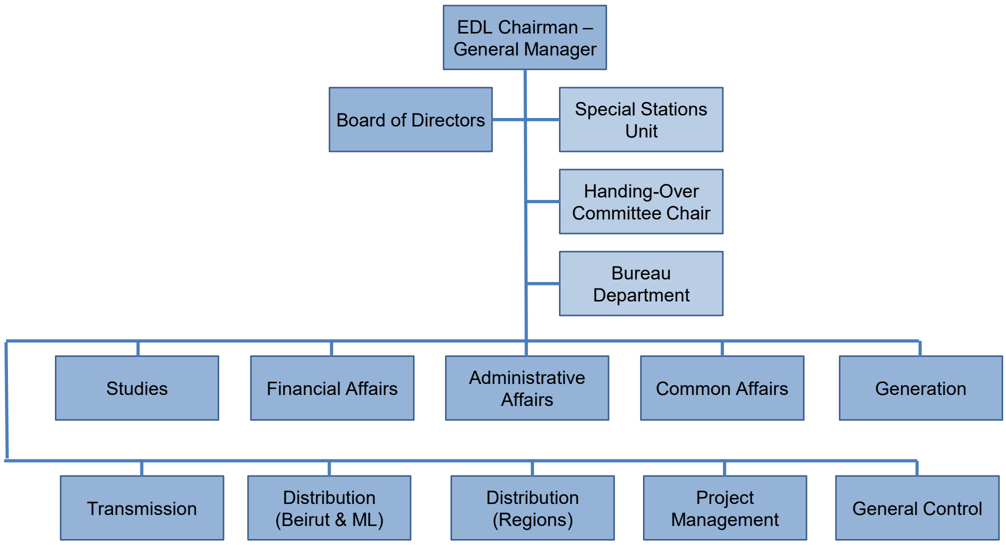


Fig. 2.3-2 EDL Organizational Chart

2.3.2 Relevant governing laws

The legal framework relation to the Lebanese electricity sector is defined by a series of laws and decrees that are summarized in Table 2.3-1 below.

Table 2.3-1 Governing Laws of Lebanese Electricity Sector

Document Number	Document Type	Date of Issuance	Subject
16878	Decree	1964	The establishment of the Electricity Authority of Lebanon (Électricité du Liban, EDL).
20	Law	1966	The establishment of the Ministry of Water and Electricity Resources.
5469	Decree	1966	The organization of the Ministry of Water and Electricity Resources, and the designation of its staff.
7580	Decree	1974	The Investment Law of Electricity for Lebanon.
247	Law	2000	Amendment of Law No. 20 from 1966, replacing the Ministry of Water and Electricity Resources with Ministry of Energy and Water.
462	Law	2002	Regulation of the Electricity Sector.
107	Law	2018	Allowing EDL to enter into an agreement with EDZ as an electricity operator for a period of two years (2018-20).

Among others, Law No. 462 was supposed to contribute to a reform of the Lebanese electricity sector. The law is comprehensive law and provides for a general framework covering the three major elements: i) establishment of an independent Electricity Regulatory Authority (ERA); ii) restructuring of the electricity sector; and iii) unbundling of energy activities to liberalize generation and distribution and create a competitive free market for electricity. Although Law No. 462 was enacted in 2002, the law has never been implemented since then for various reasons, mostly political. Noting that a reform of the electricity sector is practically considered to be one of condition precedents so as to facilitate financial supports to be provided by multilateral development banks, full implementation of the law would be strongly required.

MoEW made a step forward in partial implementation of Law No. 462, by making a public announcement of "Setting Up Lebanon Electricity Regulatory Authority (dated December 9, 2022)" which describes key functions and responsibilities of ERA, role-sharing between MoEW and ERA, and a high level organization structure of ERA. Job descriptions for key positions were also presented and a recruiting camping is currently underway.

2.3.3 EDL's tariff structure and financial situation

EDL's sales tariff of electricity was set in 1994 and had been unchanged since then until November 2022. The tariff was set then at 142 LBP per kWh on average when the barrel of oil price was below $20/barrel, which was equivalent to 9.5 US cents/kWh at the official exchange rate of 1,500 LBP/USD. EDL has been suffering from a high cost of generation from aging power plants, and high technical and non-technical losses, coupled with a politically-led low fixed tariff. Consequently, EDL has been in unviable financial situation with the electricity tariff which is well below a cost-recovery level, and has been heavily relying on subsidies from the Ministry of Finance. EDL has been financially deficit since 1992 and subsidized over the last three decades. Cumulative costs of such subsidies reportedly accounts for USD 43 billion, or around 46 per cent of Lebanon's public debt. Additionally, serious depreciation of the Lebanese currency since 2020 had a material impact on EDL's revenue system, as the low fixed tariff was LBP-denominated. With reference to a parallel exchange rate of 39,000 LBP/USD in late October 2022, the average tariff was around 0.4 US cents per kWh then.

This issue of EDL's financial unviability has been highlighted over years as a realistic threat to stability of the electricity sector. A reform of EDL's retail tariff is a practical condition precedent so as for multilateral development banks to facilitate financial supports to Lebanon.

The government of Lebanon approved increase in electricity rates in August 2022, followed by the EDL board of directors' specific decision on new tariffs in early November 2022. Described below outlines the new tariffs and their methodology, which was the tariff rise for the first time in thirty years.

- The first tranche: 10 US cents per kWh for the first 100 kWh
- The second tranche: 27 US cents per kWh for consumption of more than 100 kWh
- Electricity bills are denominated in LBP at the Sayrafa rate which is an exchange rate decided by Banque du Liban (BDL), Lebanon's central bank.
- A fuel price indexation is applied in order to pass through the fluctuations of oil prices.

The tariff will be revised every month, or two, based on the actual cost of power generation.

In case a number of conditions are not met, the tariff will be increased further by additional ten US cents as required by a preliminary study. The two major conditions for not raising the tariff are: i) the State pays for fuels imported for power generation; and ii) public administrations and public sector institutions, that are known for not paying their bills, pays for electricity consumption.

It is expected that the newly introduced tariff mechanism, which was drastically revised for the first time in thirty years, will improve EDL's financial situation and also contribute to stability and sustainability of EDL business operation.

2.4 ASSISTANCE FROM OTHER DONORS

The main support activities currently being carried out by each donor in the power sector are as follows.

2.4.1 World Bank (WB)

The World Bank has been one of the major donors for many years. Table 2.4-1 shows the list of support provided by the World Bank.

Table 2.4-1 Major Development Projects Supported by WB

No.	Component	Status
1	The Least Cost Generation Plan	Completed (2022)
2	Lebanon Power Sector Emergency Action Plan	Completed (2020)
3	PCB Management in the Power Sector Project	Completed (2014)
4	Multi-Donor TF Facility for Conflict-Affected Areas of North Lebanon	Completed (2013)
5	EMERGENCY POWER SECTOR REFORM CAPACITY REINFORCEMENT	Completed (2012)
6	Power Sector Restructuring & Transmission Expansion Project	Completed (2003)
7	Emergency Reconstruction & Rehabilitation Project	Completed (2002)
8	Litani Power and Irrigation Project	Completed (1966)

2.4.2 U.S. Agency for International Development (USAID)

Table 2.4-2 shows the list of support provided by USAID.

Table 2.4-2 Major Development Projects Supported by USAID

No.	Component	Status
Expanding Gurid Supply of Clean Enelgy		
1	Utility Cybersecurity and Grid Digitization	2021 - Ongoing
2	Powering Agriculture	Completed (2019)

2.4.3 United Nations Development Programme (UNDP)

Table 2.4-3 shows the list of support provided by UNDP.

Table 2.4-3 Major Development Projects Supported by UNDP

No.	Component	Status
1	Sustainable Energy for Security – Se4s	2019 - Ongoing
2	Energy and Waste Solutions	2014 - Ongoing

2.4.4 European Bank for Reconstruction and Development (EBRD)

Table 2.4-4 shows the list of support provided by EBRD.

Table 2.4-4 Major Development Projects Supported by EBRD

No.	Component	Status
1	BUS Distribution	Completed (2018)
2	Photovoltaic Project at Tufail area (300～500MW)	Feasibility Study

2.4.5 Islamic Development Bank (IsDB)

Table 2.4-5 shows the list of support provided by EBRD.

Table 2.4-5 Major Development Projects Supported by IsDB

No.	Component	Status
1	Construction and rehabilitation of damaged public utilities, including power plants and electricity distribution systems[2]	Completed

2.4.6 International Renewable Energy Agency (IRENA)

Table 2.4-6 shows the list of support provided by IRENA.

Table 2.4-6 Major Development Projects Supported by IRENA

No.	Component	Status
1	Renewable energy outlook: Lebanon	Completed (2020)

2.4.7 Private Company

DT Global, entrusted by USAID, is implementing "Innovation For Affordable And Renewable Energy For All" in Lebanon. The total project cost is approximately USD 30 Million, and it includes the rehabilitation of the Richamaya-Safa hydropower plant.

[2] https://www.isdb.org/news/the-islamic-development-bank-allocates-us-250-million-for-construction-in-lebanon

The rehabilitation of the Richamaya-Safa hydropower plant includes the following:

- ✓ Repairing the damaged iron pipes caused by a landslide, which currently prevents power generation at the plant.
- ✓ The existing power generation equipment consists of three units (1 x 6.8MW, 2 x 3.2MW, all manufactured by Alstom). After the repair of the iron pipes, two units (1 x 6.8MW, 1 x 3.2MW) will be operational again, supplying electricity directly to approximately 30,000 residents (17 communities) in the vicinity.
- ✓ The scope of the rehabilitation includes the following:

  a) Upgrading a 3.2MW turbine-generator to 3.4MW capacity (improvement in equipment efficiency) with ZECO, Italy as the manufacturer.

  b) Complete replacement of other related equipment (Governor, SCADA[3], auxiliary equipment).

  c) The rehabilitation work is scheduled to begin with factory tests in July 2023, and on-site rehabilitation work will commence in August.

  d) There are no plans for refurbishing the two existing operational units (1 x 6.8MW, 2 x 3.2MW) that are currently generating power.

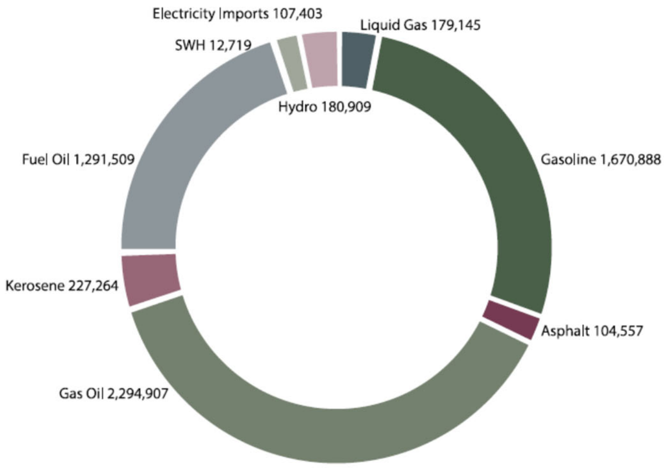
[3] Supervisory Control And Data Acquisition

2.5 PROCUREMENT PLAN OF PRIMARY ENERGY

2.5.1 Current Conditions of Procurement Plan of Primary Energy[4]

(1) Breakdown of Primary Energy Procurement

Lebanon, primary energy is basically rely on the importation of crude oil. The breakdown of primary energy in 2010 is shown in Table 2.5-1, with total fuel imports, including liquefied gas, gasoline, kerosene, heavy fuel oil, and asphalt, amounting to approximately 5,768 ktoe (5,768,269.94 toe). In addition, electricity imports from Syria and Egypt, is around 1,248,871 MWh (equivalent to 197,403 toe). As total, 96.8% of overall energy consumption is imported. Gasoline is supplied to automobiles, while heavy fuel oil and kerosene are supplied to the EDL's thermal power plants. Domestic supply constitutes only about 3.2%, which includes approximately 836,537 MWh (equivalent to 180,909 toe) from hydropower plants and approximately 12,719 toe from solar water heaters.



		toe	%
Import	Liquid Gas	179,145	96.8%
	Gasoline	1,670,888	
	Asphalt	104,557	
	Gas Oil	2,294,907	
	Karosene	227,264	
	Fuel Oil	1,291,509	
	Electricity Imports	197,403	
Domestic	SWH*	12,719	3.2%
	Hydro	180,909	

*SWH: Solar Water Heater

Source: NREAP[5] 2016-2020

Fig. 2.5-1 Primary Energy Mix in 2010 in Lebanon [toe]

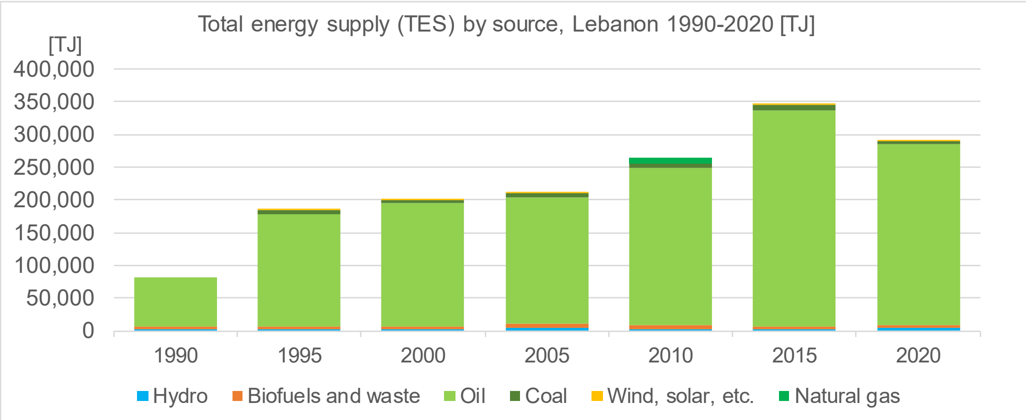
In Lebanon, the main energy supply has been relied on imported fossil fuels not only in 2010 as shown above but also up to the present. Particularly, a significant portion of the electricity in the power sector is supplied by diesel power plants using fuel oil and gas oil. Fig. 2.5-2 presents the energy supply by energy source according to the international Energy Agency (IEA), and Fig. 2.5-3 presents the annual variation in electricity generation by power source, consistently indicating a major reliance on imported crude oil. It is noted that the data for the year 2020 in an estimate value

4 MoEW/LCEC2016, NREAP2016-2020, The National Renewable Energy Action Plan for the Republic of Lebanon 2016-2020

5 National Renewable Energy Action Plan (NREAP)

by the IEA due to the unavailability of national statistics.

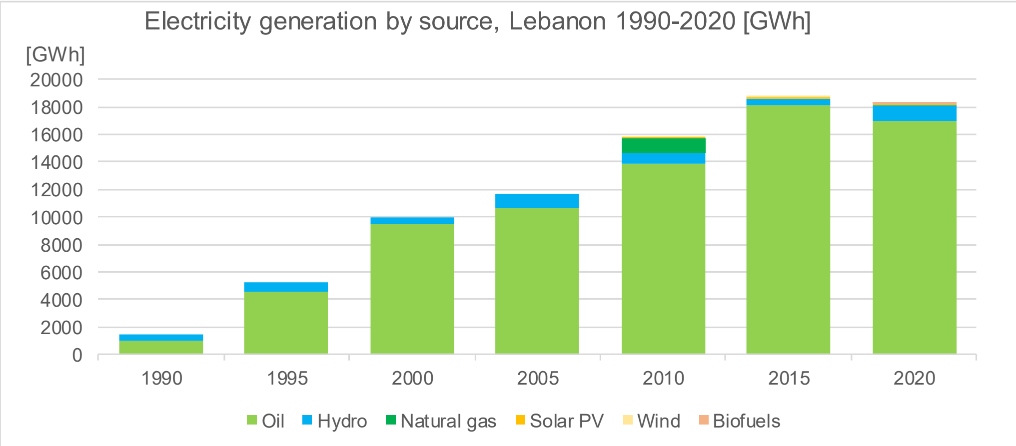
The major consumers of primary energy are the transportation sector, which consumes gasoline and gas oil, and the EDL's thermal power plants which consume gas oil and fuel oil. The list of existing thermal power plants is presented in Chapter 3.1.1.



year	Hydro		Biofuels and waste		Oil		Coal		Wind, solar, etc.		Natural gas	
1990	1,800	2%	4,302	5%	75,705	93%						
1995	2,365	1%	4,960	3%	171,503	93%	4,982	3%	55	0.03%		
2000	1,598	1%	5,519	3%	188,264	94%	5,535	3%	159	0.1%		
2005	3,766	2%	6,918	3%	193,786	92%	5,535	3%	314	0.1%		
2010	3,020	1%	5,737	2%	239,648	91%	6,227	2%	634	0.2%	8,880	3%
2015	1,724	0%	5,392	2%	330,844	95%	6,974	2%	2,120	0.6%		
2020	3,797	1%	6,039	2%	275,576	94%	4,884	2%	2,668	0.9%		

Source: IEA Key energy statistics, https://www.iea.org/countries/lebanon

Fig. 2.5-2 Total Energy Supply (TES) by Source [TJ]



year	Oil		Hydro		Natural gas		Solar PV		Wind		Biofuels	
1990	1,000	67%	500	33%								
1995	4,564	87%	657	13%								
2000	9,505	96%	444	4%								
2005	10,685	91%	1,046	9%								
2010	13,891	88%	839	5%	987	6%	1	0.01%				
2015	18,143	97%	479	3%			17	0.09%	6	0.03%		
2020	17,023	93%	1,055	6%			117	0.64%	6	0.03%	21	0.12%

Source: IEA Key energy statistics, https://www.iea.org/countries/lebanon

Fig. 2.5-3 Electricity Generation by Source [GWh]

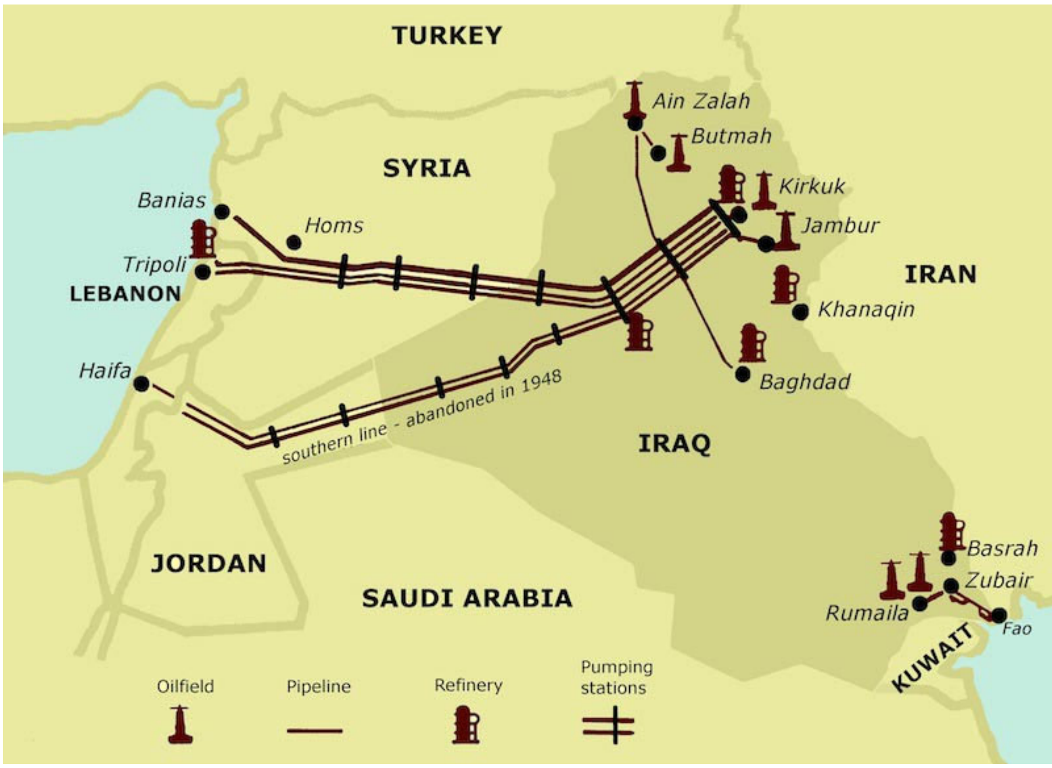
(2) Crude Oil[6]

Lebanon relies on imports for its crude oil supply. There are two pipelines for crude oil transportation between Lebanon and Syria and neighboring countries; however, both pipelines are currently not operational. Below, we provide an overview of each pipeline:

1) IPC (Iraq Petroleum Company) Pipeline

The IPC (Iraq Petroleum Company Pipeline) Pipeline is a 833 km oil pipeline constructed in 1930s, which transported oil produced in Kirkuk of Iraq through 3 pipelines across Syria and to a terminal and a refinery in Tripoli. However, it has not been operational since 1976 as Iraq ceased pumping crude to the main Syrian export terminal at Banias and thus halted direct supplies to Lebanon.

[6] Source: UNDP2016-SODEL, Sustainable Oil and Gas Development in Lebanon, "SODEL", Cost Benefit Analysis for the use of Natural Gas and Low Carbon Fuels

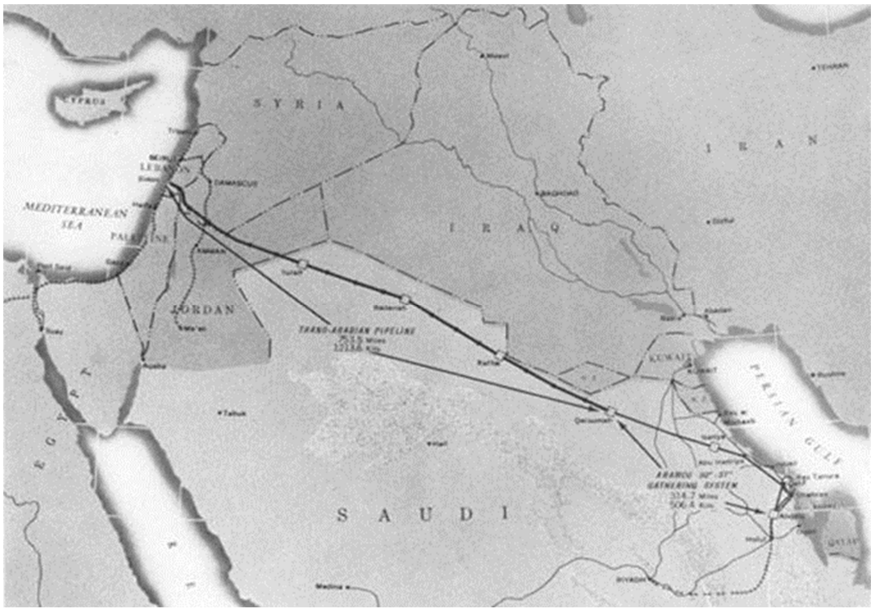


Source: GeoExpro Web page, https://geoexpro.com/

Fig. 2.5-4 The IPC pipeline route

2) TAPLINE (Trans-Arabian Pipeline)

The TAPLINE was a 1,213 km long crude oil pipeline constructed by Bechtel Co. in the late 1940s which transported light crude oil from the Abqaiq fields in Saudi Arabia across Jordan and southern Syria to an export terminal and a refinery in Zahrani. Oil was then shipped from the export terminal to markets in Europe and Eastern United States. At the time, the TAPLINE was the world's largest oil pipeline system. However, due to disagreements on transit fees between Saudi Arabia, Syria and Lebanon, continuous sabotage of the pipeline, as well as increasing competition from sea transport by supertankers, all transportation operations on the Syrian and Lebanese portions of the pipeline stopped in 1976. In 1990, Saudi Arabia also stopped oil transportation to Jordan on the Jordanian portion of the pipeline in response to Jordan's support of Iraq during the First Gulf War. Today, the entire line is understood to be unfit for oil transport.



Source: UNDP2016-SODEL

Fig. 2.5-5 The TAPLINE route

(3) Natural Gas[6]

1) The Lebanese Gas Pipeline (GASYLE) / Arab Gas Pipeline (AGP)

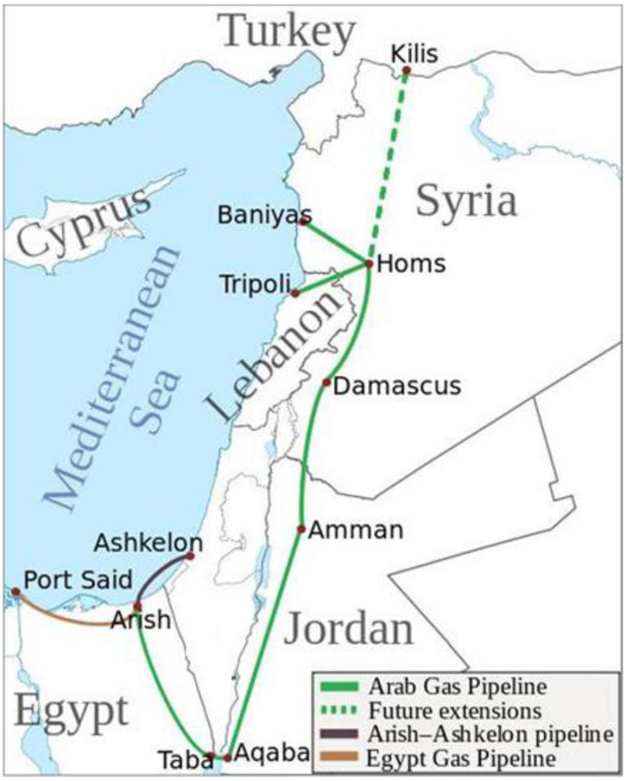
The Lebanese Gas Pipeline or GASYLE is the only gas pipeline in Lebanon which was built between 2003 and 2007 to deliver gas from Egypt to the Deir Ammar CCGT[7] power plant through swap arrangements with Syria. This pipeline is a spur of the Arab Gas Pipeline (AGP) and runs from the Syrian border to Tripoli. The AGP, originates in al-Arish of Egypt and

[7] Combined Cycle Gas Turbine

passes through Jordan and Syria.

