STUDY

CLIMATE CHANGE, ENERGY AND ENVIRONMENT

SUSTAINABLE TRANSFORMATION OF LEBANON'S ENERGY SYSTEM

Development of a Phase Model

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By applying a phase model for the renewables-based energy transition in the MENA countries to Lebanon, the study provides a guiding vision to support the strategy development and steering of the energy transition process.

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The Lebanese electricity sector faces three main challenges: an unreliable power supply, a distortive subsidy system and a weak financial stability at the utility level.

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The uptake of renewable energy (RE) can contribute to increasing the energy security in Lebanon, as the most pressing concern in Lebanon's electricity sector is the need to secure a constant electricity supply.

FRIEDRICH EBERT STIFTUNG

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Development of a Phase Model

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الجامعة الأميركية في بيروت

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INTRODUCTION

The Middle East and North Africa (MENA) region faces a wide array of challenges, including rapidly growing population, slowing economic growth, high rates of unemployment, and significant environmental pressures. These challenges are exacerbated by global and regional issues, such as climate change. The region, which is already extremely vulnerable due to its geographical and ecological conditions, will become more affected by the negative consequences of climate change in the future. Drought and temperatures will increase in what is already one of the most water-stressed regions in the world. With large sections of the population concentrated in urban areas in the coastal regions, people will also be more vulnerable to water shortages, storms, floods, and temperature increases. In the agricultural sector, climate change effects are expected to lead to lower production levels, while food demand will increase due to population growth and changing consumption patterns. Moreover, the risk of damage to critical infrastructure is increasing, and expenditure for repairs and new construction is placing additional strain on already scarce financial resources. These multi-layered challenges, arising from the interplay of economic, social, and climatic aspects, should not be ignored, as they pose serious risks to prosperity and economic and social development – and ultimately to the stability of the region.

Energy issues are embedded in many of these challenges. The region is characterised by a high dependence on oil and natural gas to meet its energy needs. Although the region is a major energy producer, many of the MENA countries are struggling to meet growing domestic energy demand. Transitioning to energy systems that are based on renewable energy (RE) is a promising way to meet this growing energy demand. The transition would also help to reduce greenhouse gas (GHG) emissions under the Paris Agreement. In addition, the use of RE has the potential to increase economic growth and local employment and reduce fiscal constraints.

Against the backdrop of rapidly growing energy demand due to population growth, changing consumer behaviour, increasing urbanisation, and other factors – including industrialisation, water desalination, and the increased use of electricity for cooling – RE is gaining attention in the MENA region. To guarantee long-term energy security and to meet climate change goals, most MENA countries have developed ambitious plans to scale up their RE production. The significant potential in the MENA region for RE production, in particular wind and solar power, creates an opportunity both to produce electricity that is almost CO_2 neutral and to boost economic prosperity. However, most countries in the region still use fossil fuels as their dominant energy source, and dependency on fossil fuel imports in some of the highly populated countries poses a risk in terms of energy security and public budget spending.

A transition towards a renewables-based energy system involves large-scale deployment of RE technology, the development of enabling infrastructure, the implementation of appropriate regulatory frameworks, and the creation of new markets and industries. Therefore, a clear understanding of socio-technical interdependencies in the energy system and the principal dynamics of system innovation is crucial, and a clear vision of the goal and direction of the transformation process facilitates the targeted fundamental change (Weber and Rohracher, 2012). An enhanced understanding of transition processes can, therefore, support a constructive dialogue about future energy system developments in the MENA region. It can also enable stakeholders to develop strategies for a transition towards a renewables-based energy system.

To support such understanding, a phase model for renewables-based energy transitions in the MENA countries has been developed. This model structures the transition process over time through a set of transition phases. It builds on the German phase model and is further complemented by insights into transition governance and characteristics of the MENA region. The phases are defined according to the main elements and processes shaping each phase, and the qualitative differences between phases are highlighted. The focus of each phase is on technological development; at the same time, insights into interrelated developments in markets, infrastructure and society are provided. Complementary insights from the field of sustainability research provide additional support for the governance of long-term change in energy systems along the phases. Consequently, the phase model provides an overview of a complex transition process and facilitates the early development of policy strategies and policy instruments according to the requirements of the different phases that combine to form the overarching guiding vision.

In this study, the MENA phase model is applied to the case of Lebanon. The current state of development in Lebanon is assessed and analysed against the phase model. Expert interviews were conducted to gain insights to specify the previously defined abstract components of the model. As a result, further steps for the energy transition (based on the steps of the phase model) are proposed. This application is based on findings from previous studies and projects conducted in the MENA region, while case study specific data for this study was collected by the local partner the Issam Fares Institute for Public Policy and International Affairs (IFI) at the American University of Beirut (AUB).

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CONCEPTUAL MODEL

2.1 THE ORIGINAL PHASE MODELS[1]

The phase model for energy transitions towards renewables-based low-carbon energy systems in the MENA countries was developed by Fischedick et al. (2020). It builds on the phase models for the German energy system transformation by Fischedick et al. (2014) and Henning et al. (2015). The latter developed a four-phase model for transforming the German energy system towards a decarbonised energy system based on REs. The four phases of the models correlate with the main assumptions deduced from the fundamental characteristics of RE sources, labelled as follows: »Take-off REs«, »System Integration«, »Power-to-Fuel/Gas (PtF/G)«, and »Towards 100% Renewables«.

Energy scenario studies foresee that in the future most countries, including those in the MENA region, will generate electricity primarily from wind and solar sources. Other sources such as biomass and hydropower are expected to be limited due to natural conservation, lack of availability and competition with other uses (BP, 2018; IEA, 2017). Therefore, a basic assumption of the phase model is a significant increase of wind and solar power in the energy mix. This includes the direct utilisation of electricity in end-use sectors that currently rely mainly on fossil fuels and natural gas. E-mobility in the transport sector and heat pumps in the building sector are expected to play a crucial role. Sectors that are technologically difficult to decarbonise include aviation, marine, heavy-duty vehicles, and high-temperature heat for industry. In these sectors, hydrogen or hydrogen-based synthetic fuels and gases (PtF/G) can replace fossil fuels and natural gas. The required hydrogen can be gained from renewable electricity via electrolysis.

There should be a strong emphasis on adapting the electricity infrastructure because the feed-in and extraction of electricity (particularly from volatile renewables) must be balanced to maintain grid stability. Thus, power production and demand need to be synchronised, or storage options need to be implemented. Electricity storage is, however, challenging for most countries, and the potential remains limited due to geographic conditions. Accordingly, a mix of flexible options that matches the variable supply from wind and solar power plants with electricity demand must be achieved by extending grids, increasing the flexibility of the residual fossil-based power production, storage, or demand-side management (DSM). Furthermore, the development of information and communication technologies (ICT) can support flexibility management. By using PtF/G applications, different sectors can be more tightly coupled. This involves adapting regulations, the infrastructure, and accommodating a new market design. Due to the power demand being four or five times higher in a renewables-based low-carbon energy system, improving energy efficiency is a prerequisite for a successful energy transition. Following the »energy efficiency first« principle means treating energy efficiency as a key element in future energy infrastructure and, therefore, considering it alongside other options, such as renewables, security of supply, and interconnectivity (European Commission DG Energy, 2019).

The phase model outlines these socio-technical interdependencies of the described developments, which build on each other in a temporal order. The four phases are crucial to achieve a fully renewables-based energy system. In the first phase, RE technologies are developed and introduced into the market. Cost reductions are achieved through research and development (R&D) programmes and first market introduction policies. In the second phase, dedicated measures for the integration of renewable electricity into the energy system are introduced. These include flexibility of the residual fossil power production, development and integration of storage, and activation of demand side flexibility. In the third phase, the long-term storage of renewable electricity to balance periods where supply exceeds demand is made essential. This further increases the share of renewables. PtF/G applications become integral parts of the energy system at this stage, and imports of renewables-based energy carriers gain importance. In the fourth phase, renewables fully replace fossil fuels in all sectors. All the phases must connect smoothly to achieve the target of a 100% renewables-based energy system. To describe the long-term changes in energy systems in these four phases, the phase model is supplemented by insights from the field of sustainability transition research. Such research is concerned with the dynamics of fundamental long-term change in societal subsystems, such as the energy system.