The GASYLE pipeline came to commercial operation on 11 November 2009 which were enough to fire one of the two gas turbines of the Deir Ammar power plant on natural gas. However, the Deir Ammar power plant ceased receiving Natural Gas (NG) from Egypt by the beginning of November 2010 due to the riots that took place in Egypt and the geo-political problems extended from Egypt, Syria, Jordan and Israel. The lines and stations supplying NG to the AGP were bombed several times and the Egyptian crisis had a great impact on the supply of NG to Lebanon and on the export to the neighboring countries.

Currently, the Deir Ammar power plant is not receiving any natural gas through GASYLE.



Source: UNDP2016-SODEL

Fig. 2.5-6 Arab Gas Pipeline and GASYLE

(4) Renewable Energy

1) Hydropower

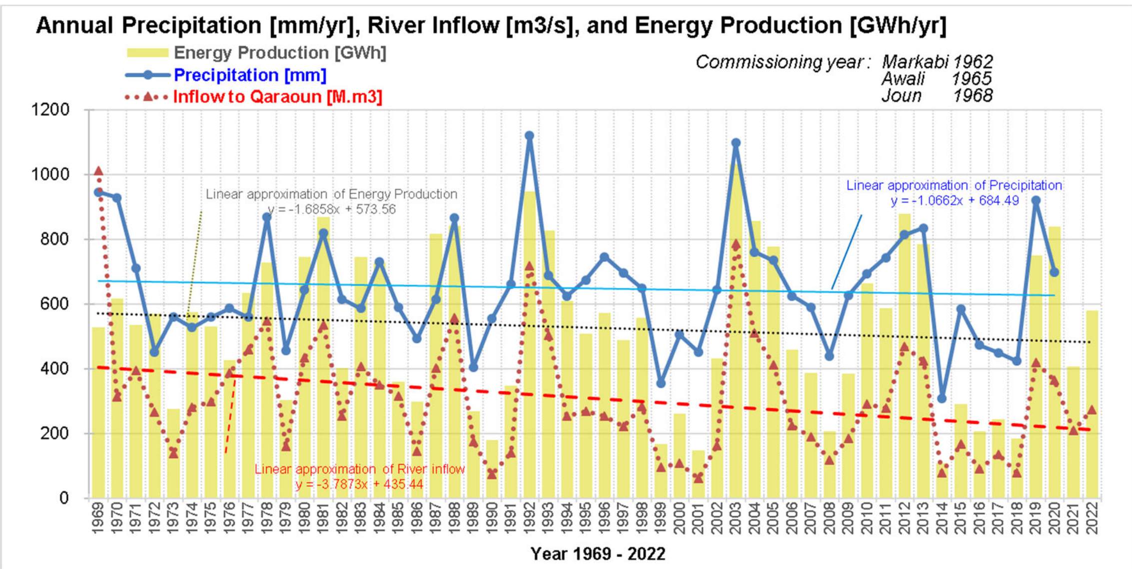
Existing hydropower facilities are listed in the Chapter 3.1.1 (Table 3.1-2). According to NREAP2016-2020, it is estimated that the current operational capacity of 190MW can be enhanced to 282MW through renovations and the introduction of some new generating units.

This increase in capacity is expected to lead to approximately 25% growth in electricity generation, from 836.5GWh in 2010 to about 1,047GWh.

Based on on-site inspections and hearings conducted by the assessment team in June 2023 at the hydropower plants along the Litani-Awali and Kadisha rivers, it can be thought that while some power plants may require partial repairs due to funding constraints and shortages of components, the rated equipment output of 282MW is still achievable.

On the other hand, the recent decline in power generation output is thought to be influenced by the decrease in precipitation and river flow. As shown in Fig. 2.5-7, the graph presents the annual electricity generation of the Markabi/Awali/Joun hydropower plants along the Litani-Awali river, annual variation in rainfall and the annual river inflow to the Quaraoun Dam on the Litani river.

The graph indicates that power generation output fluctuates from year to year, and these variations are correlated with changes in rainfall and river inflow. The decrease in power generation output in recent years is likely attributed to the reduction in both precipitation and the resulting decline in river flow.



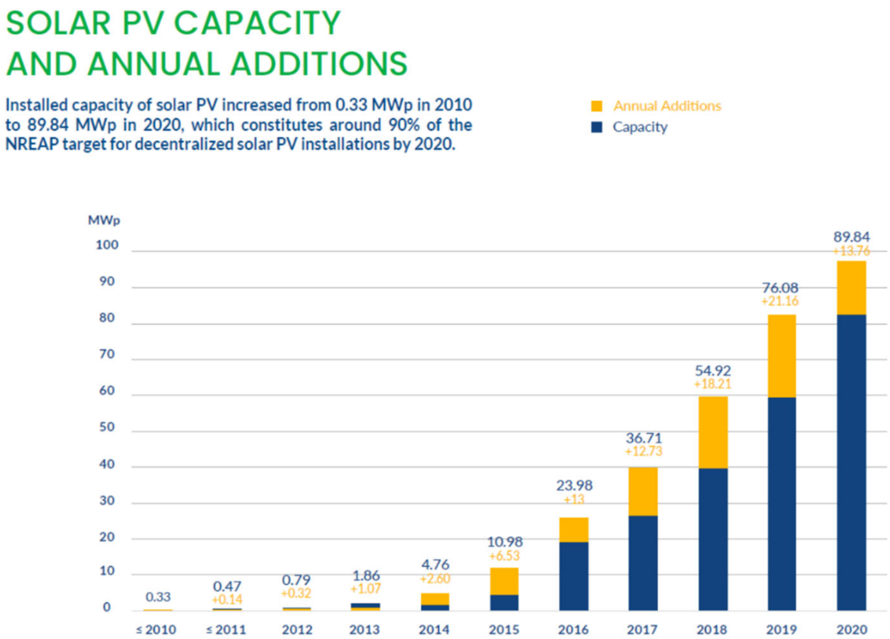
Source: Prepared by JICA Study Team based on LRA Data

Fig. 2.5-7 Variation of Annual Inflow to Quaraoun Dam, Annual Precipitation, and Annual Energy Generation of Markabi/Awali/Joun HPP in Litani-Awali River

2) Solar Power

The existing grid-connected solar power facility is only the Beirut River Solar Snake Project (BNSS), as listed in Chapter 3.1.1 (Table 3.1-3), with a capacity of 1MW.

Solar power facilities, including off-grid and hybrid systems, have been developed and promoted through the National Energy Efficiency and Renewable Energy Action (NEEREA) program. Under the management of Banque du Liban, Lebanon's central bank (BDL), NEEREA facilitates low-interest financing mechanisms for renewable energy investments from commercial banks to private enterprises. This initiative has led to the approval and development of over 1,000 projects by June 2020. As results, the total installed solar power capacity reached 89.9MW by 2020, as shown in Fig. 2.5-8.



Source: LCEC2022, Solar PV Status Report

Fig. 2.5-8 Installed Capacity of Distributed PV Solar Systems

3) Wind Power

There are no existing wind power facilities connected to the national grid system.

4) Biomass

The water-to-energy facility (7MW) co-located at Naameh Waste Treatment Plant commenced operation in 2016.

2.5.2 Procurement Plan of Primary Energy

The procurement of primary energy is carried out by the Directorate General of Oil (DGO) under the MoEW. They are responsible for planning and implementing energy procurement, and the current status is summarized as follows:

(1) AGP (Arab Gas Pipeline)

The gas pipeline, known as the Arab Gas Pipeline (AGP), transports gas from Egypt to Lebanon via Jordan and Syria. However, due to the United States' sanctions on Syria, the pipeline section within Syria has been blocked, leading to a disruption in gas supply. As a result, Lebanon is currently facing a situation where gas supply has been interrupted.

Furthermore, the AGP was intended to extend through Turkey, passing through Syria, and reaching Europe. However, this pipeline construction plan has been stalled due to the impact of U.S. sanctions on Syria. Although European countries are interested in the construction of the pipeline to receive gas supply, the project has been unable to progress due to the restrictions imposed by U.S. sanctions on Syria.

(2) FRSU（Floating Storage Regasification Unit）

The DGO is also implementing the Floating Storage Regasification Unit (FSRU) project. This project aimed to supply natural gas to the northern Deir Ammar thermal power plant and the southern Zahrani thermal power plant. Although this project began in 2011, due to political issues within the Lebanese government, it has not received approval from the Council of Ministers (CoM), and as a result, the project has been stalled.

(3) New Gas Fields

The development of new gas fields in Lebanon have seen the involvement of Total from France, Eni from Italy, and Novatek from Russia in their development. However, due to the situation in Ukraine, Novatek's participation has been replaced by Qatar. The development of the promising Block 4 and Block 9 areas has taken precedence. Although the Lebanese government had been optimistic about the gas field development, the exploration efforts in Block 4 have faced challenges, leading the government to adopt a cautious approach and await definitive results before making any decisions. Currently, the exploration and environmental assessment in Block 9, which is closer to the Israeli side where development has already progressed successfully, are scheduled for September 2023.

(4) Fuel Procurement

Lebanon has entered into contracts with the Iraqi state-owned oil marketing company, State Oil Marketing Organization (SOMO), for the procurement of High Sulfur Fuel Oil (HSFO) produced by SOMO. Additionally, Lebanon has signed Swap contracts with Oman's state-owned oil company, OQ, to exchange HSFO for Heavy Fuel Oil (HFO) (Grade A and B) and Gas Oil, which can be utilized for power generation. The arrangements between SOMO and OQ involve fuel exchanges without involving any refining processes.

The DGO serves as the main party responsible for contracts with SOMO and OQ, procuring fuel at market prices and supplying it to the EDL. Presently, EDL faces financial difficulties, leading to delayed payments to Iraq.

As a gesture of goodwill, Iraq has granted EDL a one-year grace period for payments. DGO believes that with the implementation of electricity tariff revisions, EDL's revenue will increase, enabling them to meet their financial obligations and expand fuel procurement, resulting in an increase in power supply. DGO considers expanding this cycle crucial for the sustainable development of the power sector in Lebanon.

(5) Renewable Energy

1) Hydropower

a) Hydropower Development

MoEW in collaboration with the consultant Sogreah-Artelia prepared the master plan study for Lebanon’s hydroelectric power potentials along the main rivers in Lebanon. 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).

In March 2018, the MoEW launched an expression of interest (EOI) for the installation of hydroelectric power plants on various Lebanese rivers as shown in Table 2.5-1. The MoEW received 25 EOIs from 59 companies from 15 different countries to install more than 300 MW. The main challenge lies in the fact that most of the existing concessions, are used exclusively for agricultural and irrigation purposes rather than hydropower generation. To promote hydropower in these concessions, GoL delegated the MoEW to negotiate concessions as per the newly adopted electricity plan in 2019 to find an appropriate solution for the current situation.

Table 2.5-1 Project List for EOI of Hydroelectric Power Development

Item	Water Stream	Power Plant	Establishment in Charge	Type
1	Abou Moussa	Mechmech	AL BARED	Run of River (RoR)
2	Jhannam + Abou Moussa	Qarn	AL BARED	RoR with STORAGE
3	Abou Moussa	El Mara	AL BARED	RoR with STORAGE
4	Sukkar	Sir	AL BARED	RoR
5	Bared Upper	Sir	AL BARED	RoR with STORAGE
6	Nahr Sir	Qattine	AL BARED	RoR
7	Nahr Sir	El Ouatie	AL BARED	RoR
8	Bared	Bared (Run of River)	AL BARED	RoR
9	Abou Ali	Kannoubin	LA KADISHA - SOCIETE ANONYME 'ELECTRECITE DU LIBAN NORD S.A.L.	RoR with STORAGE
10	Abou Ali	Bchanine	LA KADISHA - SOCIETE ANONYME D'ELECTRECITE DU LIBAN NORD S.A.L.	RoR
11	El Jouz	Beit Chlala		RoR
12	El Jouz	Boustane (Kfar Helda)		RoR
13	El Jouz	Mseilha (Dam)		RoR
14	Ibrahim	Hdaine	SOCIETE PHOENICIENE DES FORCES DE NAHR IBRAHIM DES EAUX ET ELECTRECITE	RoR
15	Ibrahim	Janneh (Run of the River)	SOCIETE PHOENICIENE DES FORCES DE NAHR IBRAHIM DES EAUX ET ELECTRECITE	RoR
16	Ibrahim	Ibrahim 4	SOCIETE PHOENICIENE DES FORCES DE NAHR IBRAHIM DES EAUX ET ELECTRECITE	RoR with STORAGE
17	El Kelb	Chabrouh (Run of the River)		RoR
18	El Kelb	Mayrouba		RoR
19	El Kelb	Boqaata (Run of the River)		RoR
20	El Kelb	Daraya (Run of the River)		RoR
21	El Kelb	Chamra (Run of the River)		RoR
22	Beirut	Dachouniye		RoR
23	Damour	Rechmaya		RoR
24	Damour	Mtaile		RoR
25	Damour	El Boum		RoR
26	Damour	Damour (Dam)		RoR
27	Awali	Jezzine		PEAK
28	Awali	Upstream Joun		RoR
29	Litani	Blat	LITANI WATER AUTHORITY	RoR
30	Litani	Khardaleh (Dam)	LITANI WATER AUTHORITY	RoR
31	Litani	Kfar Sir (Dam)	LITANI WATER AUTHORITY	PEAK
32	Yammouneh	Yammouneh		RoR with STORAGE
15a	Ibrahim	Janneh (Peak)	SOCIETE PHOENICIENE DES FORCES DE NAHR IBRAHIM DES EAUX ET ELECTRECITE	RoR
19a	El Kelb	Boqaata (Peak)		RoR with STORAGE
20a	El Kelb	Daraya (Peak)		PEAK
21a	El Kelb	Chamra (Peak)		PEAK

Source: MoEW/LCEC (2018), Call for Expression of Interest (EOI) to Participate in Proposal Submissions to Build and Operate Hydr oelectric Plants in Lebanon

b) Development of Micro-hydropower

UNDP-CEDRO (2014), "Hydropower from non-River sources : The potential in Lebanon" presented that potential sites where hydropower can be utilized from the cooling systems of near-shore thermal power plants, irrigation channels, water networks, and sewage networks, and identified 13 pilot sites with a capacity of approximately 5 MW. However, a bigger potential remains to be identified and tapped into. Table 2.5-2 shows a summary of the pilot sites for non-river streams micro hydropower.

Table 2.5-2 Summary of micro-hydro pilot sites

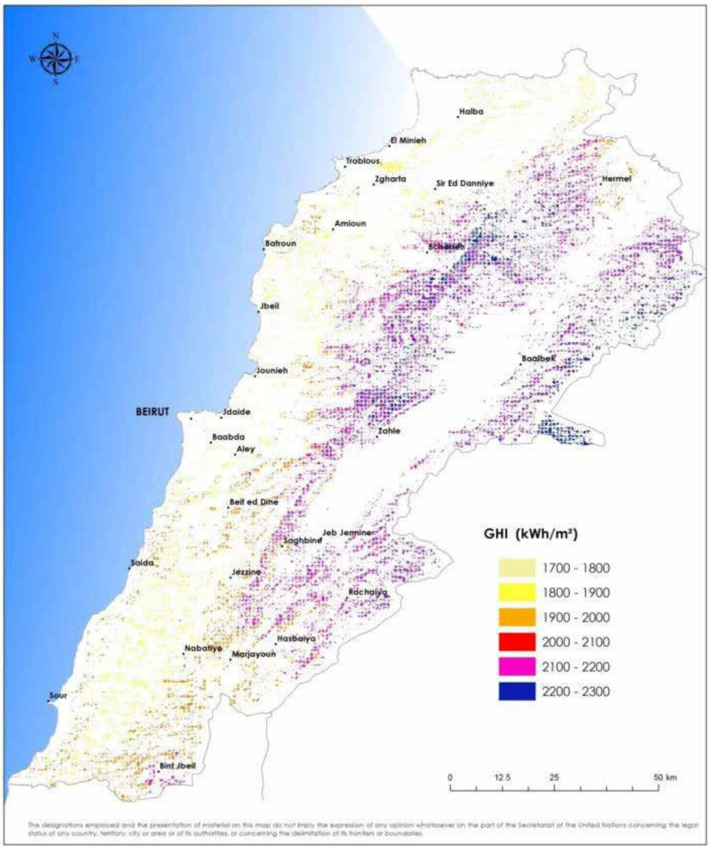
Micro-hydro Stream	Public Institution	Number of Studied sites	Potential capacity (MW)
Irrigation channels and conveyors	All water establishments, Ministry of Agriculture (MOA)	4	1.270
Wastewater treatment plant intakes and outfalls	All eater establishments	1	0.123
Electric power plant outfall channels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

Source: NREAP2016-2020

2) Solar Power

a) Potential of PV

The solar power generation potential is significant in the Bakaar region, as indicated in Fig. 2.5-9. The area comprises mostly flat terrain with abundant sunlight, making it an area with high solar irradiance levels.



Source: NREAP2016-2020

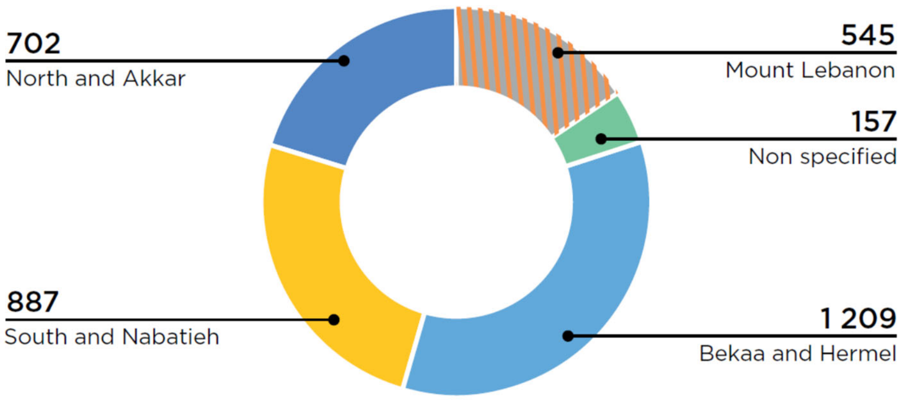
Fig. 2.5-9 Potential Land Areas for PV Farms

b) Development Plans of Solar Power

In 2018, MoEW and LCEC issued an EOI for 100MWp solar photovoltaic (PV) projects with a 70MWh energy storage system. They received proposals from 33 countries and 148 companies. The proposal distribution is illustrated in Fig. 2.5-10 The Bekaa/Hermel region demonstrated large potential for solar development.

Following this initial EOI, MoEW and LCEC are preparing for a second phase with an Expression of Interest for a total capacity of 240-260MWp.

Additionally, EBRD (European Bank for Reconstruction and Development) is conducting a feasibility study for a solar projects with a capacity of 300-500MW in the Tufail region.



Source: IRENA/LCEC (2020)

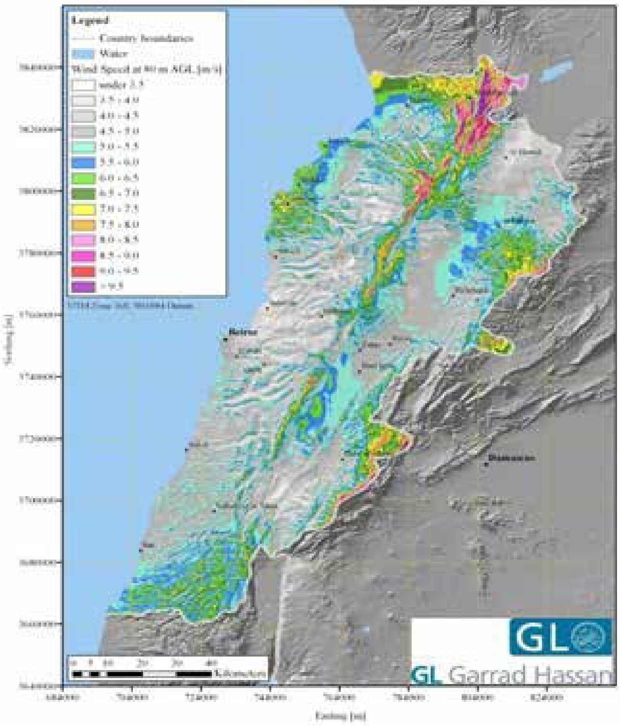
Fig. 2.5-10 Total Capacity per Region in response to the EOI of the first round of PV Projects

3) Wind Power

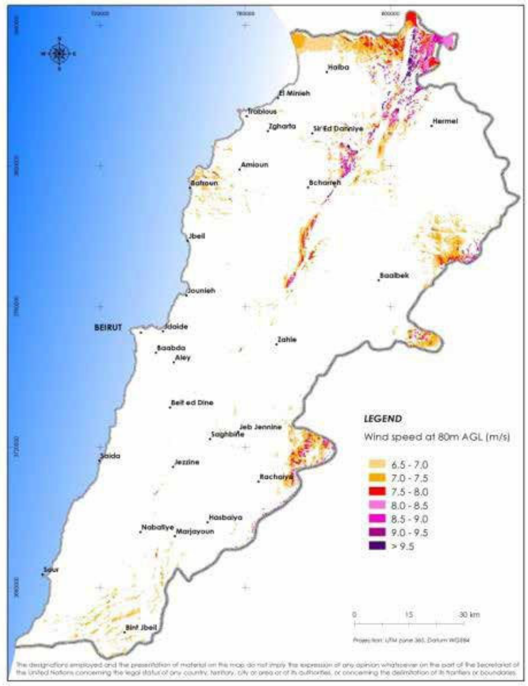
a) Potential of Wind Power

Regarding the potential of wind power, the map of Fig. 2.5-11 shows regions with land-based wind speeds at a height of 80 meters and areas that are technically and economically viable for wind power generation. The LCEC estimates that out of the domestic wind power potential of 1,500MW, the achievable capacity is up to a maximum of 500MW.

On the other hand, "The National Wind Atlas of Lebanon" by UNDP-CEDRO in 2011, presents the estimated wind power potential to be 6,100MW. In addition, IRENA (International Renewable Energy Agency) suggests that Lebanon has a wind power potential of 6,233MW.



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)

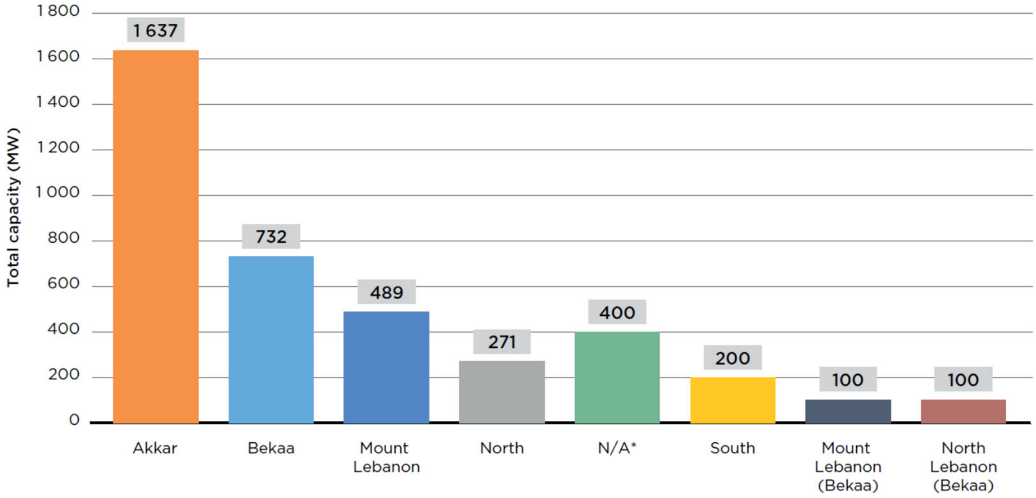
Source: NREAP2016-2020

Fig. 2.5-11 Potential for Wind Power

b) Development Plan of Wind Power

In 2018, MoEW signed a Power Purchase Agreement (PPA) for the development of three wind power facilities in the Akkar region, with a total capacity of 226MW. The project company known as Naseem Akkar, plans to sell electricity to EDL based on the PPA. However, the development progress has been delayed compared to the initial plan of completion by the end of 2022.

In 2019, MoEW issued a Request for Proposals (RFP) for the development of wind power plants with a maximum capacity of 520MW. However, the procurement process has been delayed due to the impact of COVID-19 and other factors. According to IRENA/LCEC (2020), the response to this RFP is shown in Fig. 2.5-12, indicating the large potential in the Akkar region.



Based on IRENA's work on auctions, a number of factors relevant to auction design have been identified – including country-specific conditions – that influence the price resulting from auctions, as summarised in Box 2.

*** N/A: No specific land attributed.**

Source: NREAP2016-2020

Fig. 2.5-12 Total Capacity per Region in response to the second EOI/round of Wind Auctions

4) Biomass

According to the Renewable Energy Road Map (REMAP) presented by LCEC/IRENA in 2020, there are possibilities of developing additional 5MW of biomass power generation at wastewater treatment plants. This indicates the potential for harnessing biomass energy from sewage treatment processes to further contribute to Lebanon's renewable energy developments.

2.5.3 Organizations for Promotion of Procurement and Technical Development of Gas/Oil

DGO (The Directorate General of Oil) of MoEW is responsible for promotion of gas and oil security, technological development, etc., as follows;

1) Importing crude oil, passing it through Lebanese territory and refining it locally.
2) Distribution, storage and pricing of gas and liquid fuels
3) Manufacture of petroleum materials and import / export of petrochemical products
4) Exploration for oil on Lebanese territory and in regional waters
5) Supervising private institutions that engage in oil exploration, pumping and transporting crude oil, refining, or distributing petroleum products, auditing their accounts, and monitoring the cost of producing liquid fuel or other petroleum products
6) Take the necessary measures to secure the country's need for liquid fuels
7) Studying laws, regulations, and agreements with private institutions related to oil affairs, in

preparation for introducing the necessary amendments or canceling them, or developing new rules

8) Carrying our studies and technical research or supervising them in the field of oil exploration and in the field of petrochemical industries, and granting related licenses
9) Gathering statistical information related to the production, import, export and consumption of petroleum products and preparing the necessary economic studies to draw up the state' policy related to oil affairs, to develop long-term plans for the oil industry and to supply the country with liquid fuels, and to grant licenses to import or export refined products of oil and its derivatives and petrochemical products
10) Management of the oil facilities in Tripoli and Al-Zahrani

Table 2.5-3 presents the organization of importing fuels.

Table 2.5-3 Importers and Consumers of Main Fuels used in Lebanon

No.	Fuel type	Importer	Consumer Sectors	Usage
1	HFO	MoEW	Energy, Industry	Electricity production in the thermal power plants, and energy production in some manufacturing industries
2	Gasoil	MoEW	Energy, local market	Electricity production in the thermal power plants Space heating in residential, commercial and institutional sectors
3	Diesel oil	Private Companies	Local Market	Road transport, electricity generation (private generators)
4	Gasoline	Private Companies	Transportation	Road transport, air transport
5	Kerosene Jet A1	Private Companies	International Bunkers	Air transportation
6	Pet Coke / Coal	Industry	Industry (cement only)	Energy production
7	Liquefied Petroleum Gas	Private Companies	Residential, Commercial, Institution-al, Industrial	Mainly cooking and heating, and energy production in some manufacturing industries
8	Natural Gas	MoEW	Energy	Electricity production in the thermal power plants[8]

Source: NDP2016-SODEL

[8] Natural gas was only delivered for 1 year through the GASYLE pipeline through the GASYLE pipeline to the Deir Ammar CCGT power plant, Source: UNDP2016-SODEL

2.6 POWER SUPPLY AND DEMAND SITUATION, ENERGY MARKET LIBERALIZATION, INCENTIVES FOR RENEWABLE ENERGY, OFF-GRID POWER SYSTEMS

2.6.1 Power supply and demand situation

Power demand forecast and power development plans, which are duly considered in "Least Cost Generation Plan", are described in sub-section 2.2.1 and summarized in Table2.2-1. However, unprecedented economic crisis have made a definite impact on the Lebanese electricity sector.

On the supply side, a major challenge is lack of power supply capability. As mentioned in sub-section 2.2.5, EDL's supply capacity remains around 400 MW only throughout the day, due to mainly shortage of fossil fuels for power generation. Meanwhile, chances of realizing large scale CCGT power plants development, which were anticipated in "Least Cost Generation Plan", are quite uncertain and highly questionable.

On the demand side, changes in fundamentals are need to be estimated and reflected. Due to severe and sustained economic stagnation, increasing poverty, and unaffordable high tariffs set by private generators, actual demand is thought to be considerably decreased. As described in sub-section 2.6.4 later, noting that large scale penetration of distributed solar-plus-battery systems with the total amount of 1+ GW, actual demand is thought to be further suppressed.

One can expect dramatic changes of a demand and supply situation in the Lebanese electricity sector under such complicated circumstances, whilst it is difficult to collect accurate statistic data at the current moment. In this context, we must note that "Least Cost Generation Plan (September 2021)" is already obsolete. It is strongly required to reasonably review and integrate master plans in the electricity sector, considering all those changes over the last few years and best available assumptions for the coming couple of years.

2.6.2 Energy market liberalization

As previously mentioned, EDL has the exclusive right to generate, transmit and distribute electricity in Lebanon. After the issuance of Decree No. 16878, in principle it has not been permitted to grant any person or concession license or authorization to generate, transmit or distribute electricity, or to renew or extend such power for any reason. However, several concessions remain in place contrary to EDL's exclusivity, and several public institutions and private sector companies are active in generation and distribution fields.

In the field of hydroelectric generation activities, institutions and private companies holding concession are as follows: Litani River Authority which operates the Qaraoun multi-purpose dam and a series of hydroelectric power plants on the Litani river basin, La kadisha (Societe anonyme d'electrecite du liban nord s.a.l., which is owned by EDL) which operates cascade power plants on the Kadisha river system, and Nahr Ibrahim operating company (Societe phoeniciene des forces de Nahr Ibrahim des eaux et electricite) which operates hydropower plants on the Ibrahim river. When Law No. 462 is fully implemented and then the private sector is allowed to make access to liberalized markets of generation and distribution, ERA, which was supposed to play a leading role in regulating the electricity sector, will be engaged in development and issuance of licenses and permits.

In the field of distribution activities, four Distribution Service Providers (DSPs) are operating business under contracts with EDL to provide retail services in their respective regions. Meanwhile, distribution concessions remain in place in Zahle, Jbeil, Aley and Bhamdoun, each of which serves a particular geographical area.

Prior to 2012, the distribution business was managed solely by EDL through direct contracts with contractors and daily employees responsible for operation and maintenance works and collection of bills. In 2012, MoEW launched the Distribution Service Provider (DSP) projects, which was the state's first attempt to involve the private sector in the electricity sector, with the aim of reduction of technical/non-technical losses, rehabilitation of the distribution network, modernization of the grid and metering system, and improvement of bill collection. Three companies were selected to undertake the project: BUS (Butec Utility Services), KVA (joint venture between Arabian Construction Company (ACC) and Khatib & Alami), and NEUC (Debbas Group), followed by participation of MRAD for the southern region. More details follow in Chapter 5.

2.6.3 Incentives for renewable energy

There is an obvious trend towards increasing the level of renewable energy generation as part of the implementation of the national electricity strategy. MoEW made an announcement of the "Policy Paper for the Electricity Sector" in 2010 in which expansion of renewable energy production was remarked as one of key element with the national target as being 12 % of the total electricity and thermal supply by 2020. MoEW made a further announcement of the "National Renewable Energy Action Plan (NREAP) for the Republic of Lebanon 2016–2020" in 2016 which was developed by LCEC and specifically dedicated to renewable energy strategies and their implementation to reach the national targets. LCEC is currently elaborating an action plan, following the NREAP 2016–2020, in consideration of environmental changes over the years.

(1) Wind energy

MOEW launched a tender in 2013 to private corporations to build the first wind power farm in Lebanon with a capacity of between 50 MW and 100MW, so as to achieve the national target for wind generation by 2020 which is being set at 500 MW. Following the successful bid, the Lebanese government agreed to purchase 200 MW in total from three Lebanese companies (Hawa Akkar, Lebanon Wind Power and Sustainable Akkar) for 9.6 US cents per kWh over the term of the PPA (namely, 20 years which can be extended) under its first power purchase agreement signed on February 2018. MOEW launched a second bid round in March 2018 to build additional wind farms with a capacity of between 200MW and 400MW in total. However, implementation of the said projects has been stalled due to the crisis and various challenges in Lebanon.

(2) Solar energy

The Beirut River Solar Snake demonstration project, which is the first grid-connected solar plant in Lebanon's history, is renowned for being an iconic project which created an enormous momentum in the solar market in Lebanon. The first phase of the project, which is spanning from the Yerevan Bridge to the Nahr Bridge over an area of around 10,000 m^2 with the installed capacity of one megawatt peak (MWp), was commissioned in September 2015. It is a successful example to take advantage of the "unused" space above the Beirut River, where it is difficult to install a large-scale PV farm in the middle of the city due to the lack of cheap and suitable space in the capital.

MoEW has proactively launched a series of bids to promote PV farms as PV farms is becoming more appealing with the decrease in prices of related facilities. In May 2022, CoM issued a green light approving the award of licenses to 11 unincorporated joint-ventures for the generation and sale of electricity from solar parks across the Bekaa, Mount Lebanon, South, and North regions of Lebanon in an aggregate capacity of 165MW. The costs of solar energy to be sold by these 11companies are 5.7 US cents per kWh and 6.3 US cents per kWh in the Bekaa region and in all areas outside the Bekaa, respectively, whereas the costs of fossil energy are between 10 and 15 US cents per kWh.

(3) Distributed Renewable Energy (DRE) law

In 2019, MoEW decided to develop the legal framework and administrative protocols for net metering in all its facets. A distributed renewable energy (DRE) law was developed since then with the support of EBRD. This law sets a basis to encourage distributed renewable energy production by founding the main principles for the realization of projects using net metering in all its forms, and peer-to-peer (distributed) renewable energy trading through direct power purchase agreements and/or renewable energy equipment leasing, with enabled power wheeling, time of use, priority dispatch, and other supportive programs to ensure optimal implementation.

In March 2022, CoM approved the draft law allowing solar energy system owners to get electricity credit for surplus electricity that they provide to other users connected to the grid. However, this law has yet to be passed by the Parliament.

2.6.4 Off-grid power system

The persistent economic and financial crises, resulting in widespread poverty and EDL's increasing difficulty in terms of power supply capability, has led to massive increase of distributed solar systems. Under the current severe circumstances where a power supply from EDL is available only for three to four hours a day for general customers and where a sharp hike of private generators' tariff is reaching an unaffordable level for most people, a large number of Lebanese households have adopted rooftop solar systems. The booming growth of PV market is reportedly relying on off-grid solar-plus-battery systems in residential and small business sector.

According to LCEC, a cumulative installed capacity of distributed solar systems reached 870 MW by the end of 2023 with a newly added capacity of 663 MW in 2022 alone. Recalling that in the end of 2020 Lebanon fell short of its national target of 100 MW for distributed solar capacity, with a cumulative total of 89.84 MW only, it is worth noting that they have installed a record-breaking amount of rooftop PV over the past two years. LCEC further projected that a total installed capacity of rooftop solar systems would surpass 1GW by early June 2023.

Meanwhile, EDL has vague but serious concerns that implementation of the DRE law would present a variety of technical problems with the EDL MV network, considering an impact caused by grid-connection of large scale PV firms with the capacity of up to 10 MW. EDL is expecting JICA to provide for technical supports in relation to the above mentioned potential issues, whereas EBRD has been providing EDL with administrative supports in preparation of the DRE law.

CHAPTER 3

POWER GENERATION

CHAPTER 3 POWER GENERATION

3.1 BASIC INFORMATION ON POWER GENERATION

3.1.1 Installed Capacity of Existing Power Plants

(1) Thermal Power Plants

The existing thermal power plants in Lebanon are shown in Table 3.1 1. As of 2022, there are 10 operating power plants with a total installed capacity of 2,691MW. No new power plants have been commissioned since 2017.

Table 3.1-1 Thermal Power Plants in Lebanon

Plant Name	Commissioning	Unit Type	Fuel	Owner	Unit Capacity (MW)	Installed Capacity (MW)	Effective Capacity in 2019 (MW)
Deir Ammar I	1998	Gas Turbine	Natural Gas/Diesel Oil	EDL	160	465	430
	1998	Gas Turbine	Natural Gas/Diesel Oil	EDL	160		
	2002	Steam Turbine	-	EDL	145		
Zouk Thermal Power Plant	1984	Steam Turbine	HFO	EDL	145	607	440
	1985	Steam Turbine	HFO	EDL	145		
	1986	Steam Turbine	HFO	EDL	145		
	1987	Steam Turbine	HFO	EDL	172		
Zouk 2 ICE Power Plant	2017	Internal Combusion Engine	HFO/Natural Gas	EDL	198	198	157
Zouk Power Barge	2012	Power Barge	HFO/Natural Gas	IPP	198	198	198
Jieh Thermal Power Plant	1970	Steam Turbine	HFO	EDL	65	346	180
	1970	Steam Turbine	HFO	EDL	65		
	1980	Steam Turbine	HFO	EDL	72		
	1980	Steam Turbine	HFO	EDL	72		
	1981	Steam Turbine	HFO	EDL	72		
Jieh 2 ICE Power Plant	2017	Internal Combusion Engine	HFO/Natural Gas	EDL	72	72	63
Jieh Power Barge	2012	Power Barge	HFO/Natural Gas	IPP	198	198	198
Zahrani I CCPP	1998	Gas Turbine	Natural Gas/Diesel Oil	EDL	160	465	420
	1998	Gas Turbine	Natural Gas/Diesel Oil	EDL	160		
	2001	Steam Turbine	-	EDL	145		
Baalbeck Open Cycle GT	1996	Gas Turbine	Diesel Oil	EDL	35	70	57
	1996	Gas Turbine	Diesel Oil	EDL	35		
Tyr Open Cycle GT	-	Gas Turbine	Diesel Oil	EDL	72	72	56

Note: HFO: Heavy Fuel Oil

Source: Prepared by JICA Study Team based on EDL Data

The domestic power plants are mainly classified into 1) oil power plants (Zouk, Jieh) that started operation in the 1970s-1980s, 2) Combined Cycle Gas Turbine (CCGT) (Deir Anmmar, Zahrani) that started operation from the late 1990s to the early 2000s, 3) Dual fired power plants (Zouk, Jieh) introduced in the 2010s, and 4) Open cycle gas turbine (Baalbeck, Tyr) that started operation in the 1990s in inland areas.

As of 2019, the available generation capacity was 2199MW which is only 80% of the rated capacity and the aging of the facilities is remarkable and has dropped to 65% particularly for 1) the power plants. In addition, as a recent challenge, the supply of natural gas is insufficient due to the shortage and soaring of fuel and 2) Deir Ammar and Zahrani's CCGT have no choice but to use gas oil and cannot take advantage of the combined cycle. The current power generation mainly depends on 2) power plants in in sufficient operation and fuel supply is an urgent issue.

For 3), there are internal combustion engines (ICE: Internal Combustion Engine) owned by EDL which have lower thermal efficiency than CCGT but have shorter lead times for development and are used as a temporary means of power supply to cope with sudden demand increases. In Lebanon, they are more efficient than the aging thermal power plants of 1) Zouk and Jieh. However, EDL is not able to procure fuel for them due to financial difficulties and their operating hours are limited.

In addition, there had been Turkish Power Barges equipped with heavy oil-fired generators by IPP at Zouk (198MW) and Jieh (198MW) until 2021. They have been terminated due to contract completion.

(2) Hydropower Plants

As shown in Table 3.1 1, Lebanon has 13 existing hydropower plants in five river basins: Litani, Kadisha, Bared, Nahr Ibrahim, and Richmaya-Safa, with a total installed capacity of 282MW. Details of the hydropower plants are described in Appendix 1.

Table 3.1-2 Existing Hydropower Plants in Lebanon

	Basin	Developer	Power Plant	Commis siong	Installed Capacity (MW)	Unit	Basin Wise Capacity (MW)	Actual Capacity in 2019 (MW)
1	Litani	Litani Water Authority	Markabi (Abdel Aal)	1961	36.9	1x17.9 MW + 1x19 MW	199.0	87.0
			Al Awwali	1964	113.3	3x37.76 MW		
			Joun	1967	49.3	2x24.65 MW		
2	Kadisha	Kadisha owned by EDL	Becare	1924	1.6	2 x 0.82 MW	21.0	5.0
			Mar Licha	1957	3.1	3 x 1.04 MW		
			Blaouza II	1961	8.4	3x2.8 MW		
			Abu-Ali	1932	5.4	2x2.72 MW + 1x2.04 MW		
3	Bared	Al Bared owned by EDL	Al Bared 1 (Bared 1)	1936	13.5	3 x 4.5 MW	17.0	6.0
			Al Bared 2 (Bared 2)	1936	3.7	1x1.2 MW + 1x2.5 MW		
4	Nahr Ibrahim	Nahr Ibrahim	Chouane (Nahr Ibrahim 1)	1961	15.0	2x7.5 MW	32.0	12.0
			Yahchouchi (Nahr Ibrahim 2)	1955	12.4	2x4.984 MW +1x2.464 MW		
			Fitri (Nahr Ibrahim 3)	1951	5.0	3x1.664 MW		
5	Richmaya-Safa	EDL	Richmaya-Safa (Safa)	1931	13.0	2x3.1 MW + 1x6.8 MW	13.0	0.0
Total			**13**				**282.0**	**110.0**

Source: Prepared by JICA Study Team based on EDL Data

(3) Renewable Energy Power Plants

Existing renewable energy power plants other than hydroelectric power plants are presented in Table 3.1-3. The facilities which connected to the national grid are only 2 facilities, Naameh landfill gas (Biofuel by garbage) plant and The BRSS (Beirut River Solar Snake Project).

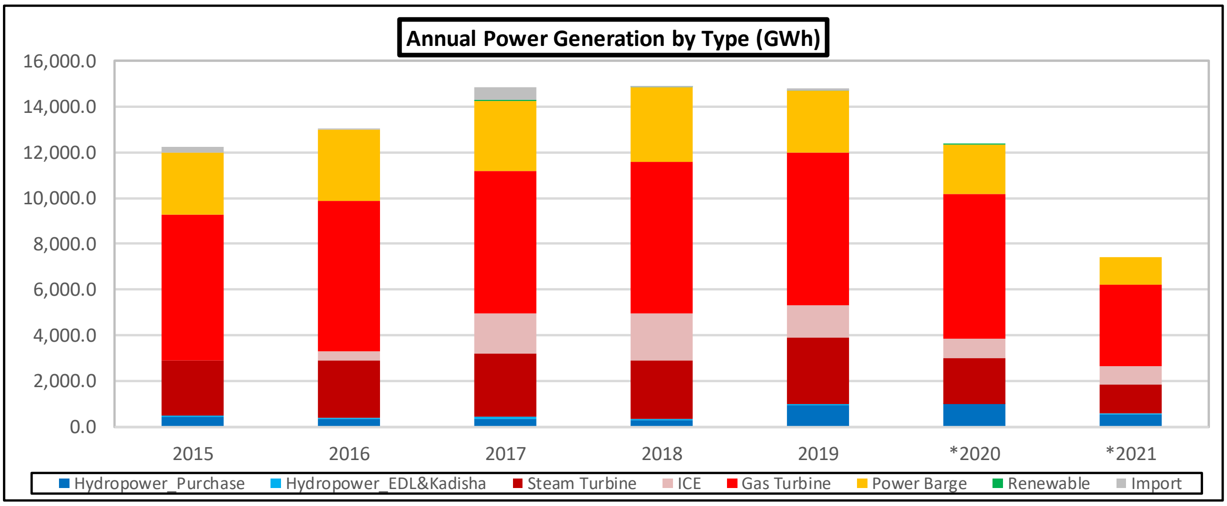
Table 3.1-3 Existing Renewable Energy Power Plants

Plant Name	Commissioning	Unit Type	Fuel	Owner	Installed Capacity (MW)
Naameh (Landfill Gas)	2016	Internal Combustion Engine	Garbage	EDL	7
The Beirut River Solar Snake Project	2020	PV	Solar	EDL&ASACO	1.08

Source: Prepared by JICA Study Team based on EDL Data

3.1.2 Annual Power Generation

The annual power generation by power sources from 2015 to 2021 is shown in Fig. 3.1-1 and the capacity factor is shown in Fig. 3.1-2.

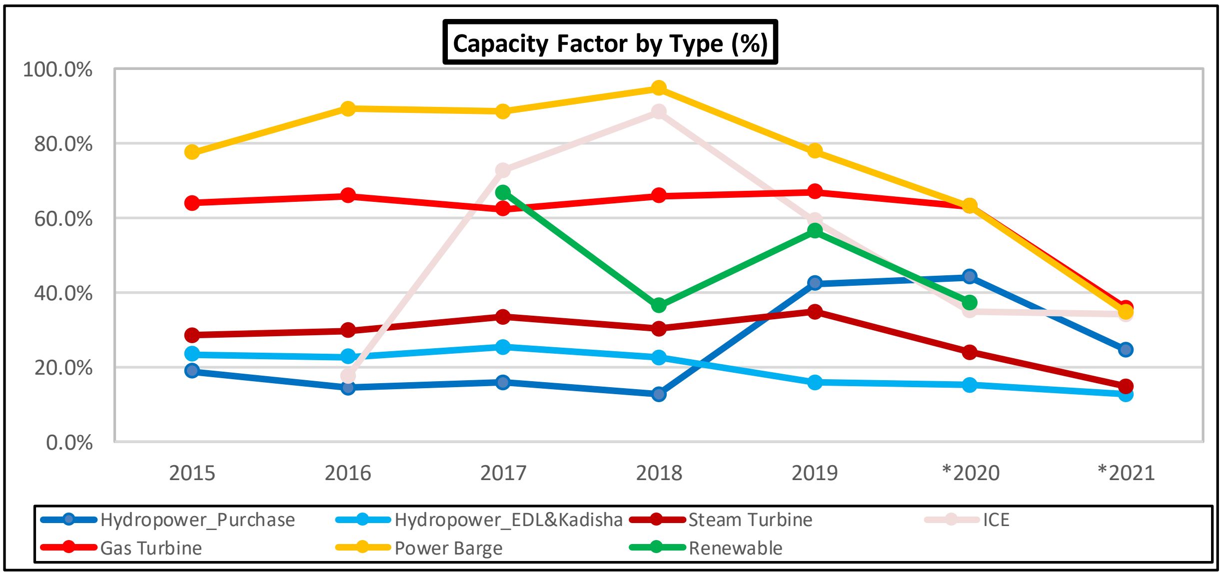


Source	Type	Installed Capacity (MW)	2015	2016	2017	2018	2019	*2020	*2021
Hydro	Hydropower_Purchase	248.0	410.2	317.1	348.3	278.0	922.4	962.1	536.0
	Hydropower_EDL&Kadisha	34.0	70.2	68.0	76.0	67.3	47.6	45.6	38.3
Thermal	Steam Turbine	953.0	2,394.4	2,494.4	2,793.5	2,535.0	2,919.4	2,006.1	1,245.4
	ICE	270.0	0.0	417.1	1,721.3	2,092.5	1,401.8	828.8	807.8
	Gas Turbine	1,072.0	6,411.2	6,599.4	6,248.2	6,594.2	6,697.0	6,314.0	3,597.6
	Power Barge	396.0	2,689.8	3,096.9	3,072.5	3,288.3	2,700.7	2,190.7	1,208.4
RE	Renewable	7.0	-	-	40.9	22.3	34.6	23.0	-
Imp.	Import	0.0	261.5	77.4	542.6	11.6	90.8	0.0	0.0
	Total	**2,980.0**	**12,237.4**	**13,070.3**	**14,843.4**	**14,889.3**	**14,814.3**	**12,370.1**	**7,433.4**

Source: Prepared by JICA Study Team based on EDL Data

Fig. 3.1-1 Annual Power Generation (GWh) from 2015 to 2021

Regarding the annual power generation from 2015 to 2021, the introduction of ICE (Zouk (198MW), Jieh (72MW)) in 2017 increased the total power generation. However, the power generation from thermal power plants has decreased significantly since 2020. It has been shifted from an annual power generation of 14,984GWh in 2019 to 12,370GWh in 2020 and half to 7,433GWh in 2021. It is supposed that power generation data for 2022 is not available but due to the impact of the Ukrainian shock on fuel prices and the depreciation of the Lebanese pound, the supply from the national power grid has dropped to about 2-4 hours per day and it is assumed that the power generation has decreased significantly in 2022.



Source	Type	2015	2016	2017	2018	2019	*2020	*2021
Hydro	Hydropower_Purchase	18.9%	14.6%	16.0%	12.8%	42.5%	44.3%	24.7%
	Hydropower_EDL&Kadisha	23.6%	22.8%	25.5%	22.6%	16.0%	15.3%	12.9%
Thermal	Steam Turbine	28.7%	29.9%	33.5%	30.4%	35.0%	24.0%	14.9%
	ICE		17.6%	72.8%	88.5%	59.3%	35.0%	34.2%
	Gas Turbine	64.1%	66.0%	62.5%	65.9%	66.9%	63.1%	36.0%
	Power Barge	77.5%	89.3%	88.6%	94.8%	77.9%	63.2%	34.8%
RE	Renewable			66.8%	36.4%	56.4%	37.5%	

Source: Prepared by JICA Study Team based on EDL Data

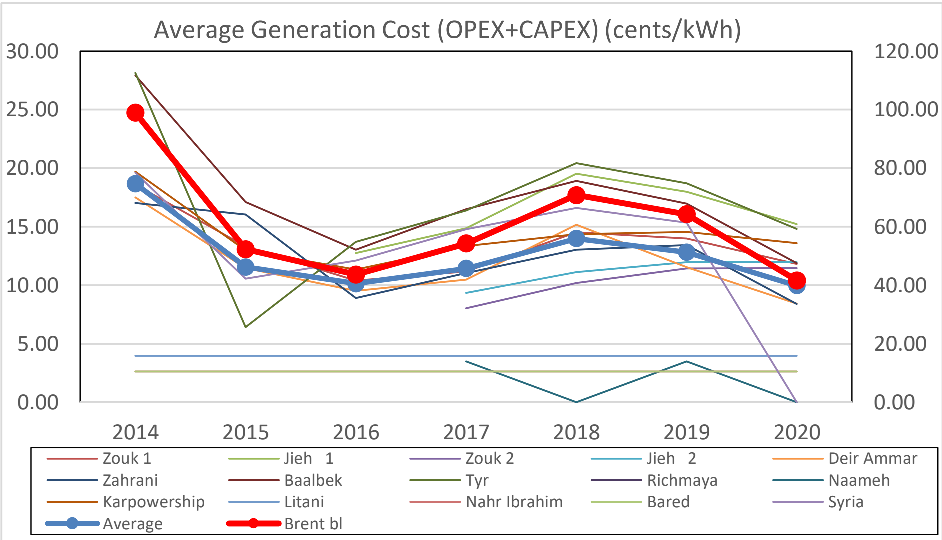
Fig. 3.1-2 Sequence of generation, transmission and distribution

Regarding the capacity factor of thermal power source, they have generally decreased since the financial crisis in 2019 and become even lower in 2021. Capacity factor of steamed turbines in oil power plants have been fluctuating around 30% until 2018. For ICEs, after starting commercial operation in 2017, it played almost the role of a base load and it marked with 88.5% in 2018. CCGT has been fluctuating around 65% until 2020 which has been operated as a base or middle load. Power Barge was used as a base load with a capacity factor close to 90% particularly in 2016-2018 but it has declined since 2020 due to worsening of financial situation of EDL. For renewable energy, there is only landfill power generation at Naameh, but the capacity factor is not stable. Hydropower is described in detail in the attached document, so it is omitted here.