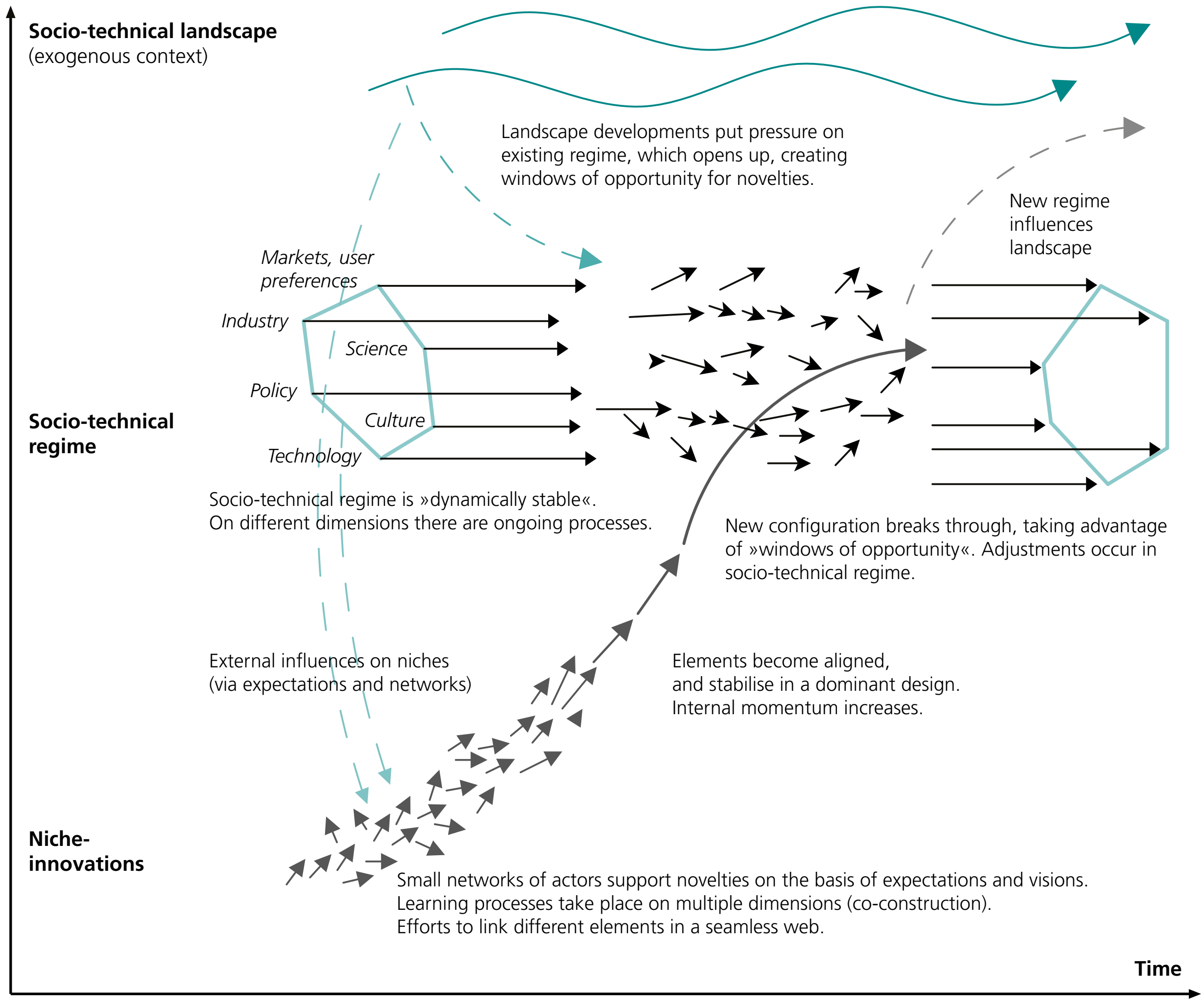
1 Text is based on Holtz et al. (2018).

2.2 THE MULTI-LEVEL PERSPECTIVE AND THE THREE STAGES OF TRANSITIONS

Energy transitions cannot be completely steered, nor are they totally predictable. The involvement of many actors and processes creates a high level of interdependency and uncertainty surrounding technological, economic, and socio-cultural developments. Due to the interlinkage of processes and dimensions, transition research typically applies interdisciplinary approaches. The multi-level perspective (MLP) is a prominent framework that facilitates the conceptualisation of transition dynamics and provides a basis for the development of governance measures (Fig. 2-1).