Lebanon has been facing various difficulties since 2019 such as financial crisis, pandemic of COVID19, Beirut port explosion, currency depreciation, etc., and the power plants have not been able to demonstrate their original supply capacity. The shortage of power supply from the system is assumed to be covered by small diesel generators installed distributed at each facility or region. In the future, as new development will take time and cost, so it is important to restore the supply capacity of existing power plants to the level at least before 2018 for the enhancement of domestic power supply.

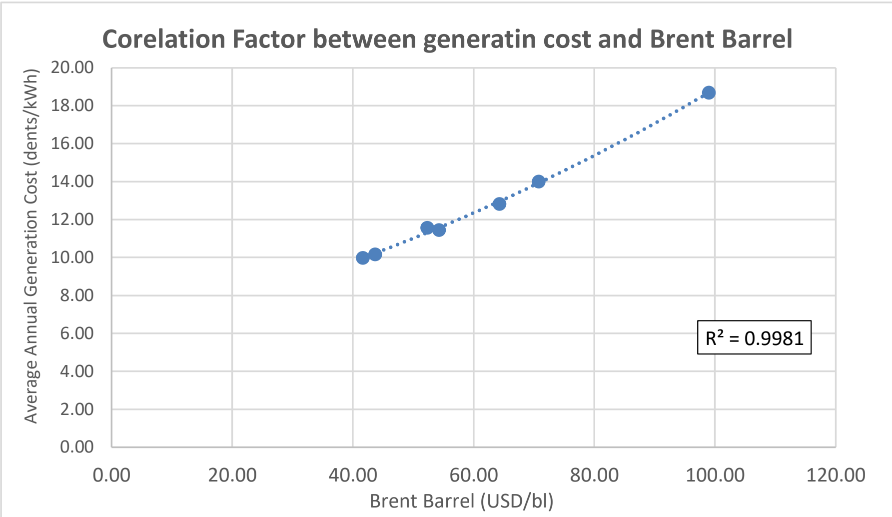
3.1.3 Power Generation Cost

The average annual generation cost (cents/kWh) of thermal power plants and hydropower plants (Litani, Nahr Ibrahim and Bared river systems) purchased by EDL from 2014 to 2020 and the average annual Brent crude oil (USD/Barrel) are shown in Fig. 3.1-3. The correlation between the average generation cost and the average Brent crude oil for the whole country is shown in Fig. 3.1-4.



Source: Prepared by JICA Study Team based on EDL Data

Fig. 3.1-3 Power Generation Cost of each Power Plant (2015 – 2020)



Source: Prepared by JICA Study Team based on EDL Data

Fig. 3.1-4 Correlation between Generation Cost and Brent Barrel Price

For the generation cost of thermal power plants, ICE (Zouk2, Jieh2) and CCGT (Deir Ammar) are the cheapest, followed by Power Barge (Karpower), oil power plants (Zouk1, Jieh1), and OCGT (Baalbek, Tyr). The average prices for 2018-2020 which can be compared are 11.36cents/kWh for ICE, 11.68cents/kWh for CCGT, 15.52cents/kWh for oil power plants and 16.96cents/kWh for OCGT.

Thermal power plants has a large share in power generation and EDL procures crude oil and gas oil through spot bidding by DGO which is linked to market prices. Therefore, the generation cost and Brent crude oil price have a very strong correlation (R2=0.9981). The annual average generation cost also fluctuates greatly from 10 to 20cents/kWh and stable fuel procurement is important for future power generation development.

3.2 POWER GENERATION DEVELOPMENT PLANNING

In this section, direction of future power generation development planning is considered based on the reviews of recently formulated development plans shown below;

(1) Least Cost Generation Plan (2021), World Bank

(2) Policy Statement "Setting Lebanon's Electricity Sector on a Sustainable Growth Path" (2022), MoEW

(3) Renewable Energy Outlook Lebanon (2020), LCEC

3.2.1 Least Cost Generation Plan

(1) Outline

Currently, Lebanon has a severe mismatch between electricity supply and demand. It is, therefore, imperative to increase the generation capacity as soon as possible to mitigate this mismatch and ensure adequate supply to consumers in a least-cost and environmentally optimal manner.

This report presents an analysis of Lebanon's options for developing its generation capacity over the next 10 years on a least-cost basis. It presents the optimization results of Base Case, High Renewable Expansion Scenario (HRE) which enhance more renewable and several scenarios that test the sensitivity of the results based on variation in certain key assumptions. The Base Case and sensitivity scenarios are selected to model a key policy consideration: the impact of the constraints on the level of penetration of renewable technologies, especially solar and wind, on the optimal generation portfolio in the country to inform decisions that must be made within a very short time on urgently needed investments in new generation to remedy the existing supply shortage.

The optimal plans, which are the result of the analysis presented in the report, envisage (a) decarbonizing the sector by transitioning its generation fleet from Heavy Fuel Oil (HFO) and diesel, as the main generation fuel, to natural gas such as Deir Ammar and Zahrani CCGTs and (b) integrating significant renewable energy (RE) capacity into the generation mix based on least-cost considerations. In addition, possibility of pumped storage hydropower project is also indicated in order to mitigate the intermittency of renewable energy.

1) Results of Base Case

The resulting generation mix will have a baseload gas demand of approximately 3.5 BCM/year starting in 2025 and will entail no RE curtailment on an average day. It will reach a capacity margin of 10% by 2028 for Base Case (2026 for HRE) and remain above this threshold for the remainder of the time horizon of the analysis. Spinning reserve will be adequate from 2025 onwards, with sizable reliance on storage units. This leads to huge improvements in carbon intensity and cost of electricity generation, dropping CO_2 emission intensity and total system cost over time from 665 kg/MWh and 130.52 US$/MWh in 2019 to 263 kg/MWh and 74.26 US$/MWh in 2030, respectively, in the Base Case scenario (in the HRE to 249 kg/MWh and 73.85 US$/MWh, respectively) by 2030.

RE penetration will increase from 4% in 2020 to 32% in the Base Case and 35% in the HRE in 2030. As such, HRE is more cost-effective for the country in the longer term. This does not take into consideration the potential environmental or health benefits from higher RE penetration in the HRE.

2) Introduction of CCGT

Both the Base Case and HRE consider additional brownfield thermal generation capacity at Deir Ammar, Zouk, Jieh and Zahrani, and greenfield thermal generation at Selaata. Brownfield development of combined-cycle power plants at Zouk and Jieh were not found to be least-cost because of the additional cost of fuel to the sites when compared to the alternatives, particularly RE generation. New gas-fired combined cycle power plants at Deir Ammar and Zahrani proved to be least-cost because of transmission access and ease of fuel supply, particularly when combined with existing generation at the same sites.

3) Introduction of Renewable Energy

Base Case caps the amount of annual RE development that can be expected, and, while HRE is more aggressive, it also assumes certain limitations that decrease over time. The rationale for this approach is that a massive build-up of RE capacity over a short period of time may be impeded by the current institutional and financial limitations. Potential consequences of generation shortages would be more pronounced should more aggressive assumptions be adopted that do not materialize. This approach also reflects the lack of a track record of performance for project-financed transactions in the country and a low level of investor confidence needed to support large scale RE investments.

4) Introduction of Temporary Power Generation Units

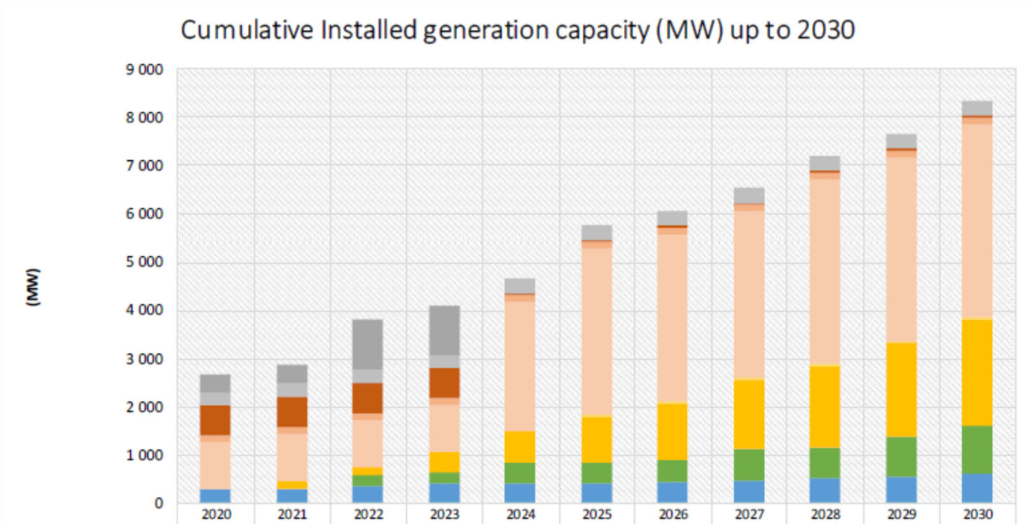
Because of the required time to undertake competitive procurements, arrange financing, secure fuel supply and complete construction, it is unlikely that any permanent generation solutions can be installed and commissioned earlier than 2024. If, as a policy matter, generation is expected to significantly increase before then (especially if this is tied to a potential tariff increase), temporary solutions must be introduced to provide the generation capacity needed until the permanent plants can be deployed. It may be possible to avoid these temporary solutions by maintaining the status quo, with consumers relying on existing small private distributed diesel-fired generators for much of supply that cannot be provided by EDL. However, aside from the significantly higher environmental impact of diesel generation in dense urban settings, this approach is likely to be at a much higher cost when compared to centralized large scale rented power plants and would push the additional higher cost of this capacity to consumers.

5) Cooperation with Neighboring Countries

It is important to note that there are currently certain regional developments that could potentially have significant impact on Lebanon’s least-cost generation path. Egypt, Jordan, Syria and Lebanon are currently in advanced discussions about Lebanon’s purchase of Egyptian gas and Jordanian electricity through Syria. These trades will use existing transmission lines (though the Syrian portion was damaged during its civil war and is currently being repaired) and the Arab Gas Pipeline (AGP). This will have a positive impact on available options for increasing generation capacity in Lebanon and diversifying its sources of supplies without significant capital investments in new assets. In respect to gas, for example, availability of supplies from Egypt at Deir Ammar through AGP would obviate the need to install a new floating gas import terminal, as assumed in this study. A floating terminal would still be needed at Zahrani until a north-to-south national gas transmission pipeline is completed to link Deir Ammar with Zahrani. Electricity purchases from Jordan will also add more generation capacity in EDL’s system without having to resort to temporary generation or capital investments in new power plants in the short-term.

(2) Analysis Results of Base Case

Fig. 3.2-1 shown below depicts the current generation capacity state and its evolution throughout the horizon of the study. EDL’s derated maximum generation capacity is currently at 2670 MW, distributed between thermal (2018MW), hydro (282MW) and rental barges (370MW). The optimal generation plan will ramp up the total capacity to 8,331 MW including 4,483MW of thermal, 595MW of RoR hydro, 50 MW of CSP, 2,180 MW of solar PV and 1,016 MW of wind.



	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030
RENTAL (incl. barges)	370	370	1 030	1 030	0	0	0	0	0	0	0
ICE (non rental)	272	272	272	272	289	289	289	289	289	289	289
ST	620	620	620	620	50	50	50	50	50	50	50
OCGT	144	144	144	144	144	144	144	144	144	144	144
CCGT	975	975	975	975	2 658	3 450	3 450	3 450	3 824	3 824	4 000
CSP	0	0	0	0	0	50	50	50	50	50	50
SOLAR PV	0	180	180	430	680	930	1 180	1 430	1 680	1 930	2 180
WIND	0	0	226	226	426	446	456	636	636	816	1 016
HYDRO	283	283	341	395	395	395	435	475	515	555	595
BIOGAS	7	7	7	7	7	7	7	7	7	7	7

Source: Least Cost Generation Plan, WB

Fig. 3.2-1 Cumulative Installed Generation Capacity up to 2030

Table 3.2-1 below provides the schedule for the installation and commissioning of each generation unit proposed in this plan. Note however that all NG fired power plants depend completely on the availability of Natural Gas in the concerned sites. The above-mentioned NG schedule requires:

Availability of NG in Deir Ammar by 2023;

Availability of NG in Zahrani by 2023;

Availability of NG in Selaata by 2024.

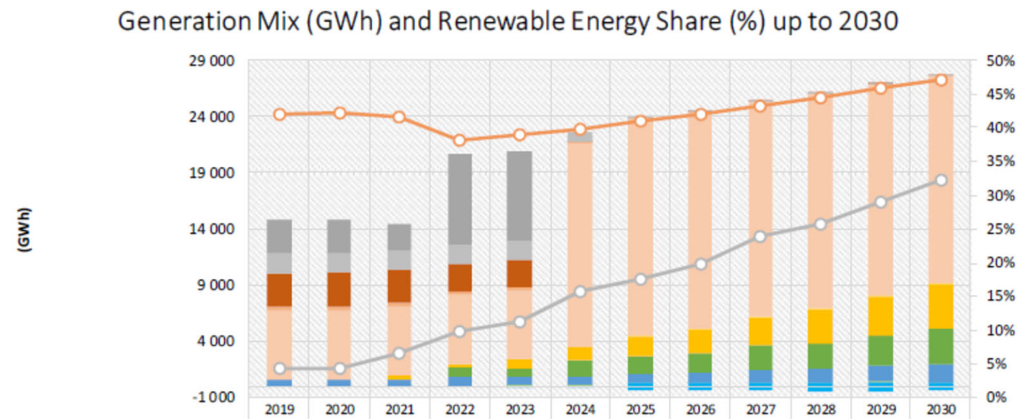
Delays on these timings will result in delays on the overall generation planning. Note that a one-year delay in Deir Ammar and Zahrani may be absorbed with minor modifications to the planning (i.e. delaying the switch to NG by 1 year).

Table 3.2-1 Schedule for the Installtion and Commissioning of New Power Plants

Location/technologie	Power plant available capacity (MW) Number of FSRU or pipeline	Base Case										
		2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030
BINT JBEIL	N ICE FO			83	83							
JIB JANNINE	N ICE FO			83	83							
DEIR AMMAR	E CCGT RUNNING ON GO	490	490	490								
	E CCGT RUNNING ON NG				490	490	490	490	490	490	490	490
	N RENTAL ICE			504	504							
	N FSRU				1	1	1	1	1	1	1	1
	N CCGT 2x1 - E									374	374	550
	N CCGT 3x1 - E					561	825	825	825	825	825	825
	Total	490	490	994	994	1 051	1 315	1 315	1 315	1 689	1 689	1 865
HRAYCHE	E ST	50	50	50	50	50	50	50	50	50	50	50
SELAATA	N PIPELINE DEIR AMMAR TO SELAATA					1	1	1	1	1	1	1
	N CCGT 3x1 - E					561	825	825	825	825	825	825
	Total	0	0	0	0	561	825	825	825	825	825	825
ZOUK	E ICE BARGE	185	185									
	E ICE FO	194	194	194	194	194	194	194	194	194	194	194
	E ST	380	380	380	380							
	Total	759	759	574	574	194	194	194	194	194	194	194
ZAHRANI	E CCGT RUNNING ON GO	485	485	485								
	E CCGT RUNNING ON NG				485	485	485	485	485	485	485	485
	N RENTAL ICE			252	252							
	N FSRU				1	1	1	1	1	1	1	1
	N ICE DF NG					17	17	17	17	17	17	17
	N CCGT 3x1 - E					561	825	825	825	825	825	825
	Total	485	485	737	737	1 063	1 327	1 327	1 327	1 327	1 327	1 327
BAALBACK	E OCGT	74	74	74	74	74	74	74	74	74	74	74
JIEH	E ICE BARGE	185	185									
	E ICE FO	78	78	78	78	78	78	78	78	78	78	78
	E ST	190	190	190	190							
	N RENTAL ICE			108	108							
	Total	453	453	376	376	78	78	78	78	78	78	78
SOUR	E OCGT	70	70	70	70	70	70	70	70	70	70	70
HYDRO	KADISHA	21	21	21	21	21	21	21	21	21	21	21
	LITANI	199	199	199	199	199	199	199	199	199	199	199
	NAHR BARED	17	17	17	17	17	17	17	17	17	17	17
	NAHR IBRAHIM	32	32	32	32	32	32	32	32	32	32	32
	SAFA	13	13	13	13	13	13	13	13	13	13	13
	DARAYA, CHAMRA, YAMOUNEH & BLAT			58	58	58	58	58	58	58	58	58
	JANNEH				54	54	54	54	54	54	54	54
	REMAP BALANCE							40	80	120	160	200
	Total	283	283	341	395	395	395	435	475	515	555	595
SOLAR PV		0	180	180	430	680	930	1 180	1 430	1 680	1 930	2 180
CSP	N_CSP_STORAGE_7.5H_CF_27_MAX_1187						50	50	50	50	50	50
WIND		0	0	226	226	426	446	456	636	636	816	1 016
BIOGAS	E_BIOGAS_NAAMEH	7	7	7	7	7	7	7	7	7	7	7
Storage	BESS (MW/MWh)				201/213	201/213	201/213	201/213	201/213	201/213	201/213	201/213
	N_JOUN_PHS_UPGRADE_49.3MW_4H							49	49	49	49	49
	Total (MW/MWh)	0/00	0/00	0/00	201/213	201/213	201/213	250/410	250/410	250/410	250/410	250/410

Source: Least Cost Generation Plan, WB

As is visible in Fig. 3.2-2 below, Lebanon's generation mix is mainly reliant on Open/Closed cycle gas turbines, along with steam turbines, ICEs and rental solutions. As the system evolves per the optimal generation plan, the existing CCGTs will switch to NG and see their share in the mix increase. While ICEs and ST recede, RE technologies will ramp up. Rental solutions in the graph reflect the strategy (Temporary Solutions). By 2024, the mix is predominantly CCGT based with a decent share of RE. Solar PV will continuously increase throughout the horizon of the study, thus ensuring demand satisfaction. Wind and hydro follow the same trend, with a slower pace. Under this plan, RE penetration will increase from 4% in 2020 to 32% in 2030.



	2019	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030
RENTAL (incl. barges)	2 932	2 940	2 247	8 018	7 899	0	0	0	0	0	0	0
ICE (non rental)	1 739	1 745	1 739	1 739	1 696	752	79	130	96	70	83	48
ST	2 946	2 952	2 946	2 480	2 458	40	0	3	0	0	0	0
OCGT	370	370	370	243	259	114	3	3	2	1	2	0
CCGT	6 147	6 165	6 147	6 136	6 145	18 066	19 348	19 321	18 958	19 106	18 786	18 467
CSP	0	0	0	0	0	0	121	121	121	121	120	119
SOLAR PV	0	0	317	317	771	1 228	1 665	2 107	2 547	2 994	3 427	3 864
WIND	0	0	0	833	833	1 551	1 612	1 642	2 191	2 200	2 684	3 216
HYDRO	578	580	578	833	707	706	701	876	1 050	1 232	1 398	1 569
BIOGAS	50	50	50	50	50	50	50	50	50	50	49	49
STORAGE charge (incl. CSP)	0	0	0	0	-76	-83	-365	-388	-381	-420	-450	-370
STORAGE discharge (incl. CSP)	0	0	0	0	66	72	332	350	344	377	402	334
Demand (GWh)	24 247	24 339	23 979	21 890	22 429	22 861	23 547	24 254	24 981	25 731	26 503	27 298
Renewable Energy share (%)	4%	4%	7%	10%	11%	16%	18%	20%	24%	26%	29%	32%

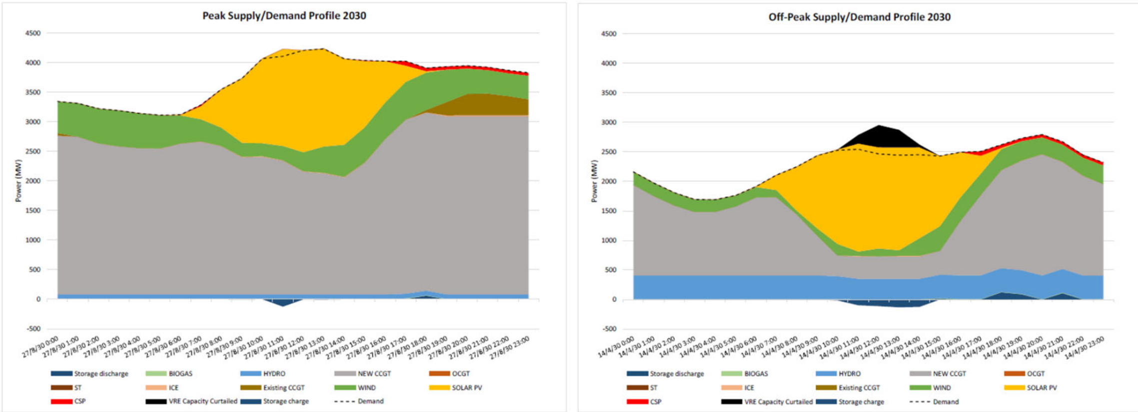
Source: Least Cost Generation Plan, WB

Fig. 3.2-2 Generation Mix (GWh) and Renewable Energy Share (%) upto 20230

Fig. 3.2-3 shows the hourly dispatch of the generation during the annual peak demand. The new CCGTs remain the base load power plants throughout the day, while RoR Hydro contribution is minimal. The existing CCGTs are activated with the loss of solar PV, so as to respond to the high demand. During noon hours, the fuel fired power plants' set point is reduced in order to give way to wind and solar PV.

During off-peak days, the same analysis remains applicable, with the particularity that Variable Renewable Energy is curtailed during high solar production periods. In order to guarantee enough system inertia for system stability, thermal units are run at minimum technical level during sunny hours. However, the annual VRE[1] curtailment represents less than 1% (0.1% for solar PV and 0.5% for wind) of the available energy and is not a reason for concern given the conservative approach used to determine system inertia requirements.

[1] Variable Renewable Energy

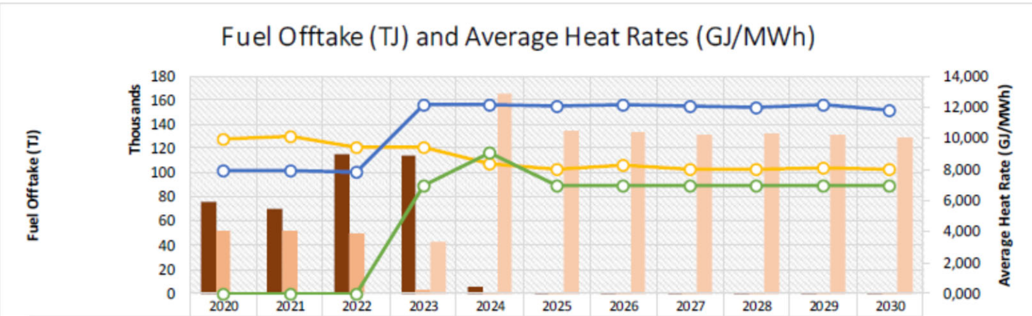


Source: Least Cost Generation Plan, WB

Fig. 3.2-3 Load Curve with Generation Mix in Peak and off-Peak Demand

Fig. 3.2-4 details the fuel consumption (offtake in TJ) and the average heat rate for each fuel type, in the 2020 – 2030 interval. Note that while pre-2024 the system's offtake was dominated by Fuel Oil, once the new NG CCGTs are introduced and the old CCGTs are switched to NG, Natural Gas displaces Fuel Oil as the main fuel type for the system. Fuel oil efficiency increases around 2022 – 2024 as the inefficient Zouk and Jieh units are decommissioned.

As the CCGTs of Deir Ammar and Zahrani switch from Gas Oil to Natural Gas in 2022, only the Sour and Baalback units will remain on Gas Oil, thus increasing its overall heat rate. Meanwhile, with the aforementioned conversion, the NG heat rate comes into play in 2023. It increases in 2024 due to the new CCGTs being commissioned in Open Cycle. Then the heat rate decreases starting 2025, as these new CCGTs are fully commissioned.



	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030
Fuel Oil (TJ)	76 063	69 948	115 206	114 006	5 379	165	567	282	62	134	37
Gas Oil (TJ)	51 832	51 693	50 056	3 159	1 381	31	39	29	13	29	4
NG (TJ)	0	0	0	42 648	164 944	134 206	134 071	131 596	132 907	131 086	128 497
Fuel Oil (GJ/MWh)	9,959	10,091	9,414	9,459	8,321	8,000	8,261	8,041	8,000	8,057	8,006
Gas Oil (GJ/MWh)	7,932	7,933	7,847	12,190	12,162	12,101	12,168	12,044	11,988	12,182	11,824
NG (GJ/MWh)	0,000	0,000	0,000	6,941	9,057	6,916	6,916	6,919	6,934	6,953	6,942

Source: Least Cost Generation Plan, WB

Fig. 3.2-4 The Fuel Consumption (offtake in TJ) and the Average Heat Rate for each Fuel Type

Table 3.2-2 summarize the comparison between Base Case and HRE. Both studies secure the supply reliability and dynamic stability of power system. Renewable energy will reach to the share in annual power generation 32% in Base Case and 35% in HRE. Although overall generation cost ($/MWh) is almost same price, HRE has slight advantage on it. Total expense for power generation from 2020 to 2030 is approx. 20 B$ in both studies.

Table 3.2-2 Comparison between Base Case and HRE

Scenario	Key Performance Indecators								
	2030 planting	Retirements	Renewable energy share	Dispatch	Operability and renewable penetration	Fuel and emissions for 2030	Total system cost 2030	Generation cost 2030	Total Cost 2020 - 2030
Base Case	ICEs: 289 MW ST: 50 MW OCGT: 144 MW CCGT: 4 000 MW Hydro: 595 MW Solar PV: 2 180 MW CSP: 50 MW Wind: 1 016 MW BioGas: 7 MW BESS: 201 MW/213 MWh PHS: 49 MW/197 MWh	Zouk and Jieh ST in 2024	32%	Fulfills minimum kinetic energy requirements for dynamic stability	Negligible renewable energy curtailment (<1%)	Fuel Oil: 37 TJ Gas Oil: 4 TJ NG: 128 497 TJ CO2 emission: 7.18 Mt CO2 intensity: 263 g/kWh	74.26 $/MWh	40.11 $/MWh	2020: 1 314 M$ 2021: 1 402 M$ 2022: 2 135 M$ 2023: 2 074 M$ 2024: 1 817 M$ 2025: 1 621 M$ 2026: 1 696 M$ 2027: 1 764 M$ 2028: 1 873 M$ 2029: 1 949 M$ 2030: 2 027 M$ Total: 19 672 M$
High Renewable Expansion	ICEs: 709 MW ST: 50 MW OCGT: 144 MW CCGT: 3 450 MW Hydro: 595 MW Solar PV: 3 230 MW CSP: 50 MW Wind: 656 MW BioGas: 7 MW BESS: 246 MW/246 MWh PHS: 49 MW/197 MWh	Zouk and Jieh ST in 2024	35%	Fulfills minimum kinetic energy requirements for dynamic stability	Acceptable renewable energy curtailment (~2%)	Fuel Oil: 99 TJ Gas Oil: 16 TJ NG: 125 003 TJ CO2 emission: 6.99 Mt CO2 intensity: 256 g/kWh	73.87 $/MWh	38.89 $/MWh	2020: 1 314 M$ 2021: 1 402 M$ 2022: 2 135 M$ 2023: 2 079 M$ 2024: 1 821 M$ 2025: 1 642 M$ 2026: 1 719 M$ 2027: 1 783 M$ 2028: 1 849 M$ 2029: 1 926 M$ 2030: 2 016 M$ Total: 19 687 M$

Source: Least Cost Generation Plan, WB

(3) Sensitivity Analysis by Additional Scenarios

In this Study, following four additional scenarios are prepared as sensitivity analysis;

1. Introduction of CO_2 Cost based on the forecast by WB and EIB
2. Annual 3% decrease of power demand
3. Termination of restriction on the introduction of renewable energy
4. Restriction on development of new thermal power plants upto 1GW

These sensitivities lead to some interesting observations:

- With respect to RE penetration, removing constraints on annual RE growth rates results in the same level of RE penetration as HRE (35 percent), which itself is only 3 percent higher than the Base Case. This is due to the fact that the techno-economic optimum, defined by the hypotheses of the study, is reached.
- More significant RE scale-up is achieved when adopting carbon pricing policies (RE penetration increases to 41 percent) and when combining these policies with unconstrained

annual RE growth (RE penetration increases to 54 percent, if World Bank carbon pricing forecasts are used, and 68 percent, in case of EIB's). It is important to note, however, that such a significant increase in RE penetration, requiring doubling of RE energy in the system when compared to the Base Case, is expected to have significantly increased transmission costs associated with it (which will be tested in the next phase of this study) and, as of yet, seems unprecedented in an electric system.

- Constraining annual thermal generation investments to 1GW does not change the level of RE penetration from the Base Case. Instead, it is expected to increase the amount of temporary generation needed for a longer time and/or increase unserved demand.

- A third gas-fired combined cycle power plant (presumed at Salaata) is needed in all scenarios based on the assumptions with respect to demand and RE growth rate, except in the case of adopting carbon pricing coupled with unconstrained annual RE growth. This is largely because of (a) limited available land at the Deir Ammar and Zahrani sites for new generation, (b) the need for baseload generation in a short period of time and (c) the two assumed 2x1 and 3x1 configurations for all new thermal power plants. This conclusion may change in the

3.2.2 Policy Statement "Setting Lebanon's Electricity Sector on a Sustainable Growth Path"

(1) Outline

This national policy statement and plan to set Lebanon's electricity sector on a sustainable growth path adopts a pure technical approach, without any political or electoral prejudice. It rather entails practical, transparent and clear initiatives to reform the sector, absent which, the current dire situation limiting daily electricity supply to three hours will persist. Any delay in approving its terms and starting its implementation adds monthly losses amounting to US$ 70 million approximately, or more than US$ 800 million per year.

The reform plan is based on the Least Cost Generation Plan prepared by Électricité de France EDF in September 2021, and on "Lebanon Power Sector Emergency Action Plan" developed by World Bank in 2020. It also builds on policy papers and plans previously approved by the Council of Ministers. This plan will gradually and quickly increase supply of electricity, to achieve 24 hours per day within four years, it will put Électricité du Liban (EDL) on the path to financial recovery within two years, it will establish the Electricity Regulatory Authority (ERA), and will implement Public Private Partnerships (PPP) in the generation and distribution sectors. The plan rests on the following main pillars:

I. Increasing supply hours while preparing to increase generation capacity on the grid.
II. Increasing generation by commissioning three new power plants with the participation of the private sector.
III. Improving performance of the network, reducing losses and enhancing collection
IV. Achieving financial sustainability
V. Addressing the regulatory and legislative frameworks as soon as possible

Conditions for the successful implementation of the plan include the following main factors:

- Securing with Arab partners the arrival of gas from Egypt and electricity from Jordan through Syria, and the final approval from the international partners
- Commitment of all stakeholders, including ministries, institutions, military and security forces, each according to its responsibilities, to support the successful implementation of the plan
- Serious and diligent escort by the concerned parties to the illegal connections removal campaigns
- Security protection for substations, EDL and DSPs[2] facilities and personnel as well as the Lebanese portion of the AGP
- Payment of due electricity bills by the public sector
- Metering the energy consumption of the displaced Syrians and the Palestinian refugees and collecting their corresponding bills
- Securing sustainable access to US dollars using SAYRAFA platform exchange rate to enable EDL to settle its financial dues in foreign currency
- Provision of public/private financing for the investments mentioned in the plan, along with all associated legislations as required

(2) Increase Supply of Cheaper, more Sustainable Electricity Supply

The policy objective is ensuring reliable, affordable, and sustainable (24/7) electricity services across Lebanon in an efficient, fiscally balanced, and environmentally friendly manner. This goal should be achieved while accelerating the transition to a sustainable energy future for Lebanon that prioritizes affordable renewable energy solutions, enabled by accelerated transition of baseload generation from liquid fuels to cheaper, cleaner natural gas.

As part of this objective, the plan outlines immediate action that will help improve electricity supply in the short‐term to reduce consumers' continued reliance on expensive, polluting private diesel generation. This interim solution aims to bridge a transition period while the sector undertakes wider structural reforms, which will take several years to complete. Immediate goals comprise the following points:

[2] Distribution Service Providers

- Diversify the energy mix towards affordable renewables sources
- Switch from liquid fuel to cheaper and cleaner gas for baseload generation
- Strengthen regional integration to rapidly increase supply in a least cost manner

Electricity imports from Jordan could also increase supply in the short‐term. The connection between the Lebanese and Jordanian grids (though the connection through Syria was damaged during Syria's civil war but was recently repaired) is another existing channel that can be tapped. Jordan has a surplus electricity that Lebanon can buy to increase its power supply.

In the medium‐to long‐term, however, EDL must increase its generation resources. EDF's Least Cost Generation Plan clearly indicates the need to significantly increase gas‐fired generation capacity and Renewable Energy (RE) generation in the country. In 2019, Lebanon ratified the Paris agreement and committed itself to increase its share of renewable energy generation to 20% by 2030, this commitment could be increased to 30% with international commitments in line with the national renewable energy action plan developed by the International Renewable Energy Agency (IRENA) and the Least Cost Generation Plan. With an existing 100 MW average generation from hydropower, the key to reaching the Paris agreement's target is to scale up utility scale RE generation as well as distributed RE system to increase the share of RE in the generation mix. To enable this scale‐up and to ensure reliability and stability of the electric system, there is also a need to increase gas‐fired generation. Because of the current severe lack of generation capacity, the initial gas‐fired power plants need to urgently be developed and commissioned to provide a solid baseload capacity to meet demand and expand the transmission system's capacity to integrate more intermittent RE generation and energy storage.

(3) Action Plan

The main objective is to increase supply to meet national demand in a cost‐effective, fiscally balanced, and sustainable manner, with RE to account for at least 30 percent of the energy mix by 2030 in accordance with EDF's Least Cost Generation Plan expansion analysis (September 2021). MoEW's plan aims to provide all customers with reliable 24h electricity services in 2026. This requires a multi‐faceted program to initiate short‐, medium‐ and long‐term solutions in parallel to transition the sector from expensive liquid fuel‐based generation towards a generation mix that combines cheaper, cleaner gas for existing and new power plants with RE generation. Regional connection is a strategic option that will provide immediate access to affordable gas for Deir Amar through the existing Arab Gas Pipeline, while electricity imports from Jordan would rapidly increase supply. Temporary generation capacity will be used for a transition period until permanent capacity is commissioned through building new power plants in locations to be determined according to need and necessity, taking into consideration the environmental conditions, while locating one of the plants on the northern coast of Lebanon. In parallel, utility - scale RE projects will be scaled up across the country, whereby competitive and transparent approaches will be used to mobilize private sector investments in a timely and cost - effective manner.

In 2018, the Government committed to undertake future generation investments in the sector through private sector led independent power generation. This remains the policy of this Government. However, mobilization of the private capital needed for these investments will require a macro - fiscal stabilization program to enable commercial financing and provide the confidence needed for investors to commit the sizable investments needed for both thermal and RE power plants. In this respect, the urgency of the initial power plant investments needed may necessitate alternative financing approaches to ensure timely implementation, while, at the same time, recognizing the limitations on public debt expansion within the current macro - fiscal environment. This may include considering public, development finance, or other innovative solutions to ensure availability of the capital investments needed to start construction in the short - term.

Table 3.2-3 show the action plan for the power generation development planning.

Table 3.2-3 Action Plan for the Power Generation Development Planning

	Action	Responsibility	Milestones	
	Generation			
	Electricity imports from Jordan	EDL	2022	
	Fuel switching to gas for Deir Amar Power Plant (AGP)	MoEW - EDL	2022	
	Temporary generation capacity (at Deir Amar III – 520 MW), as a transition before permanent solutions are deployed	MoEW - EDL	2023	
	RE additional capacity :	MoEW - EDL	*Procurement*	*Commissioning*
	• Wind: 226 MW		2022	2024
	• Solar: 180 MW		2022	2023
	• Solar: 200 MW		2023	2026
	• Wind: 520 MW		2022	2028
	• Hydro: 282 MW (rehab.)		2023	2025
	• Hydro: 112 MW (greenfield)		2023	2025
	• Solar: 300 MW (+ 210 MW storage)		2023	2026
	Adopt a faster timetable for the development of the new power plants and associated transmission upgrades by preparing the tendering documentation as per approved practices	MoEW - EDL	2022	

	Action	Responsibility	Milestones	
	Permanent power plant (CCGT1): 825 MW	MoEW - EDL	2022	2025
	Permanent power plant (CCGT2): 825 MW	MoEW - EDL	2023	2026
	Permanent power plant (CCGT3): 825 MW	MoEW - EDL	2024	2027

Source: Setting Lebanon's Electricity Sector on a Sustainable Growth Path

(4) Short Term Action (within a year)

1) Secure electricity imports from Jordan.

In line with MoEW's effort to secure a fast, affordable electricity from neighboring Arab countries, MoEW and EDL have concluded an agreement with Jordan to import an average of 200 MW surplus Jordanian electricity, equivalent to around two hours of additional electricity supply per day on EDL's grid. Purchased electricity would be transported to Ksara substation in the Bekaa region, therefore keeping transportation costs to a minimum. The agreement is defined on a one - year renewable basis, and, therefore, should ensure an additional stable source of supply.

2) Secure gas imports from Egypt through AGP.

With the help of the World Bank and the Egyptian authorities, a ten - year agreement with Egypt (with a clause allowing its extension for another five years) is being finalized to supply Deir Amar with natural gas through the AGP. The gas would be channeled through the pipeline at a rate of around 650 million cubic meter per year, allowing the generation of an average of approximately 400 MW in Deir Amar. This solution will ramp up Deir Amar's capacity and increase daily supply by about 4 hours, while, at the same time, free up available fuel resources that would otherwise be used at Deir Amar instead to be used at Zahrani to increase its electricity supply.

(5) Short to Middle Term (1 to 2 years)

1) Provide natural gas to existing plant and build gas - fired combined cycle power plant at Zahrani.

To cover the natural gas needs of the existing power plant at Zahrani, MoEW intends to competitively procure natural gas through an FSRU infrastructure/gas access allowing fuel - switching of Zahrani I in 2023, while addressing the legal implications from the latest FSRU tender, such that the Zahrani I generation cost post switching to natural gas does not exceed the overall improved average generation cost according to this plan.

Moreover, and as per the recommendations of EDF's Least Cost Generation Plan (September

2021) that include building a power plant at Zahrani of 825 MW capacity (Zahrani II), MoEW will launch competitive procurement for the design, construction and operation of a new power plant using a creative PPP approach, and by considering the site location and tender documents already prepared by MoEW and approved by CoM earlier, after technical verification that the proposed land area and transmission grid could readily accommodate the planned power plant capacity. In this regard, the CoM approval is needed to formally allocate the proposed land at Zahrani to MoEW for the purpose of developing Zahrani II power plant. Initial public financing may also be contemplated (possibly using IMF's extra SDR allocation), with possible subsequent (built-in) divestment to the private sector after commissioning.

2) Temporary generation capacity at Deir Amar.

Given the contemplated availability of natural gas through AGP at Deir Amar (or international LNG gasified in Jordan and channeled to Deir Amar), and the readiness of the existing transmission network to evacuate additional generation capacity as per EDF confirmation5, it is expected that gas-fired temporary generation units of up to 520 MW at Deir Amar (Deir Amar III land belonging to MoEW, under the disposal of Tripoli Oil Installations) would be supplied during 2023-24 until the permanent Deir Amar II plant is constructed and commissioned. Active market sounding efforts have already identified interests from Egypt, US and others to supply such temporary infrastructure late 2022/early 2023.

3) Solar PV IPPs.

To introduce on grid solar energy, MoEW through the Lebanese Center for Energy Conservation (LCEC) is piloting a project aiming to deploy solar farms throughout Lebanon with a total generation capacity of 180 MW in 2023 divided into 15 MW per solar farm. 11 private investors[3] have already answered the call for tenders (as shown below), but implementation, however, awaits required financial guarantees. The program prioritizes medium size units which are simpler to structure and locate geographically without a major re-design of the transmission system.

(A) In the Bekaa implementation region (governorates of Bekaa and Baalbek-Hermel):

1) ECOSYS-KACO
2) DAWTEC-LOOOP-STAUNCH
3) LABWE SOLAR FARM

(B) In the Mount Lebanon implementation region (governorate of Mount Lebanon):

[3] https://lcec.org.lb/our-work/MEW/solar-Farm-180

4) JOUN PV
5) SIBLINE SOLAR FARM
6) E/ONE

(C) In the South implementation region (governorates of South Lebanon and Nabatiyeh):

7) SOUTH POWER
8) RIMAT 15
9) GDS-ET-NABATIYEH

(D) In the North implementation region (governorates of North Lebanon and Akkar)

10) KFIFANE-PHOENIX POWER PLANT
11) ELECT - STC - SOLISTIS

4) Wind Farms.

MoEW has committed to develop an RE program. Power Purchase agreements (PPA) were signed for three wind energy projects with a total capacity of 226 MW in 2024, with wind farms located in Akkar, with implementation pending financial guarantees. The three companies committed to execute these projects following negotiations with the MoEW that secured the right of the government to renegotiate to decrease the kWh price at the time of financial close.

(6) Middle to Long Term (3 to 5 years)

1) Renewable Energy scale - up.

MoEW will scale up utility - scale RE projects (solar, wind and hydropower) towards an objective of reaching at least 30 percent of generation capacity from renewable sources in the energy mix by 2030, as per EDF's Least Cost Generation Plan. Projects will be developed and procured through fully structured competitive process and supported by credit enhancement mechanisms.

2) Finalizing the agreements for Solar PV IPPs with storage.

To introduce on - grid solar energy, the LCEC under the supervision of MoEW is piloting a long - term project involving additional Solar Farms with storage. Private investors have already answered the call for tenders, but implementation, however, awaits financial guarantees. The Lebanese Center for Energy Conservation (LCEC) launched the study phase for these solar parks but is waiting for financial guarantee and foreign currency liquidity to continue with the project. The program prioritizes medium - size units which are simpler to structure and locate geographically without a major redesign of the transmission system. Additional tenders will be prepared to increase supply to 2,180 MW of solar PV and 50 MW

CSP storage by 2030, as per EDF's Least Cost Generation Plan.

3) Wind farms.

Ongoing tender for four wind projects are prepared by the LCEC to increase supply to 746 MW by 2028, with the aim of around 1,000 MW by 2030, as per EDF's Least Cost Generation Plan.

4) Hydropower.

MoEW intends to rehabilitate the existing 282 MW hydroelectric capacity and develop 112 MW of potential greenfield projects financed and operated by the private sector.

5) CCGT

Based on Least Cost Generation Plan, additional CCGTs are developed under fair competitive bidding process.

3.2.3 Renewable Energy Outlook Lebanon (2020), LCEC

(1) Overview

This survey report was compiled by International Renewable Energy Agency (IRENA) in collaboration with Ministry of Energy and Water (MoEW) and Lebanese Center for Energy Conservation (LCEC) in 2020. It presents analyses of the current status and institutional challenges in renewable energy development, along with the policy measures (Reference Scenario) and the Renewable Energy Roadmap (REmap) aimed at achieving a 30% share of renewable energy in the power generation mix by 2030.

(2) Renewable Energy Road Map

Two scenarios have been established for renewable energy developments as the Reference scenario and Renewable Energy Roadmap (REmap).

The first scenario, the Reference Scenario, is established by aggregating the current planned and implemented developments based on NREAP2016-2020 (National Renewable Energy Action Plan 2016-2020). The second scenario, REmap, is designed to achieve a 30% share of renewable energy in the electricity consumption by 2030, based on the projected electricity demand forecast for that year.

<Reference Scenario (REF)>

- Hydropower capacity is 601MW, comprising the existing 285MW and planning additional 315MW that MoEW received EOI applications as new developments.
- Wind power capacity is 626MW, combining the ongoing 226MW projects with the planned

400MW, which is currently in the procurement phase following the RFP announcement.

- Solar power capacity is 1,030MW, considering both ongoing and planned projects.
- Biomass power generation capacity is 8MW of existing installed facilities.

<REmap>

- Hydropower capacity will maintain the same capacity as the Reference Scenario, combining the existing and new installations for a total of 601MW.
- Wind power capacity will be 1,000MW, considering the reference scenario's 626MW and an assumed additional developments.
- Solar power will be total capacity of 1,280MW, which includes the 1,030MW from the Reference Scenario, along with an additional 150MW by promoting with such as NEEREA and an additional 150MW with storage-integrated CSP plants.
- Biomass power generation capacity will be 13MW with additional 5MW from a newly established facility at the wastewater treatment plants along with an existing 8MW plant.

Table 3.2-4 Renewable Energy Roadmap

Reference Case REF 2030	Capacity (MW)	Average LCOE (USD ¢/KWh)	Generation (GWh)	Cost (M.USD)
Natural Gas	4,909	10.76	27,432	2,951
Wind	626	8.27	1,817	150
Hydropower	601	5.33	1,749	93
Solar PV*	1,030	4.47	1,789	80
Biogas	8	4.55	59	3
Total energy cost (Million USD)				3,277

* : includes centralized solar PV only

Renewable Energy Roadmap REmap 2030	Capacity (MW)	Average LCOE (USD ¢/KWh)	Generation (GWh)	Cost (M.USD)
Natural Gas	4,909	10.76	23,393	2,517
Wind	1,000	8.27	2,655	219
Hydropower	601	5.33	1,749	93
Solar PV*	2,500	4.47	4,342	194
Biogas	13	4.55	99	5
Total energy cost (Million USD)				3,028

* : includes centralized solar PV only

Source: IRENA (2020), Renewable Energy Outlook Lebanon – Based on Renewables Readiness Assessment and REmap analysis

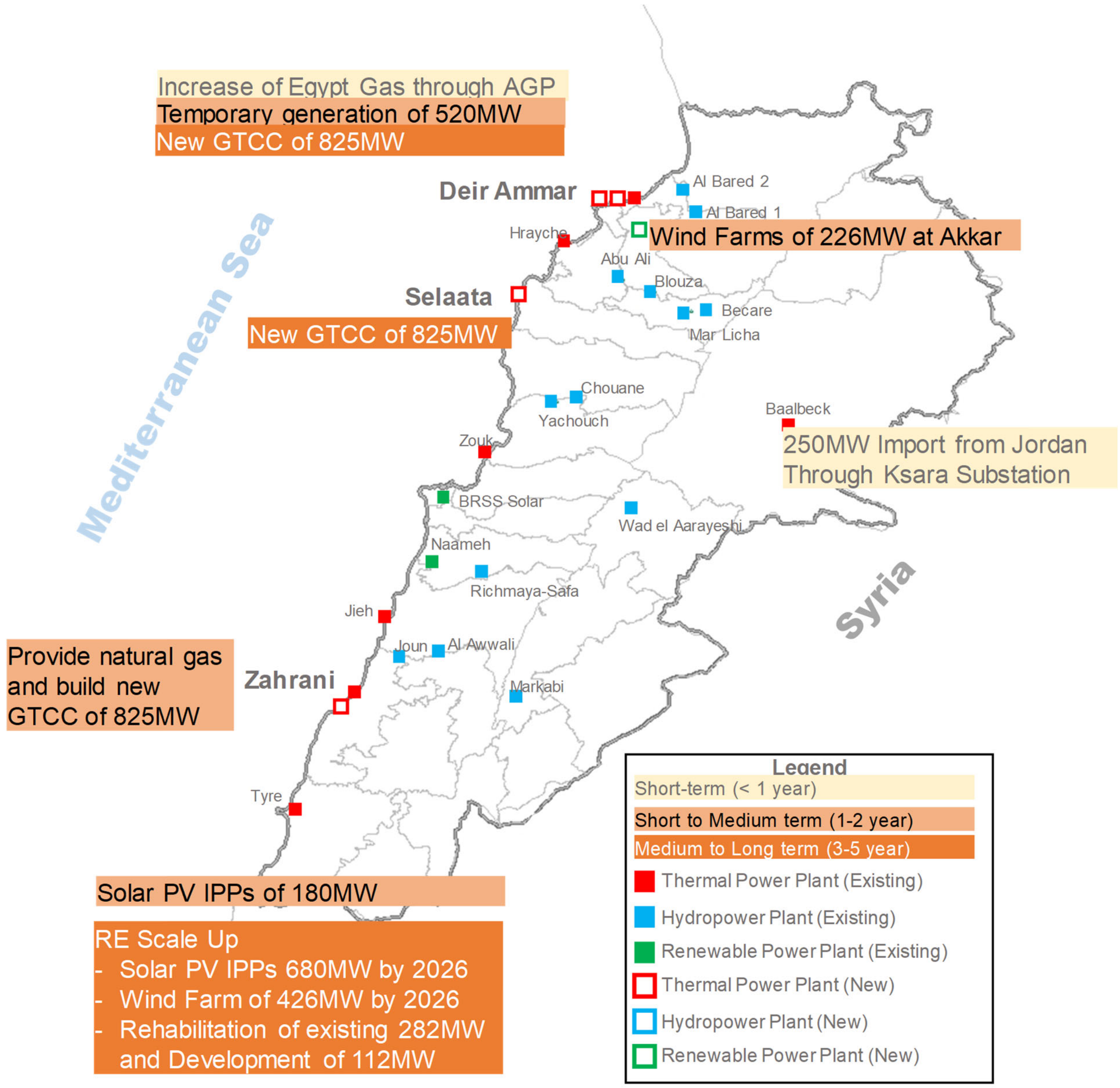
3.3 FUTURE FORECAST FOR THE POWER GENERATION DEVELOPMENT IN LEBANON

The location map of new and existing power sources is shown in Fig. 3.3-1

As of June 2023 when JICA Study Team conducted 2nd dispatch, there was no concrete prospect for the development of new power sources which had been still trapped in a difficult situation. In addition, the U.S. sanctions against Syria and the stagnation of the government's plan for Liquefied Natural Gas (LNG) imports are expected to be difficult to resolve by MoEW or EDL alone. In order to improve the power supply situation, the measures that EDL can take in the current situation where it is difficult to obtain financing from development partners or banks are limited to the following.

i. Financial soundness through tariff collection based on new electricity rates
ii. Increase of fuel procurement, existing thermal power generation and power sales

In addition, an increase in power supply by DRE introduction is also expected. From the perspective of EDL's reconstruction, it is important to rotate the cycle of i and ii and steadily realize financial soundness and supply increase. Under such circumstances, it is also necessary to consider a fund allocation plan, such as whether to use the revenue to fuel procurement, investment in new facilities, or personnel replenishment.