At »landscape« level, pervasive trends such as demographic shifts, climate change, and economic crises affect the »regime« and »niche« level. The »regime« level captures the socio-technical system that dominates the sector of interest. In this study, the regime is the energy sector. It comprises the existing technologies, regulations, user patterns, infrastructure, and cultural discourses that combine to form socio-technical systems. To achieve system changes at the »regime« level and avoid lock-in and path dependencies, innovations at the »niche« level are incremental because they provide the fundamental base for systemic change. Niches develop in protected spaces such as R&D labs and gain momentum when visions and expectations become more widely accepted. Therefore, actor-network structures that have the power to spread knowledge and change societal values are of key importance for the transition process (Geels, 2012) this paper introduces a socio-technical approach which goes beyond technology fix or behaviour change. Systemic transitions entail co-evolution and multi-dimensional interactions between industry, technology, markets, policy, culture and civil society. A multi-level perspective (MLP. The governance of transitions requires experimentation and learning, continuous monitoring, reflexivity, adaptability, and policy coordination across different levels and sectors (Hoogma et al., 2005; Loorbach, 2007; Voß et al., 2009; Weber and Rohracher, 2012). The development of niches in the framework of »strategic niche management« is an essential precondition for fundamental change. Within transition phases, three stages with associated policy approaches can be distinguished: »niche formation«, »breakthrough«, and »mar-

Figure 2-1
The Multi-Level Perspective



(Source: Geels and Schot, 2007)

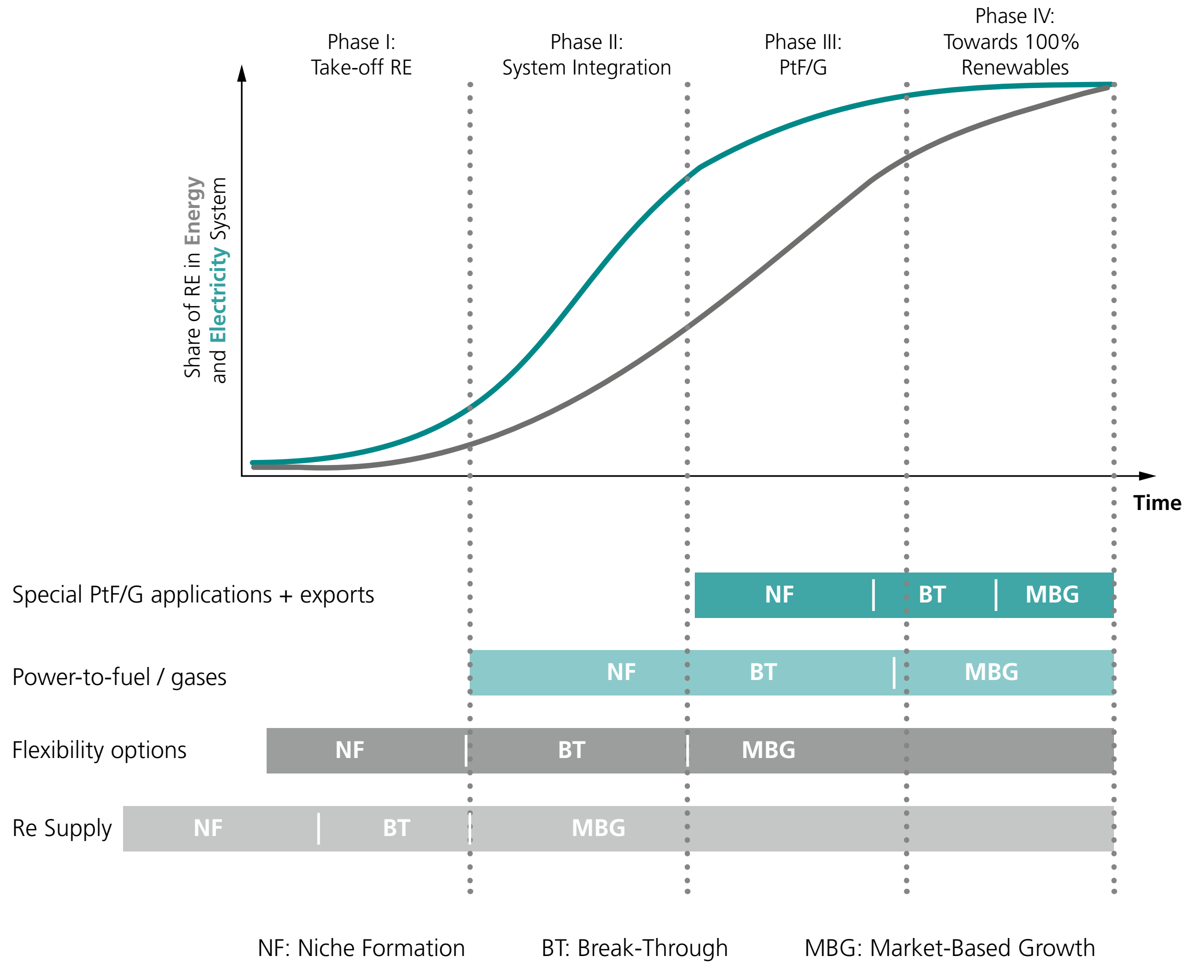
ket-based growth«. In the »niche formation« stage, a niche develops and matures, and it may offer solutions that can be absorbed by the regime. Within this stage, expectations and visions that provide direction to learning processes are essential. In addition, actor involvement and social networks can support the creation of the necessary value chains, and learning processes at different levels have the potential to advance the technology.