Source: Prepared by JICA Study Team based on Setting Lebanon's Electricity Sector on a Sustainable Growth Path

Fig. 3.3-1 Location of New and Existing Power Plants

CHAPTER 4

INFORMATION RELATED TO THE FIELD OF TRANSMISSION LINE AND SUBSTATION

CHAPTER 4 INFORMATION RELATED TO THE FIELD OF TRANSMISSION LINE AND SUBSTATION

4.1 CURRENT STATUS AND ISSUES OF TRANSMISSION LINE AND SUBSTATION TRANSFORMATION FACILITIES

EDL's Transmission Division is responsible for planning, development and operation of the Lebanese power grid. Fig. 4.1-1 shows the transmission system of Lebanon. Lebanon's major power demand areas are located in the central and western parts of Lebanon, including the capital city of Beirut. The main transmission line is a 220kV transmission line running north-south from Sour in the south to Behsas in the north, parallel to the Mediterranean Sea. This trunk transmission line supplies power from the power station belt located on the coast to the capital Beirut located in the Midwest. In addition, another 220 kV transmission line has been installed from central Syria to the north in parallel to form a ring system, and a ring system of 220 kV transmission lines has also been formed around the capital city of Beirut, improving reliability so that the supply route can be secured even in the event of a transmission line failure. The EDL's transmission grid is interconnected with the Syrian transmission grid by three interconnection lines. An overview of the transmission and transformation facilities is shown in Table 4.1-1. Fig. 4.1-2, Fig. 4.1-3 shows a single-line diagram of the entire system in Lebanon.

Table 4.1-1 Overview of transmission line and substation facilities in Lebanon

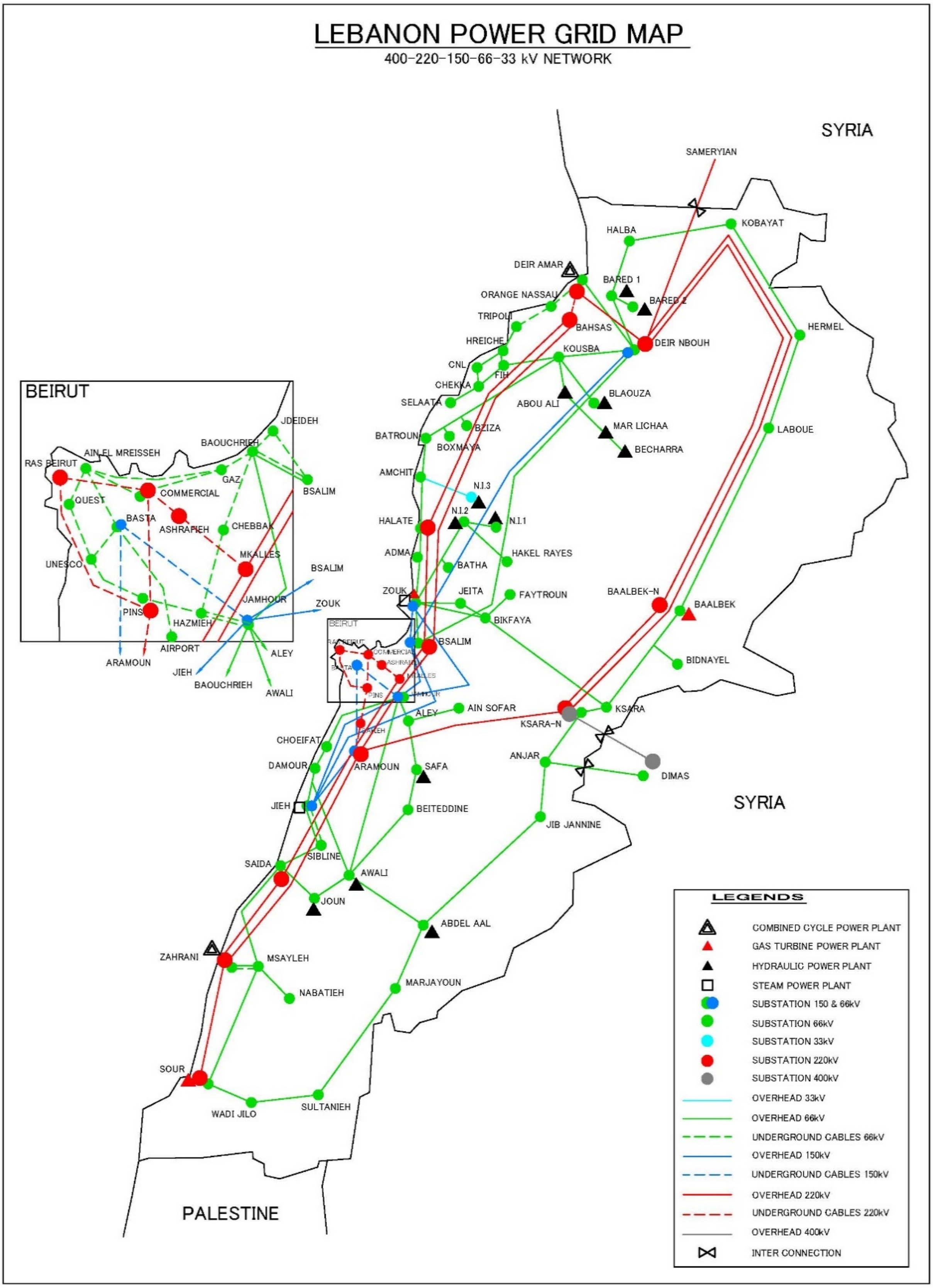
（Top：Transmission Line, Middle:Substation(by voltage),Bottom:Substation(by region)）

Voltage		400kV	220kV	150kV	66kV	Total
Transmission Line Length (km)	Over Head	21	677	164	754	1,616
	Under Ground	0	71	26	102	199

Voltage	400kV	220kV	150kV	66kV	Total
Number of Substation	1	17	4	46	68
Capacity (MVA)	300	4,030	1,360	2,387	8,377

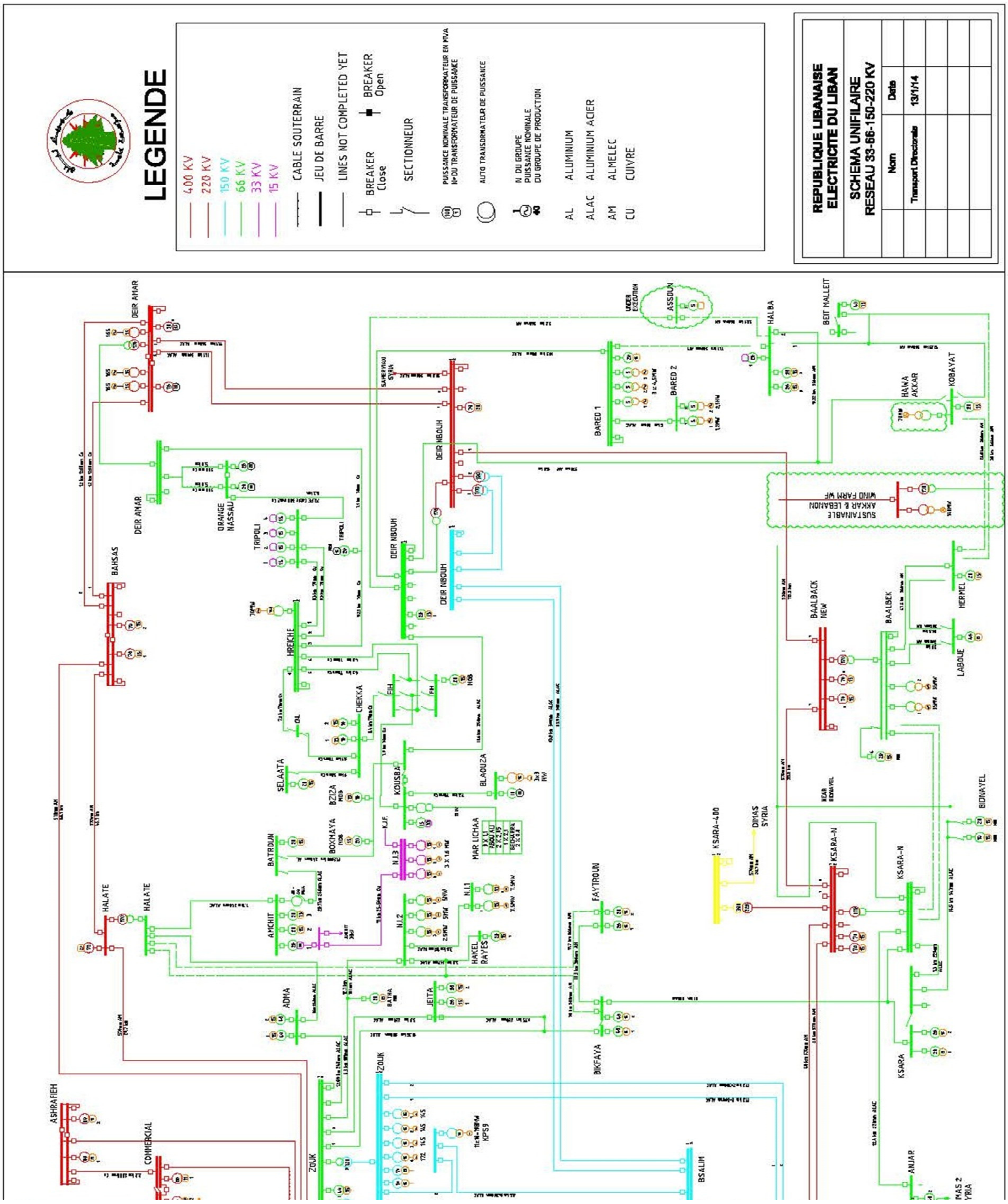
Area	*Beirut*	*Mount Lebanon*	*Bekaa*	*South*	*North*	*Total*
Number of Substation	*20*	*16*	*11*	*10*	*11*	*68*
Capacity (MVA)	*3,470*	*1,432*	*1,375*	*1,050*	*1,050*	*8,377*

Source：EDL(June, 2023)



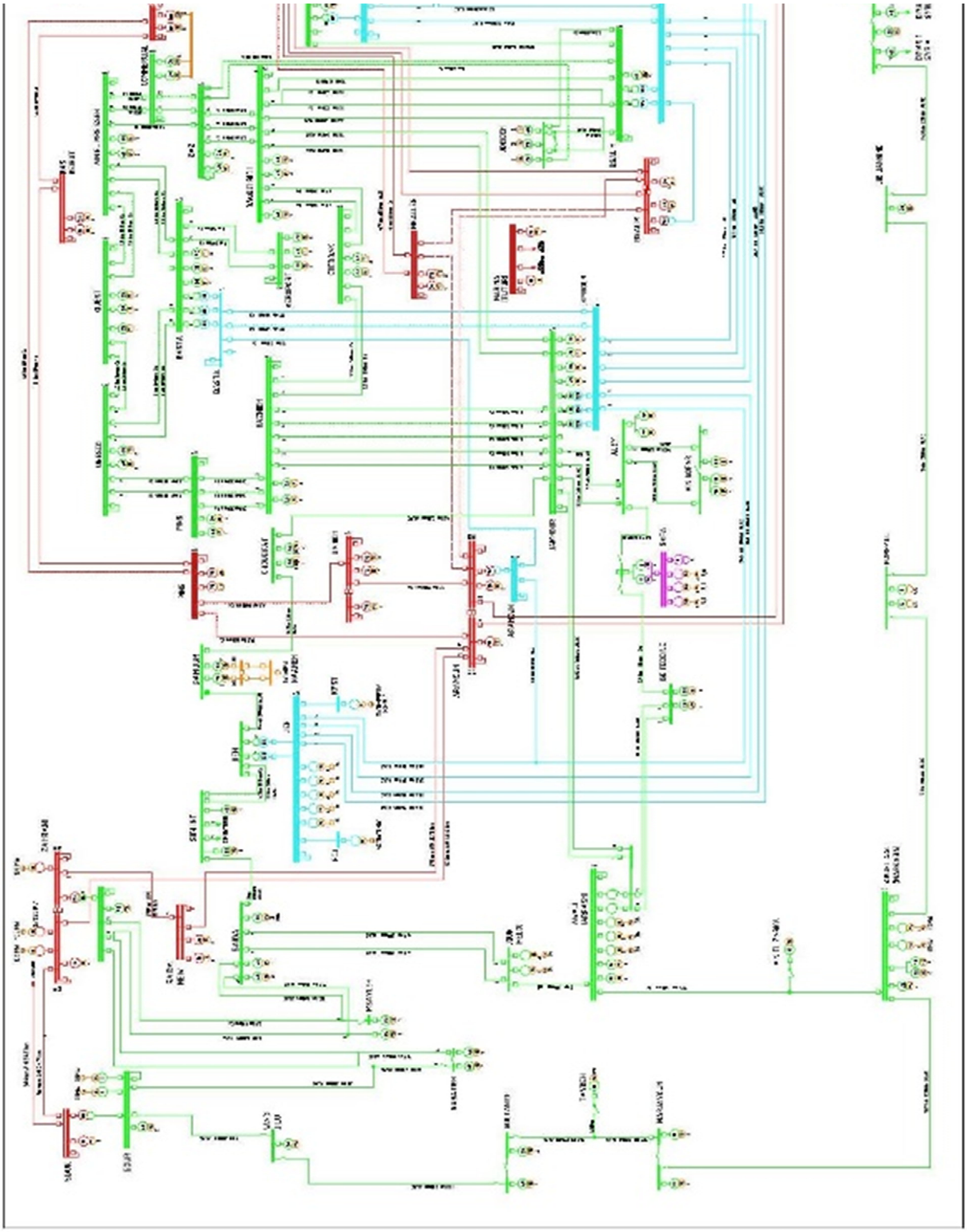
Source：Edited by the JICA study team based on the transmission master plan update (EDF, May 2017)

Fig. 4.1-1 Transmission System in Lebanon



Source: EDL

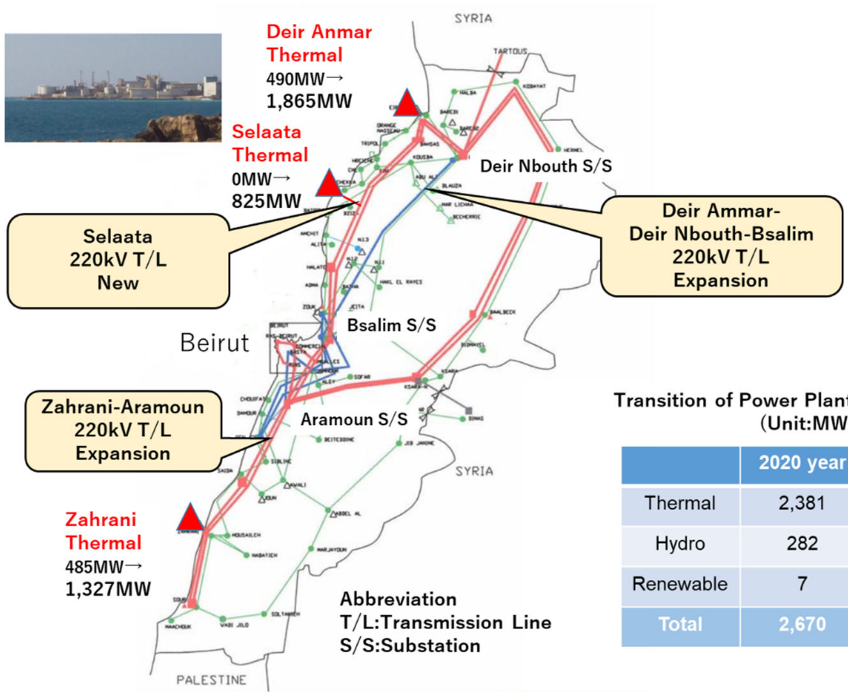
Fig. 4.1-2 Single Line Diagram of the Entire System in Lebanon 1



Source: EDL

Fig. 4.1-3 Single Line Diagram of the Entire System in Lebanon2

In order to realize the power sector reforms advocated by the Lebanese government, it is essential to develop a power transmission and distribution network to meet domestic demand. Therefore, in the transmission grid development plan, an important objective is to update the existing development plan and develop a transmission network that can meet the domestic demand of 4,200 MW expected in 2030, thereby supplying electricity from thermal and hydroelectric power that will be developed in the future to meet domestic demand in a timely manner. A major project is the enhancement of 220kV trunk transmission lines (Fig. 4.1-4) accompanying the enhancement of thermal power plants in the Mediterranean coastal area. Here, the rated power generation capacity of 4,017 MW is planned for 2030 at the three power stations of Deir Anmar, Zahrani, and Selaata, accounting for about half of the total rated power generation capacity of 8,331 MW in 2030. Reinforcement and maintenance of the backbone system to transmit this generated power to demand areas is an urgent issue.



Transition of Power Plant Rated Capacity (Unit:MW)

	2020 year	2030 year
Thermal	2,381	4,483
Hydro	282	595
Renewable	7	3,253
Total	2,670	8,331

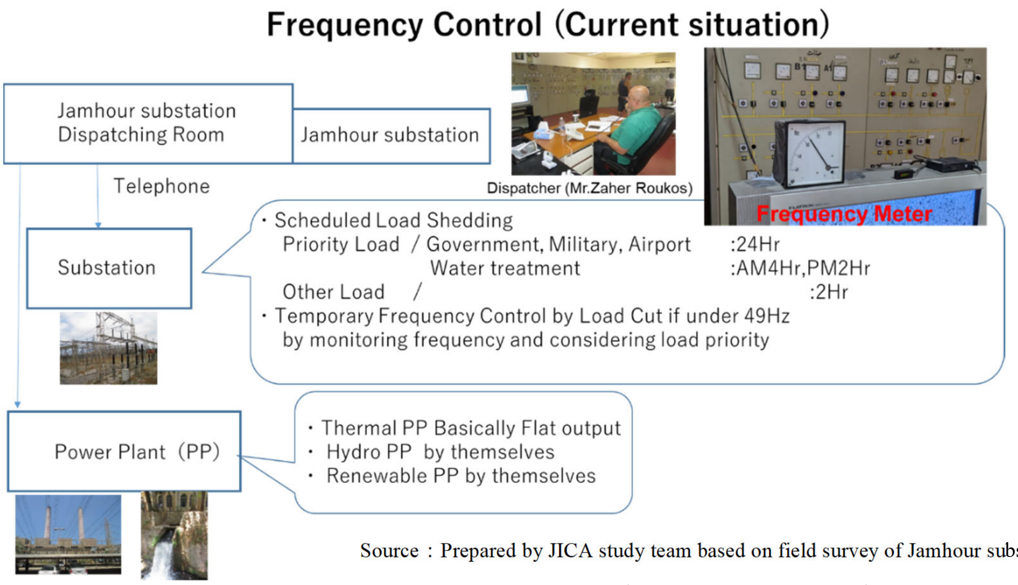
Fig. 4.1-4 Overview of Major Thermal Power Plants and Bulk System Reinforcement by 2030

4.2 BASIC INFORMATION IN THE FIELD OF TRANSMISSION LINE AND SUBSTATION

4.2.1 System Operation Status（alternative function of NCC）

In the Bay of Beirut in August 2020, the EDL headquarters and the National Control Center (NCC) located there collapsed and lost their functions. After that, as an alternative function of NCC, the control room at 132k Jamhour Bulk Substation located in the eastern part of Beirut city, fulfills that function. One dispatcher and one operator are stationed there, and the dispatcher orders to other substations and power stations by telephone while monitoring the frequency meter (Fig. 4.2-1). In order to maintain the frequency at the reference value of 50Hz, the substation feeders are manually cut off to perform load shedding and frequency regulation. There are two methods of load shedding: systematic shedding according to the priority of the load, and temporary shedding in consideration of the priority when the frequency falls below 49Hz. High-priority government, military, and airports are scheduled for 24-hour transmission, next-priority water treatment plants are scheduled for 4 hours in the morning and 2 hours in the afternoon, and finally general loads for only 2 hours (Fig. 4.2-2) .Regarding the output of power plants, thermal power plants are operated at a constant output, while hydroelectric power plants are operated according to the amount of water, etc., and output is basically not adjusted.

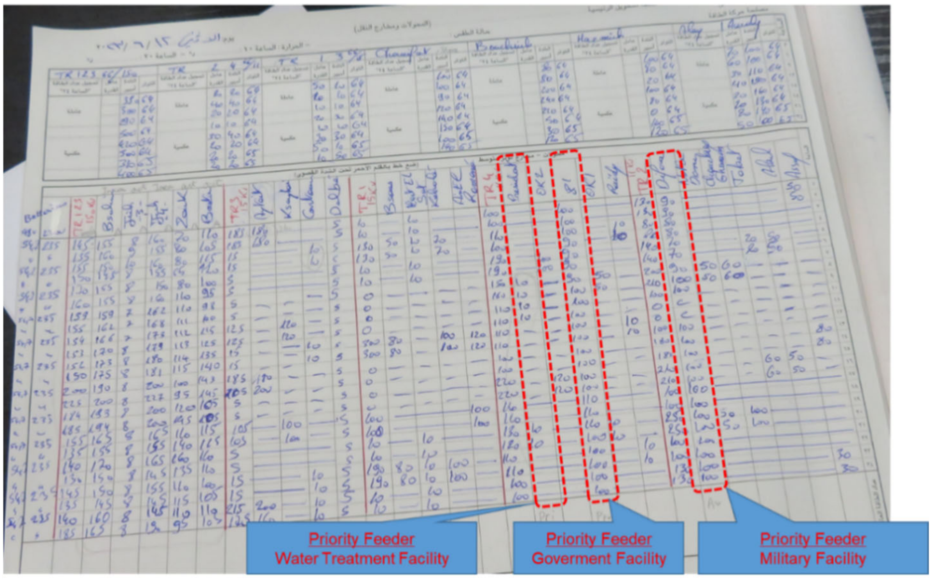
On the other hand, when the previous NCC was functioning, the SCADA system was used to perform operations such as voltage adjustment and system switching for power flow adjustment, etc., in addition to the above frequency adjustment. However, at present, the frequency is only adjusted by load shedding, but during the on-site investigation, the dispatcher was able to respond without problems by restoring the power outage, etc., and the substitute function was sufficiently fulfilled.



Source：Prepared by JICA study team based on field survey of Jamhour substation

Fig. 4.2-1 Power System Operation Situation（Frequency Control）

Operation Record of Jamhour substation (12th June 2023)

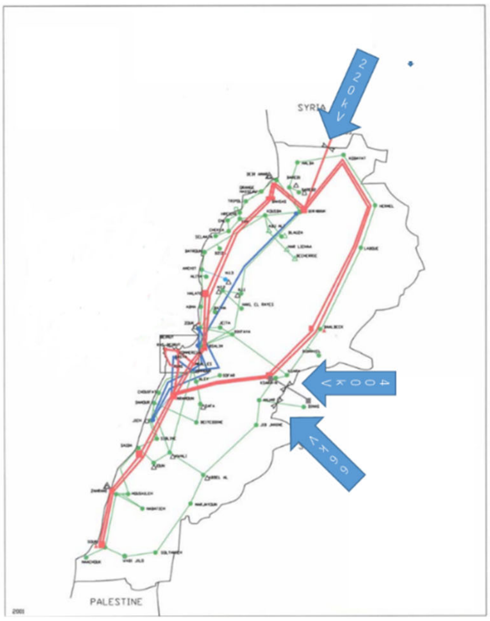


Source: Edited by JICA study team based on Jamhour substation operation record

Fig. 4.2-2 Jamhour Substation Operation Record（Load Shedding Situation）

4.2.2 Interconnection Line Operation Situation

Lebanon has three interconnectors with neighboring Syria (Fig. 4.2-3). Previously, 200MW of power was imported from Jordan via Syria using a 400kV interconnection line. However, since the US sanctions against Syria, the transportation of electricity from Jordan to Syria has been suspended, and all international interconnection lines have been suspended, and electricity has not been imported. According to EDL's transmission department, even if the sanctions are lifted in the future, Lebanon aims to cover the domestic load solely with power plants in Lebanon, basically not relying on electricity imports.



➢ **Concerning to Interconnection Line**

	400kV	220kV	66kV
Capacity (MW)	2 5 0 MW	2 0 0 MW	4 0 MW
Current Situation(MW)	0 MW	0 MW	0 MW
If not used, the reason	USA sanction for Syria by Ceaser Law		
Future Plan (MW)	Basically depending on internal power source		
Remark	Previously Import from Jordan via Syria, 200MW		

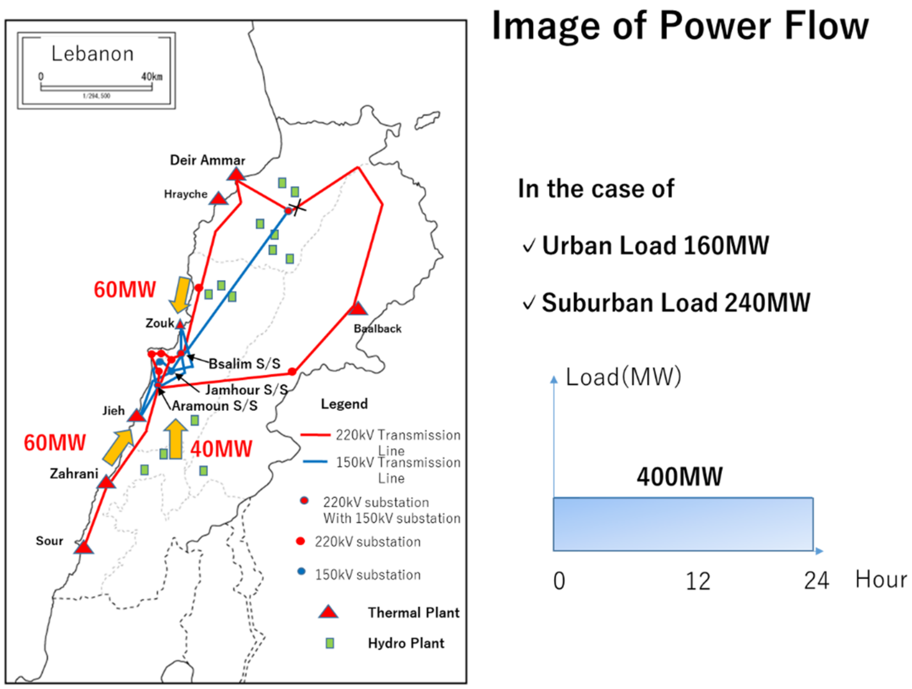
Source: Prepared by JICA study team based on EDL interview

Fig. 4.2-3 Operation Situation of Interconnection Lines

4.2.3 Power Flow of Bulk Power System

Fig. 4.2-4 shows the power flow in the transmission line estimated from the field survey of the Jamhour substation and Bsalim substation, which are Lebanon's main substations, and the operation situation of generators and demand distribution obtained from EDL. There are two thermal power plants currently in operation, the Dier Ammar power plant in the north and the Zahrani power plant in the south. Among hydroelectric power plants, the Awali power plant in the Litani river basis in the central and southern part of the country is particularly large, and it is assumed that power flows from that direction toward Beirut city. The distribution of demand is 40% in Beirut city and 60% in the suburbs, and the total demand after the economic collapse is about 400MW[1] throughout the day.

[1] Source EDL.



Source: Prepared by JICA study team based on EDL interview

Fig. 4.2-4 Power Flow Situation of Bulk Power System (Image)

4.2.4 Power System Stabilizing Technology

An automatic load shedding device for frequency maintenance, i.e., a device that automatically shuts off each substation feeder at a frequency of 49 Hz or less, has been introduced, but currently it is manually operated as mentioned above and is not used.

The Power System Stabilizer (PSS) for power generators has been installed in two large-scale power plants, the Deir Ammar thermal power plant and the Zahrani thermal power plant.

4.2.5 Introduction Situation of Communication Equipment

As for the SCADA system, before the NCC blasting, there was a SCADA system, but now it does not exist, and dispatcings are given by telephone from the Jamhour substation.

As for Optical Ground Wire (OPGW), 220kV transmission lines and recently enhanced 66kV transmission lines have adopted OPGW. (12 cores for 220kV, 24 cores for 66KV)

Other 150kV and 66kV transmission lines adopt the microwave radio system.

In addition, a pilot system is adopted for underground transmission lines. These communications were also used for supervisory control before the NCC detonation, but since then they have been used only for protective relays.

4.3 INFORMATION ON EXISTING TRANSMISSION LINE AND SUBSTATION FACILITIES

In Lebanon's transmission system, the 66kV system started operation in around the 1960s, the 150kV system in the 1970s, and the 220kV system in the late 1990s. The total length of transmission lines is 1,815km (including 1,616km of overhead transmission lines and 199km of underground transmission lines), and there 68 substations with total capacity of 8,377MVA. Table 4.3-1, Table 4.3-2, Table 4.3-3 show the list of existing transmission line facilities, and Table 4.3-4, Table 4.3-5, Table 4.3-6 show the list of existing substation facilities. The 150kV system was developed in Beirut city from the north to Beirut city, but according to EDL's transmission department, 150kV will be upgraded to 220kV by 2040, aiming for a simple system with only two voltages, 220kV and 66kV.

Table 4.3-1 List of Existing Transmission Line Facilities 1

NO	NAME OF LINE		PROPERTY	Year put in service	No. of Circuits	BASE K.V	LENGTH K.M	TYP COND	SEC MM2	I MAX A per phase	MVA TOTAL
	FROM	TO									
1	Ksara	Syria (Dimas)	EDL	2005	2	400	20.75	ALM	2x570	1760	2438.7
2	Deir Amar	Deir Nbouh	EDL	1995	2	220	11.1	ALAC	366	550	419.1
3	Deir Nbouh	Syria (Tartous)	EDL	1979	1	220	30.6	ALAC	366	550	209.6
4	Deir Nbouh	Baalbak	EDL	2001	1	220	115.6	ALM	570	880	335.3
5	Ksara	Baalbak	EDL	2001	1	220	35.55	ALM	570	880	335.3
6	Deir Nbouh	Ksara	EDL	2001	1 operating under 66k.v	220	151.16	ALM	570	880	335.3
7	Ksara	Aramoun	EDL	2005	2	220	40.1	ALM	570	880	670.6
8	ARAMOUN	MKALLES	EDL	2019	1	220	18.83	ALM	2x570	1760	670.6
9	MKALLES	BSALIM	EDL	2019	1	220	7	ALM	2x570	1760	670.6
10	ARAMOUN	BSALIM	EDL	2019	1	220	24	ALM	2x570	1760	670.6
11	Bahsas	Halate	EDL	2006	1	220	44.7	ALM	2x570	1760	670.6
12	Bahsas	Bsalim	EDL	2008	1	220	68.07	ALM	2×570	1760	670.6
13	Halate	Bsalim	EDL	2008	1	220	26.6	ALM	2×570	1760	670.6
14	Sour	Zahrani	EDL	2002	2	220	28.7	ALM	366	670	510.6
15	Zahrani	Saida	EDL	2002	1	220	10.88	ALM	2×570	1760	670.6
16	Saida	Aramoun	EDL	2002	1	220	26.84	ALM	2×570	1760	670.6
17	Zahrani	Aramoun	EDL	2002	1	220	37.72	ALM	2×570	1760	670.6
18	Mkalles	Commercial	EDL	2000	UGC	220	9	CU,XLPE	630	630	240.1
19	Commercial	Pins	EDL	2000	UGC	220	4.6	CU,XLPE	630	630	240.1
20	Commercial	Ras Beirut	EDL	2000	UGC	220	4.6	CU,XLPE	630	630	240.1
21	Ras Beirut	Pins	EDL	2000	UGC	220	5.1	CU,XLPE	630	630	240.1
22	Pins	Aramoun	EDL	2000	UGC	220	14.5	CU,XLPE	630	630	240.1
23	Aramoun	Daheih	EDL	2017	UGC	220	11	AI,XLPE	2000	1800	685.9
24	Daheih	Pins	EDL	2017	UGC	220	2.57	AI,XLPE	2000	1800	685.9
25	Commercial	Achrafeih	EDL	2017	UGC	220	2	AI,XLPE	2000	1800	685.9
26	Achrafeih	Mkaless	EDL	2018	UGC	220	6	AI,XLPE	2000	1800	685.9
27	Bahsas	Deir Amar	EDL	2001	2UGC	220	12	CU,XLPE	1200	1000	762.1
28	Jieh	Jamhour	EDL	1971	2	150	26.34	ALAC	366	550	285.8
29	Jieh	Bsalim	EDL	1971	2	150	36.2	ALAC	366	550	285.8
30	Zouk	Jamhour	EDL	1984	2	150	17.18	ALAC	2x366	1100	571.6
31	Zouk	Bsalim	EDL	1984	2	150	8.5	ALAC	2x366	1100	571.6
32	Bsalim	Jamhour	EDL	1981	2	150	11.8	ALAC	366	550	285.8
33	Bsalim	Deir Nbouh	EDL	1983	2	150	63.73	ALAC	366	550	285.8

Table 4.3-2 List of Existing Transmission Line Facilities 2

NO	NAME OF LINE FROM	NAME OF LINE TO	PROPERTY	Year put in service	No. of Circuits	BASE K.V	LENGTH K.M	TYP COND	SEC MM2	I MAX A per phase	MVA TOTAL
34	Pole #19 of Jieh - Jamhour	Aramoun	EDL	1995	UGC	150	1.8	Al,XLPE	500	450	116.9
35	Jamhour	Basta	EDL	1984	2UGC	150	4.14	CU,OIL	500	450	116.9
				2015	2UGC	150	7	CU,XLPE	500	500	129.9
36	Aramoun	Basta	EDL	1991	UGC	150	13	AL,XLPE	500	450	116.9
37	Sour	Wadi Jilo	EDL	under const.	2	66	8.44	ALM	366	660	150.9
38	Wadi Jilo	Sultanieh	EDL	1965	1	66	11.64	ALAC	228	343	39.2
39	Sultanieh	Marjayoun	EDL	1965	1	66	24.6	ALAC	228	343	39.2
40	Marjayoun	Abdel Aal	EDL	1965	1	66	18.76	ALAC	228	343	39.2
41	Abdel Aal	Awali	LITTANI	1965	1	66	17.5	ALAC	366	550	62.9
42	Abdel Aal	Pompage	EDL	1965	1	66	7.7	ALAC	228	343	39.2
43	Pompage	Jib Janine	EDL	1965	1	66	11.9	ALAC	228	343	39.2
44	Jib Janine	Anjar	EDL	1965	1	66	14.4	ALAC	228	343	39.2
45	Anjar	Dimas 1	EDL	1972	1	66	7.7(till the boarder	ALAC	228	343	39.2
46	Anjar	Dimas 2	EDL	1972	1	66		ALAC	228	343	39.2
47	Anjar	Ksara-N	EDL	1967	1	66	11.5	ALAC	228	343	39.2
48	Ksara-N	Ksara	EDL	1967	1	66	1.3	ALAC	228	343	39.2
49	Ksara	Bikfaya	EDL	1967	1	66	20.89	ALAC	228	343	39.2
50	Ksara	Bidnayel	EDL	under const.	2	66	14.5	ALM	366	660	150.9
51	Bidnayel	Baalbak	EDL	under const.	2	66	21.1	ALM	366	660	150.9
52	Baalbak	Laboue	EDL	2019	2	66	22.85	ALM	366	660	150.9
53	Laboue	Hermel	EDL	2019	2	66	24.42	ALM	366	660	150.9
54	Hermel	Kobayat	EDL	2019	2	66	25	ALM	366	660	150.9
55	Kobayat	Halba	EDL	2019	2	66	19.18	ALM	366	660	150.9
56	Beit mallat	Deir Jenine	EDL	2012	2	66	3.54	ALM	366	660	150.9
57	Bared	Assoun	EDL	2018	2	66	6.9	ALM	366	660	150.9
58	Halba	Bared 1	EDL	2019	2	66	11.9	ALM	366	660	150.9
59	Deir Nbouh	Bared	EDL	2019	2	66	10.9	ALM	366	660	150.9
60	Bared 1	Bared 2	BARED (EDL exploitation) , derivations are EDL property	1955	1	66	5	ALAC	80	120	13.7
61	Bared 1	Deir Nbouh		1955	1	66	10.9	ALAC	248	372	42.5
62	Deir Nbouh	Kousba		1955	1	66	10.6	ALAC	248	372	42.5
63	Kousba	Batroun		1955	1	66	23.85	ALAC	248	372	42.5
	(T to Bziza)			1955	1	66	0.1	ALAC	248	372	42.5
64	Batroun	Amchit		1955	1	66	20.7	ALAC	248	372	42.5
65	Amchit	Halate		1955	1	66	9	ALAC	248	372	42.5
66	Halate	Adma		1955	1	66	6	ALAC	248	372	42.5
67	Adma	Zouk		1955	1	66	12.69	ALAC	248	372	42.5
68	Zouk	NI2	Naher Ibrahim		1	66	20	ALAC	181	272	31.1
69	Zouk	Jeita	EDL	1966	1	66	3.14	ALAC	228	343	39.2
70	Zouk	Bikfaya	EDL	1966	1	66	9.4	ALAC	228	343	39.2
71	Zouk	Bsalim	BARED EDL exploitation		1	66	13.27	ALAC	248	372	42.5
72	Jeita	Bikfaya	EDL	1966	1	66	6.26	ALAC	228	343	39.2
73	Bikfaya	Halate	EDL	2019	1	66	22	ALM	366	660	75.4
74	Bikfaya	Faytroun	EDL	2012	1	66	10.5	ALM	366	660	75.4
75	Faytroun	Halate	EDL	2019	1	66	11.5	ALM	366	660	75.4
76	NI2	Hakl-Rayess	EDL	1972	1	66	3.8	ALAC	147	221	25.3
77	NI2	NI1	Naher Ibrahim		1	66	3.7	ALAC	181	272	31.1
78	Zahrani	Nabatieh	EDL	1995	2	66	19.3	ALAC	288	433	99.0

Table 4.3-3 List of Existing Transmission Line Facilities 3

NO	NAME OF LINE FROM	NAME OF LINE TO	PROPERTY	Year put in service	No. of Circuits	BASE K.V	LENGTH K.M	TYP COND	SEC MM2	I MAX A per phase	MVA TOTAL
79	Sour	Mousaileh (T from Zahrani - Nabateih)	EDL	1969	1	66	26.3	ALAC	228	343	39.2
80	Zahrani	Mousaileh	EDL(spare line)	1995	1	66	3	ALAC	228	343	39.2
81	Mousaileh	Saida 1	EDL	1994	1	66	11.3	ALAC	228	343	39.2
82	Mousaileh	Saida 2 (T from Zahrani - Nabateih)	EDL	1965	1	66	11.3	ALAC	228	343	39.2
83	Saida	Joun	EDL	1979	2	66	4.55	ALAC	288	433	99.0
84	Saida	Sibline	EDL	1978	1	66	8.17	ALAC	288	433	49.5
85	Joun	Awali	LITTANI		1	66	7	ALAC	366	550	62.9
86	Sibline	Jieh	EDL	1978	1	66	6.25	ALAC	288	433	49.5
87	Awali	Jamhour	LITTANI		2	66	32.5	ALAC	366	550	125.7
88	Jieh	Damour	EDL	1978	1	66	9.37	ALAC	288	433	49.5
89	Damour	Choueifat	EDL	1974	1	66	14.8	ALAC	288	433	49.5
90	Awali	Kfarhim	LITTANI		2	66	13	ALAC	366	550	125.7
91	Kfarhim	Beiteddine	EDL	1986	2	66	6.16	ALAC	366	550	125.7
92	Beiteddine	Safa	EDL	1967	1	66	7.64	CU	35	75	8.6
93	Safa	Aley	EDL	2018	2	66	8.3	ALM	366	660	150.9
94	Aley	Sofar	EDL	1970	2	66	10.26	ALAC	228	343	78.4
95	Aley	Jamhour	EDL	1967	2	66	5.29	ALAC	288	433	99.0
96	Choueifat	Jamhour	EDL	1973	1	66	4.6	ALAC	288	433	49.5
97	Bouchrieh	Jdeideh	BARED EDL exploitation		1	66	2.23	ALAC	248	372	42.5
98	Bouchrieh	Bsalim			2	66	5.4	CU	228	343	78.4
99	Bouchrieh	Jamhour	EDL	1980	2	66	6.9	ALAC	366	550	125.7
100	Jdeideh	Bsalim	BARED / EDL exploitation	1955	1	66	3.4	ALAC	248	372	42.5
101	Sibline	Jieh	EDL	1999	UGC	66	4.7	CU,XLPE	300	450	51.4
102	Zahrani	Mousaileh	EDL	2000	UGC	66	3.9	CU,XLPE	630	945	108.0
103	Ouest	Mreisseh	EDL	1982	2UGC	66	1.88	CU,OIL	300	300	68.6
104	Pins	Hazmieh	EDL	1964	3UGC	66	3.84	CU,XLPE	300	450	154.3
105	Commercial	Gas	EDL	1996	2UGC	66	3	CU,XLPE	300	450	102.9
106	Unesco	Pins	EDL	2013	2UGC	66	2.6	CU,XLPE	630	945	216.0
107	Unesco	Basta	EDL	1982	2UGC	66	2	CU,OIL	300	300	68.6
108	Unesco	Ouest	EDL	1982	2UGC	66	2.7	CU,OIL	300	300	68.6
109	Mreisseh	Commercial	EDL	1996	2UGC	66	1.52	CU,XLPE	300	450	102.9
110	Basta	Mreisseh	EDL	1984	2UGC	66	2.86	CU,OIL	300	300	68.6
111	Gas	Baouchrieh	EDL	1965	3UGC	66	3.7	CU,OIL	300	300	102.9
112	Hazmieh	Jamhour	EDL	1964	5UGC	66	6.1	CU,XLPE	300	450	257.2
113	Hazmieh	Chebbak	EDL	1965	2UGC	66	3.23	CU,OIL	300	300	68.6
114	Airoport	Khaldeh	EDL	1991	2UGC	66	3.1	CU,XLPE	300	450	102.9
115	Bouchreih	Chebbak	EDL	1994	2UGC	66	4.9	CU,XLPE	300	450	102.9
116	Basta	Airoport	EDL	1991	2UGC	66	7	CU,XLPE	300	450	102.9
117	Bsalim	Bouchreih	EDL	2004	UGC	66	7.5	CU,XLPE	630	945	108.0
118	Bsalim	Gaz	EDL	2004	UGC	66	11.5	CU,XLPE	630	945	108.0
119	Bsalim	Jdeideh	EDL	2004	UGC	66	5.5	CU,XLPE	630	945	108.0
120	Jdeideh	Gaz	EDL	2004	UGC	66	6	CU,XLPE	630	945	108.0
121	Gaz	Mreisseh	EDL	1996	UGC	66	4.5	CU,XLPE	300	450	51.4
122	Baddawi	Orange nassu	KADISHA		2UGC	66	5.8	CU,XLPE	300	450	102.9
123	Orange nassu	Tripoly	KADISHA		UGC	66	3.9	CU,XLPE	300	450	51.4

Note: A LM (Aluminum): Aluminum stranded wire, ALAC (ACSR): Steel core aluminum stranded wire, CU (Cupper): Copper stranded wire, AL , XLPE (Cross-Linked Polyethylene) : Aluminum cross-linked polyethylene cable, C U, XLPE: Copper cross-linked polyethylene cable CU, O IL : Copper oil-filled cable, U GC: Underground cable (the number in front indicates the number of lines)

Source: EDL

Table 4.3-4 List of Existing Substation Facilities 1

Substations List and Transforming Capacity							
Substation	**Area**	**SS Type**	**Voltage Level (KV)**	**Transformers**	**Transformer Capacity (MVA)**	**Total Transforming Capacity (MVA)**	**Remark**
AASSOUN	North	Mobile	66/20/15	66/20	20	20	Not Operational Currently
ABED EL AL	Bekaa	AIS	66/15	66/15	20	30	
				66/15	10		
ACHRAFIEH	Beirut	GIS	220/20/11	220/11	70	140	Not Operational Currently
				220/11	70		
ADMA	Mount Lebanon	AIS	66/15	66/15	40	80	
				66/15	40		
AEROPORT	Beirut	AIS	66/20/11	66/11	20	60	
				66/11	20		
				66/11	20		
AIN EL MREISSEH	Beirut	AIS	66/11	66/11	40	80	
				66/11	40		
AIN SOFAR	Mount Lebanon	AIS	66/20/15	66/15	10	40	
				66/15	10		
				66/15	20		
ALEY	Mount Lebanon	AIS	66/15	66/15	20	40	
				66/15	20		
AMCHIT	Mount Lebanon	AIS	66/33/15	66/66	40	100	
				66/33	20		
				66/15	20		
				66/15	20		
ANJAR	Bekaa	AIS	66/15	66/15	20	100	
				66/66	40		
				66/66	40		
ARAMOUN	Beirut	GIS	220/150/20/11	220/150	100	240	
				220/15	70		
				220/11	70		
BAALBECK	Bekaa	AIS	220/66/20/15	220/66	170	310	
				220/15	70		
				220/15	70		
BAOUCHRIEH	Beirut	AIS	66/20/11	66/11	40	120	
				66/11	40		
				66/11	40		
BARED	North	AIS	66/20/15	66/15	20	20	
BASTA	Beirut	GIS	150/66/11	150/66	80	320	
				150/66	80		
				150/66	80		
				66/11	20		
				66/11	20		
				66/11	40		
BATHA	Mount Lebanon	Mobile	66/20/15	66/20	20	20	
BATROUN	North	AIS	66/20/15	66/15	20	20	
BEIT EDDINE	Mount Lebanon	AIS	66/20/15	66/20	20	40	
				66/20	20		
BEIT MALAT	North	AIS	66/15	66/15	40	40	
BEDNAYEL	Bekaa	Mobile	66/15	66/15	20	40	
		Mobile	66/15	66/15	20		
BIKFAYA	Mount Lebanon	AIS	66/15	66/15	40	80	
			66/15	66/15	40		
BOKSMAYA	North	Mobile	66/20/15	66/15	20	20	Not Operational Currently
BOULOS ARKACH	Bekaa	AIS	66/15	66/15	20	125	
				66/15	20		
				66/66	85		
BSALIM	Beirut	GIS/AIS	220/150/20/15	220/150	100	520	
				150/66	120		
				150/66	120		
				66/15	40		
				220/15	70		

Table 4.3-5 List of Existing Substation Facilities 2

Substations List and Transforming Capacity							
Substation	**Area**	**SS Type**	**Voltage Level (KV)**	**Transformers**	**Transformer Capacity (MVA)**	**Total Transforming Capacity (MVA)**	**Remark**
BZIZA	North	Mobile	66/15	66/15	10	10	
CHEBBAK	Beirut	AIS	66/11	66/11	40	80	
				66/11	40		
CHOUEIFAT	Beirut	AIS	66/11	66/11	40	60	
				66/11	20		
COMMERCIALE	Beirut	GIS	220/66/20	220/20	80	320	
				220/20	80		
				220/20	80		
				66/20	40		
				66/20	40		
DAHIYEH	Beirut	GIS	220/20/11	220/11	70	210	
				220/11	70		
				220/11	70		
DAMOUR	Mount Lebanon	AIS	66/15	66/15	20	40	
				66/15	20		
DEIR NBOUH	North	AIS	220/150/66/15	220/150	100	460	
				220/150	100		
				220/66	170		
				220/15	70		
				66/15	20		
DEIR AMMAR	North	GIS/AIS	220/66/20	220/66	170	240	
				220/20	70		
BAHSAS	North	GIS	220/20/15	220/20	70	140	
				220/20	70		
FEYTROUN	Mount Lebanon	AIS	66/20/15	66/15	20	40	
				66/15	20		
GAZ	Beirut	AIS	66/20/11	66/11	40	60	
				66/11	20		
HAKL EL RAYES	Mount Lebanon	AIS	66/15	66/15	20	20	
HALATE	Mount Lebanon	AIS	220/66/20/15	220/66	170	240	
				220/15	70		
HALBA	North	AIS	66/20/15	66/15	40	60	
				66/15	20		
HAZMIEH	Beirut	AIS	66/20/11	66/11	40	80	
				66/11	40		
HERMEL	Bekaa	AIS	66/20/15	66/15	20	40	
				66/15	20		
JAMHOUR	Beirut	AIS	150/66/15/11	150/66	120	460	
				150/66	120		
				150/66	120		
				66/15	40		
				66/15	20		
				66/11	20		
				66/11	20		
JDEIDEH	Beirut	AIS	66/15/11	66/15	40	100	
				66/15	20		
				66/11	40		
JEITA	Mount Lebanon	AIS	66/20/15	66/15	20	40	
				66/15	20		
JIB JANINE	Bekaa	AIS	66/20/15	66/15	40	40	
JIEH	MountLebanon	AIS	150/66	150/66	120	200	
				150/66	80		
KOBAYAT	North	AIS	66/20/15	66/15	20	20	
KSARA 400	Bekaa	AIS	400/220	400/220	300	300	
KSARA 220	Bekaa	AIS	220/66/20/15	220/66	170	310	
				220/15	70		
				220/15	70		

Table 4.3-6 List of Existing Substation Facilities 3

Substation	Area	SS Type	Voltage Level (KV)	Transformers	Transformer Capacity (MVA)	Total Transforming Capacity (MVA)	Remark
KSARA 66	Bekaa	AIS	66/15	66/15	20	40	
				66/15	20		
LABOUE	Bekaa	AIS	66/20/15	66/15	40	40	
MARJEYOUN	South	AIS	66/20/15	66/15	20	40	
				66/15	20		
MKALLES	Beirut	GIS	220/20/11	220/11	70	140	
				220/11	70		
MESSAYLEH	South	AIS	66/15	66/15	20	40	
				66/15	20		
NABATIEH	South	AIS	66/20/15	66/15	40	90	
				66/15	40		
				66/15	10		
OUEST	Beirut	AIS	66/11	66/11	20	60	
				66/11	20		
				66/11	20		
PINS	Beirut	GIS/AIS	220/66/20/11	220/11	70	200	Partially Damaged , Not Fully Operational
				220/11	70		
				66/11	40		
				66/11	20		
RAS BEIRUT	Beirut	GIS	220/20/11	220/11	70	140	
				220/11	70		
SAFA	MountLebanon	AIS	66/33/5.5	66/33	6	12	
				66/33	6		
SAIDA 66	South	AIS	66/15	66/15	40	100	
				66/15	40		
				66/15	20		
SAIDA 220	South	AIS	220/20/15	220/15	70	140	
				220/15	70		
SIBLINE	MountLebanon	AIS	66/20/15	66/15	40	60	
				66/15	20		
SULTANIEH	South	AIS	66/15	66/15	40	60	
				66/15	20		
TAYBEH	South	Mobile	66/15	66/15	20	20	
TYR	South	AIS	220/66/15	220/66	170	280	
				220/15	70		
				66/15	40		
UNESCO	Beirut	AIS	66/11	66/11	40	80	
				66/11	40		
WADI JILO	South	Mobile	66/15	66/15	20	20	
ZAHRANI	South	GIS/AIS	220/66/15	220/66	170	260	
				220/15	70		
				66/15	20		
ZOUK	MountLebanon	GIS/AIS	150/66/20/15	150/66	80	380	
				150/66	120		
				150/20	70		
				150/20	70		
				66/15	40		

Note: GIS: Gas Insulated Switchgear, AIS: Air Insulated Switchgear

Source: EDL

Regarding the maintenance system for transmission and transformation facilities, a maintenance team (1-3 people) is assigned to each of 12 areas in Lebanon, and maintains 5-7 substations (68 substations nationwide).At one substation, visual inspections are carried out once a week, transformer insulation oil tests and battery tests are carried out once or twice a year, and relays and communication equipment are inspected as necessary. In addition, patrol inspections of transmission lines are carried out twice a month. Maintenance is outsourced to a private company. An example of a maintenance sheet (visual inspection) is shown in Table 4.3-7.