In the »breakthrough« stage, the niche innovation spreads by actors involved, market share, and replication in other locations. At this stage, improved price-performance is relevant, and access to necessary infrastructure and markets must be open. Amending rules and legislation as well as increasing societal awareness and acceptance serve to reduce the barriers to deployment. When the niche innovation becomes fully price-competitive and specific supportive policy mechanisms are no longer needed, the »market-based growth« stage is achieved. RE technologies are, at this stage, fully integrated into the system.

2.3 ADDITIONS IN THE MENA PHASE MODEL

Assuming that the phase model for the German energy transition by Fischedick et al. (2014) and Henning et al. (2015) is relevant for the MENA countries, the four transition phases remain the same. The »system layer«, which was adopted from the original phase models, provides clear targets for the development of the system by orienting guidelines for decision-makers. Since niche formation processes are required for successfully upscaling niche innovations, a »niche« layer was added into the original phase model by Fischedick et al. (2020). A specific cluster of innovations was identified for each phase: RE technologies (phase 1), flexibility options (phase 2), PtF/G technologies (phase 3), and sectors such as heavy industry or aviation that are difficult to decarbonise (phase 4). In its breakthrough stage, each innovation cluster is dependent on the niche-formation process of the previous phase. Therefore, specific governance measures support the breakthrough and upscaling processes in the current phase. In later phases, the innovation clusters continue to spread through market-based growth (Fischedick et al., 2020). Consequently, the addition of the »niche layer« creates

Figure 2-2
Transition Phase Model for the MENA Region



(Source: Holtz et al., 2018)

a stronger emphasis on the processes that must occur to achieve the system targets (Fig. 2-2).

Changing the deployment of technologies across markets is described in a »techno-economic layer«, while the governance stages are captured in the »governance layer«. The aim of this layer is to connect developments in the techno-economic layer with governance approaches to support the transition phases. Specific measures with a strong focus on building a renewables-based energy system are included in the phase model. Factors such as capacities, infrastructure, markets, and the destabilisation of the existing fossil fuel-based regime have also been added to the model. These aspects, however, serve as reflexivity about governance and need to be individually assessed and adapted for each MENA country.

This study pays particular attention to the »landscape« level and its role in pressurising existing regimes and creating opportunities for system change. Questions regarding the influence of international frameworks on climate change, global and regional conflicts, and the long-term impacts of the Coronavirus Disease 2019 Pandemic (COVID-19) on the transition processes are discussed in the individual country case studies. As well as focusing on the need to continuously improve energy efficiency through all the phases, the model is enlarged with resource efficiency. This assumes the continuing reduction of material intensity through efficiency measures and circular economy principles.

3

THE MENA PHASE MODEL

3.1 SPECIFIC CHARACTERISTICS OF THE MENA REGION

The original phase model was developed for the German context, meaning particular assumptions were made. As the MENA region context is different, the fundamental assumptions of the phase model were adapted to suit the characteristics of the MENA countries. Fischedick et al. (2020) outlined the differences and described the adaptations of the MENA phase model, which serves as a starting point for the individual country model transfer in this study.

One of the differences is the current energy situation in the MENA region, which varies from country to country. Several countries, including Iraq, are rich in fossil fuel resources. Others, such as Morocco, Tunisia, and Jordan, are highly dependent on energy imports. Furthermore, subsidised energy prices, as well as non-liberalised energy markets, present further challenges for the energy transition in many MENA countries (IRENA, 2014).

Another fundamental difference to the German context is the growing trend in energy demand in the MENA region. According to BP (2019), the Middle East will face an annual increase in energy demand of around 2% until 2040. The power, transport, industrial, and non-combusted sectors are mainly responsible for the high increase in final energy consumption. An additional contributory factor is population growth, which is expected to further increase – particularly in Egypt and Iraq (Mirkin, 2010). In addition, energy-intensive industries, including steel, cement, and chemical, account for a substantial proportion of the energy demand. Energy demand is increasing due to the installation and expansion of seawater desalination capacities in most MENA countries: the electricity demand for seawater desalination is expected to triple by 2030 compared to the 2007 level in the MENA region (IEA-ETSAP and IRENA, 2012). Furthermore, the energy intensity in many MENA countries is high, due to low insulation quality in buildings, technical inefficiencies of cooling and heating technologies, and distribution infrastructure. The electricity losses in distribution are between 11% and 15% in stable MENA countries compared to 4% in Germany (The World Bank, 2019).

Although the MENA region does benefit from significant RE resources, much of the economic RE potential remains untapped. By exploiting this potential, most of the countries could become self-sufficient in terms of energy, and they could eventually become net exporters of renewables-based energy. As energy and hydrogen imports become an important pillar of Europe's energy strategy (European Commission, 2020), the MENA countries could – in the future – benefit from emerging synthetic fuel markets and profit from energy carrier exports to neighbouring countries in Europe. In this regard, some MENA countries with infrastructure for oil and gas could build on their experience in handling gas and liquid fuels. With the support of power-to-X (PtX) technologies, these energy-exporting MENA countries could switch smoothly from a fossil fuel phase to a renewables-based energy system. However, to achieve this goal, the infrastructure would have to be retrofitted on a large-scale for transmission and storage. For other countries in the MENA region, harnessing their RE potentials at a later transition phase to export PtX products could present new economic opportunities.

Yet a further difference is that the electricity grid in Germany is fully developed, whereas most of the MENA countries have grid systems that need to be expanded, developed nationally, and connected cross-border. Physical interconnections exist, but these are mainly in regional clusters (The World Bank, 2013). Therefore, the region lacks the necessary framework for electricity trade. In addition, technical grid codes would need to be developed to integrate RE and balance its variability. Moreover, as there are few standards for photovoltaics (PV) and wind, clear regulations would need to be established to enable grid access.

The MENA countries could benefit considerably from global advances in RE technologies. Global experience in the deployment of RE technology adds to the learning curve, which has resulted in cost reductions. Against this backdrop, the costs of PV modules have fallen by around 80% since 2010, and wind turbine prices have dropped by 30% to 40% since 2009 (IRENA, 2019). While the phase model for the German context assumes that RE technologies need time to mature, the phase model for the MENA context can include cost reductions. Additionally, there is already a wide actor network of companies that provide expertise in the field of RE technologies.

The energy systems in the MENA region are in a developmental phase; REs are attractive, seeing as they provide sustainability and energy security. Furthermore, they have the potential to stimulate economic prosperity. However, the conditions for developing RE industries are weak due to a lack of supporting frameworks for entrepreneurship and technological innovation. While in Germany private actors play a major role in small-scale PV and wind power plants, state-owned companies in the MENA region are central to large-scale projects. The mobilisation of capital is an additional significant factor that would require dedicated strategies.

3.2 ADAPTATION OF MODEL ASSUMPTIONS ACCORDING TO THE CHARACTERISTICS OF THE MENA COUNTRIES

The phases of the original phase model must be adapted to correspond to the characteristics of the MENA region. Based on Fischedick et al. (2020), changes to the original model were made within the four phases and their temporal description. In addition, the »system layer« description is complemented by a stronger focus on the destabilisation of the regime, and the »niche layer« is highlighted in each phase to prepare for the subsequent phase.

In order to meet the expected increase in the overall energy demand, the volume of renewables in phases 1 and 2 rises considerably without undermining the existing business of industries that provide fossil fuel and natural gas. The grid in the MENA countries is limited in its ability to accommodate rising shares of renewables, which results in greater emphasis on grid retrofitting and expansion during phase 1. Moreover, phase 2 must start earlier than in the German case, and the development in some countries could include a stronger focus on solutions for off-grid applications and small isolated grids. The growing domestic demand for energy in the MENA countries could be satisfied by renewables-based energies and energy carriers, such as synthetic fuels and gases. While in Germany imports play a considerable role in the later phases (in phase 3 in particular), excess energy in the MENA countries could be exported and offer potential economic opportunities in phase 4. The growing global competitiveness of REs offers the opportunity to accelerate the niche formation stages in all phases of the transition. However, niche formation processes would have to be integrated into domestic strategies. Institutions to support niche developments would need to be established and adapted to the country context.