Table 4.3-7 Example of Maintenance Record Sheet (Visual Inspection)

Stock	Result	Hour	Date	Name	Signature
Record the charger voltage of the batteries					
Record charger current from batteries					
Lamp test					
Horn test					
Check operation measuring devices					
Operation of MV cubicle protection relays					
Battery electrolyte level					
Operation of air coolers of the power transformers					
Operation of compressors					
Auditory control of MT cells					
Generator fuel level					
External cleaning of desks and control panels					

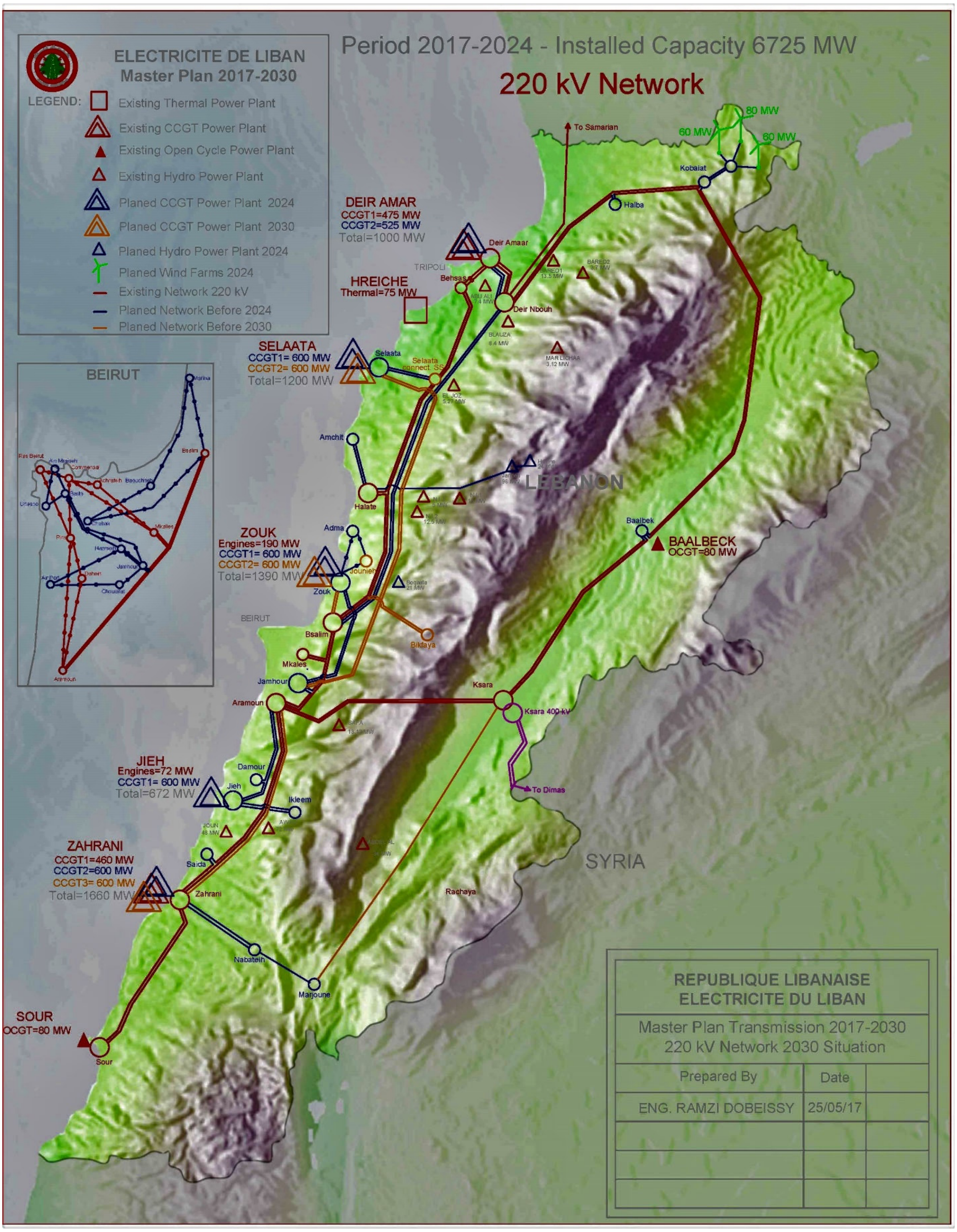
Source: EDL

4.4 INFORMATION ON PLANNED TRANSMISSION LINE AND SUBSTATION FACILITIES

Fig. 4.4-1 and Fig. 4.4-2 show the planned transmission system diagrams (220kV system and 66kV system). This information is based on EDL's transmission department's plan for 2015 to 2017, targeting 2025 to 2030 in the future. While the situation is the same in 2023, we have confirmed that the start of operation will be delayed by at least 5 years. Table 4.4-1 and Table 4.4-2 show a list of planned transmission facilities and substation facilities compiled with reference to this information and EDF's transmission master plan. There was no information that financing has been secured for the planned project.

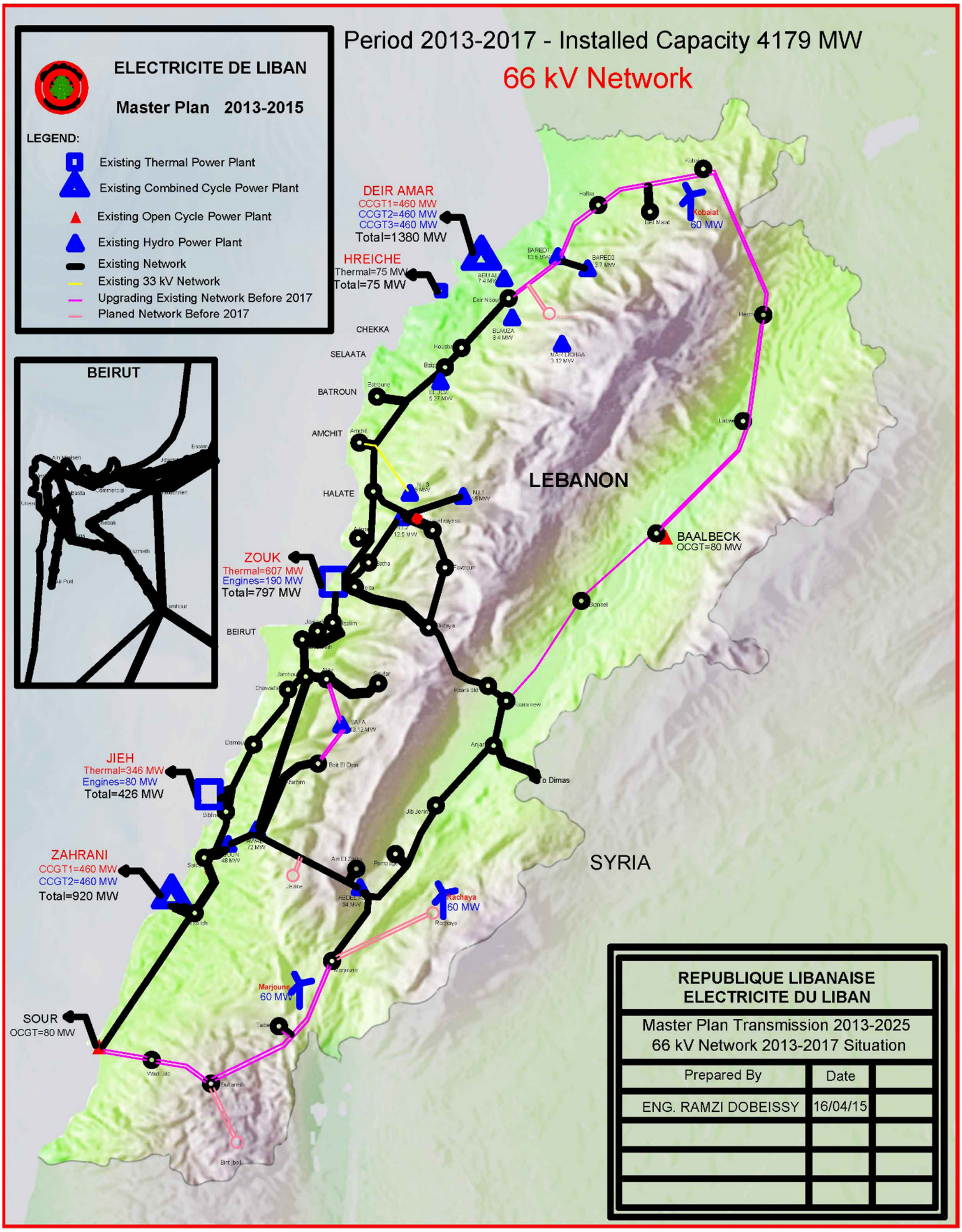
According to EDL, as mentioned above, the existing 150kV system will be upgraded to a 220kV system by 2040, and as a result, a simple two-voltage configuration of the 220kV system and the 66kV system will be aimed. Fig. 4.4-3 shows the future system of the 220kV system. Here, the expansion of the 220kV system (Deir Ammar-Deir Nbouth-Bsalim transmission line, Selaata - Jamhour transmission line,etc., Zahrani- Aramoun transmission line) corresponding to the development of future large-scale thermal power plants, that is, the development of three thermal power plants, Deir Ammar thermal power plant, Zahrani thermal power plant, and Selaata thermal power plant , is reflected here. In addition, the importance of these 220kV system enhancements is also emphasized in the WB, EDF, and MoEW's "Analysis Report on Transmission System Planning (Tentative Version)" (March 2022).

On the other hand, the existing 150kV system in Beirut city is also planned to be upgraded to a 220kV system. This upgrade is expected to reduce transmission loss and improve voltage quality.



Source：EDL

Fig. 4.4-1 Planned Transmission System Diagram (220kV System)



Source：EDL

Fig. 4.4-2 Planned Transmission System Diagram (66kV System)

Table 4.4-1 List of Planned Transmission Line Facilities

NO	NAME OF LINE		PROPERTY	Year put in service	No. of Circuits	BASE K.V	LENGTH K.M	TYP COND	SEC MM2	I MAX A per phase	MVA TOTAL
	FROM	TO									
1	Deir Ammar	Deir Nbouth	EDL	2030	2	220	11.1	ALM	2x570	1760	1341.3
2	Deir Nbouth	Bsalim	EDL	2030	2	220	63.73	ALM	2x570	1760	1341.3
3	Selaata	Behsas-Bsalim	EDL	2030	2	220	14	ALM	2x570	1760	1341.3
4	Amchit	Halate	EDL	2030	2	220	10	ALM	2x366	1340	1021.2
5	Halate	Janneh	EDL	2030	1	220	13	ALM	2x366	1340	510.6
6	Janneh	Hdaine	EDL	2030	1	220	1	ALM	2x366	1340	510.6
7	Halba	Deir Nbouth-Baalbeck	EDL	2030	2	220	0.4	ALM	2x570	1760	1341.3
8	Kobaiat	Deir Nbouth-Baalbeck	EDL	2030	2	220	0.4	ALM	2x570	1760	1341.3
9	Adma	Zouk	EDL	2030	2	220	9	Al,XLPE	2000	1800	685.9
10	Zouk	Jamhour	EDL	2030	2	220	17.18	ALM	2x570	1760	1341.3
11	Jamhour	Bsalim-Aramoun	EDL	2030	2	220	1	ALM	2x570	1760	1341.3
12	Aramoun	Jieh	EDL	2030	2	220	19	ALM	2x570	1760	1341.3
13	Damour	Aramoun-Jieh	EDL	2030	1	220	1	ALM	2x570	1760	670.6
14	Jieh	Ikleem(Sibline)	EDL	2030	2	220	4	ALM	2x366	1340	1021.2
15	Zahrani	Nabatieh	EDL	2030	2	220	14	ALM	2×570	1760	1341.3
16	Nabatieh	Marjoune	EDL	2030	1	220	12	ALM	2×570	1760	670.6
17	Jamhour	Hazmieh	EDL	2030	2	220	9	Al,XLPE	2000	1800	685.9
18	Hazmieh	Airport	EDL	2030	1	220	5.5	Al,XLPE	2000	1800	685.9
19	Airoport	Coueiffat	EDL	2030	1	220	3	Al,XLPE	2000	1800	685.9
20	Coueffiat	Jamhour	EDL	2030	1	220	5.5	Al,XLPE	2000	1800	685.9
21	Jamhour	Basta	EDL	2030	1	220	11	Al,XLPE	2000	1800	685.9
22	Hazmieh	Basta	EDL	2030	1	220	5.5	Al,XLPE	2000	1800	685.9
23	Basta	Ain Araiseh	EDL	2030	1	220	2.9	Al,XLPE	2000	1800	685.9
24	Unesco	Basta	EDL	2030	1	220	2	Al,XLPE	2000	1800	685.9
25	Bsalim	Marina	EDL	2030	1	220	5	Al,XLPE	2000	1800	685.9
26	Marina	Baouchrieh	EDL	2030	1	220	7	Al,XLPE	2000	1800	685.9
27	Baouchrieh	Chebak	EDL	2030	1	220	5	Al,XLPE	2000	1800	685.9
26	Chebak	Bsalim	EDL	2030	1	220	12	Al,XLPE	2000	1800	685.9
27	Selaata	Jamhour	EDL	2035	2	220	66	ALM	2x570	1760	1341.3
28	Zouk	Bsalim	EDL	2035	2	220	8.5	ALM	2x366	1340	1021.2
29	Bikfaya	Behsas-Bsalim	EDL	2035	2	220	5.5	ALM	2x570	1760	1341.3
30	Ksara	Marjoune	EDL	2035	1	220	62	ALM	2x366	1340	510.6
31	Aramoun	Zahrani	EDL	2035	1	220	38	ALM	2x570	1760	670.6
32	Zouk	Bikfaya	EDL	2030	2	66	9.4	ALAC	2x366	660	150.9
33	Wadi Jilo	Sultanieh	EDL	2030	2	66	11.64	ALAC	366	330	75.4
34	Sultanieh	Marjayoun	EDL	2030	2	66	24.6	ALAC	366	330	75.4
35	Anjar	Ksara-N	EDL	2030	2	66	11.5	ALAC	366	330	75.4
36	Selaata	Batroune	EDL	2030	2	66	5	ALAC	366	330	75.4
37	Bint jball	Sultanieh	EDL	2030	2	66	12	ALM	366	330	75.4
38	Rachaya	Marjayoun	EDL	2030	2	66	16	ALAC	366	330	75.4

Note: ALM (Aluminum) : Aluminum stranded wire, ALAC (ACSR) : Steel core aluminum stranded wire, AL, XLPE (Cross-Linked Polyethylene) : Aluminum cross-linked polyethylene cable

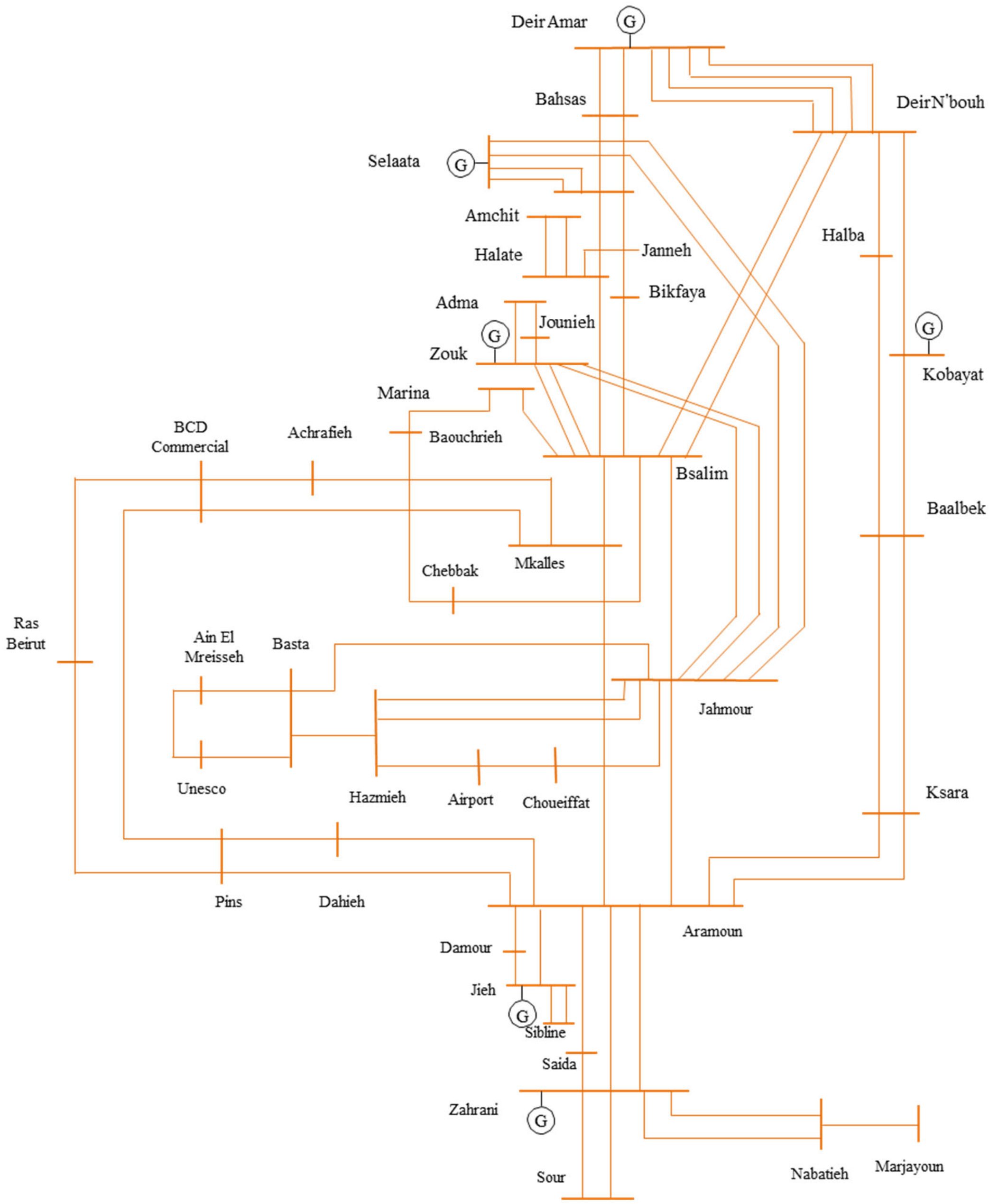
Source: Edited by JICA study team based on EDL data and EDF transmission master plan

Table 4.4-2 List of Planned Substation Facilities

NO	NAME OF SUBSTATION	PROPERTY	Year put in service	Voltage K.V	Voltage K.V	Capacity MVA	Number TR	MVA TOTAL	REMARK
1	Amchit	EDL	2030	220	MV	70	2	140	
2	Halba	EDL	2030	220	66	170	2	340	
3	Kobaiat	EDL	2030	220	66	170	1	170	
4	Baalbek	EDL	2030	220				0	SW/S
5	Adma	EDL	2030	220	MV	70	1	70	
6	Zouk	EDL	2030	220				0	TPP
7	Jamhour	EDL	2030	220	MV	70	2	140	
8	Jieh	EDL	2030	220				0	TPP
9	Damour	EDL	2030	220	66	100	1	100	
10	Ikleem(Sibline)	EDL	2030	220	MV	70	2	140	
11	Nabatieh	EDL	2030	220				0	SW/S
12	Marjoune	EDL	2030	220	66	170	1	170	
			2035	220	MV	70	1	70	
13	Hazmieh	EDL	2030	220	MV	70	2	140	
14	Airport	EDL	2030	220	MV	70	3	210	
15	Coueiffat	EDL	2030	220	MV	70	2	140	
16	Basta	EDL	2030	220	MV	70	3	210	
17	Ain Araiseh	EDL	2030	220	MV	70	2	140	
18	Unesco	EDL	2030	220	MV	70	3	210	
19	Marina	EDL	2030	220				0	SW/S
20	Baouchrieh	EDL	2030	220	MV	70	3	210	
21	Chebak	EDL	2030	220	MV	70	3	210	
22	Selaata	EDL	2030	220	60	100	2	200	
23	Bikfaya	EDL	2030	220	66	100	1	100	
					MV	70	1	70	
24	Jounieh	EDL	2035	220	MV	70	2	140	
25	*Aramoun*	EDL	2035	220	MV	70	1	70	TR Expansion
26	Deir Ammar	EDL	2035	220	MV	70	1	70	TR Expansion
27	Bahsas	EDL	2035	220	MV	70	1	70	TR Expansion
28	Sour	EDL	2030	220	MV	70	2	140	TR Expansion
29	Jezine	EDL	2030	66	MV	20	2	40	
30	Ain Sofar	EDL	2030	66	MV	40	1	40	TR Expansion
31	Baskinta	EDL	2030	66	MV	20	2	40	
32	Baabdat	EDL	2030	66	MV	40	2	80	
33	Ras Baalbek	EDL	2030	66	MV	20	2	40	
34	Yamouni	EDL	2030	66	MV	20	2	40	
35	Koussaya	EDL	2030	66	MV	40	2	80	
36	Rachaya	EDL	2030	66	MV	20	2	40	
37	Tebna	EDL	2030	66	MV	20	2	40	

Note MV (Middle Voltage) : Middle voltage (11, 15, 20kV), SW/S (Switch Station) : Switching station, TPP (Thermal Power Plant) : Switching station with thermal power plant, TR: Transformer

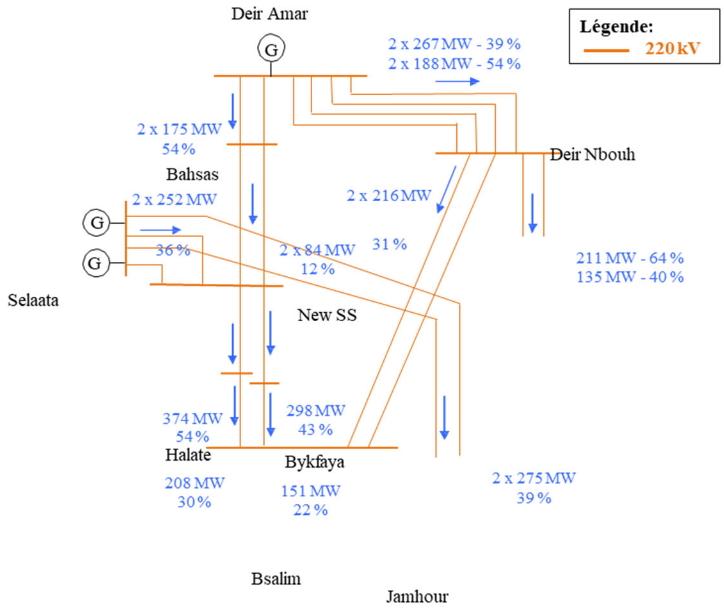
Source: Edited by JICA study team based on EDL data and EDF transmission master plan



Source: Transmission Master Plan Update (EDF, May 2017)

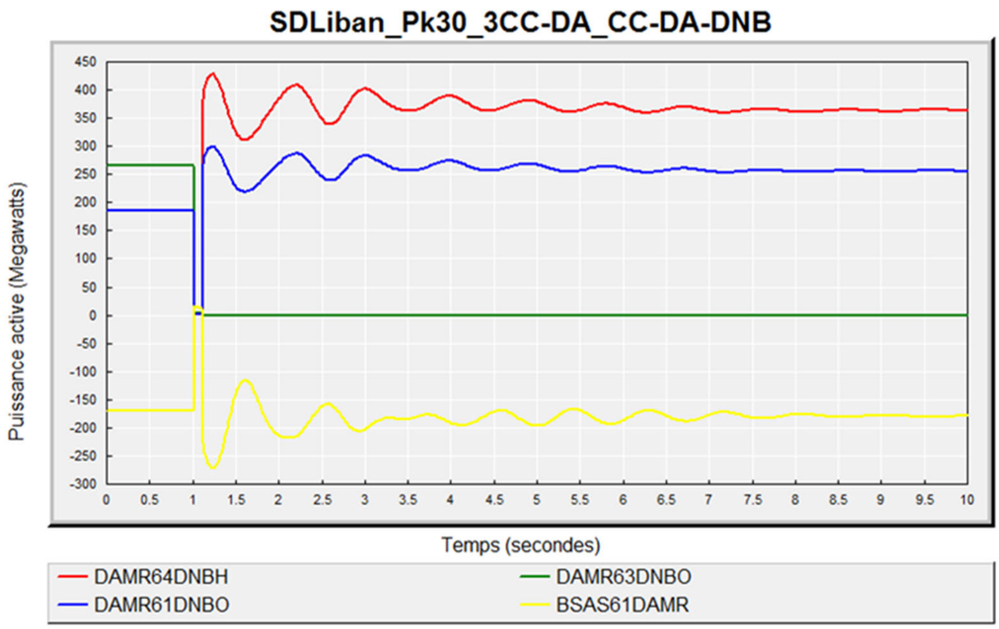
Fig. 4.4-3 220kV Trunk Line System in Lebanon

EDF's transmission master plan, a system analysis is being carried out on the 220kV trunk line system associated with the development of large scale thermal plants (Fig. 4.4-4, Fig. 4.4-5). These study examples show that when a large-scale thermal power plant is developed, stable power transmission is possible by reinforcing the 220kV trunk system even in the case of a power transmission fault.



Source: Transmission Master Plan Update (EDF, May 2017)

Fig. 4.4-4 Study example of trunk system for large-scale thermal power plants (Power Flow)



Source: Transmission Master Plan Update (EDF, May 2017)

Fig. 4.4-5 Study example of trunk system for large-scale thermal power plants (Stability)