3.3 PHASES OF THE ENERGY TRANSITION IN MENA COUNTRIES

The Wuppertal Institute developed the phase model for the MENA countries based on the German phase model and the experience gained during the project *Development of a Phase Model for Categorizing and Supporting the Sustainable Transformation of Energy Systems in the MENA Region*, which was supported by the Friedrich-Ebert-Stiftung (Holtz et al., 2018; Fischedick et al., 2020). The phases for the MENA region are presented in detail in their dimensions, which are based on supply, demand, infrastructure, markets, and society. The multi-dimensional perspective of transitions research is reflected in these layers, highlighting the interrelation of these dimensions during the transition phases. Table 31 summarises the main developments in the »techno-economic« and »governance« layers, as well as on the »landscape«, »system«, and »niche« levels during the four phases.

The renewable electricity supply capacities are expanded throughout the phases to meet the increasing demand for energy from all sectors. A crucial assumption is the need for energy efficiency to be increased considerably in all phases. The developments in phases 3 and 4 are dependent on many technological, political, and societal developments and, therefore, have high uncertainties from today's perspective.

In addition, a more detailed analysis of the influence of the »landscape« level was conducted. The assumption is made that the following factors would impact on all phases: I) International frameworks on climate change; II) decarbonisation efforts of industrialised countries, including green recovery programmes after the COVID-19 pandemic; III) global and regional conflicts (affecting trade); IV) long-term impacts of the COVID-19 pandemic on the world economy; V) geographic conditions and natural resource distribution; and VI) demographic development.

Phase 1 – »Take-Off REs«

Renewable electricity is already introduced into the electricity system before the first phase, »Take-off RE«, is reached. Developments at the »niche« level, such as assessing regional potential, local pilot projects, forming networks of actors, and sharing skills and knowledge about the domestic energy system, are initial indicators that diffusion is starting. During this pre-phase stage, visions and expectations for the expansion of RE-based energy generation are developed.

In the first phase, the characteristic development at the system level is the introduction and initial increase of RE, particularly electricity generated by PV and wind plants. MENA countries could benefit considerably from the globally available technologies and the global price drops of REs, which would facilitate the market introduction of PV and wind energy. As energy demand in the region is growing considerably, the share of RE entering the system would not be capable of replacing fossil fuels at this stage. To accommodate variable levels of RE, the grid must be extended and retrofitted. Laws and regulations come into effect, aiming to integrate renewables into the energy system and to enable renewables-based electricity to enter the grid. The introduction of price schemes as incentives for investors facilitates the large-scale deployment of RE and decentralised PV for households.

Developments occurring at the »niche« level pave the way for phase 2. The regional potential of different flexibility options is assessed (e.g. the possibilities for pump storage and DSM in industry), and visions are developed that broach the issue of flexibility options. At this stage, the role of sector coupling (e.g. e-mobility, power-to-heat) is discussed, and business models are explored. Expected flexibility needs and sector coupling lay the ground for ICT start-ups and new digital business models.

Phase 2 – »System Integration«

In phase 2, the expansion of RE continues at the »system« level, while growing markets still provide room for the co-existence of fossil fuel-based energy. The grid extension continues, and efforts to establish cross-border and transnational power lines are made to balance regional differences in wind and solar supply. At this stage, flexibility potentials (DSM, storage) are recognised, and the electricity market design is adapted to accommodate these options. The ICT infrastructure is fully integrated with the energy system (digitalisation). At the political level, regulations in the electricity, mobility, and heat sectors are aligned to provide a level playing field for different energy carriers. The direct electrification of applications in the mobility, industry, and heat sectors adds further flexibility to the system.

PtF/G applications are developed at the »niche« level to prepare the system for a breakthrough in phase 3. Pilot projects test the application of synthetic fuels and gases under local conditions. Green hydrogen is expected to replace fossil fuels in sectors such as chemical production. In the short to mid-term, the production of CO_2 from carbon capture in energy-intensive industries is acceptable. In the long term, however, the focus must shift to direct carbon capture from air or bioenergy to guarantee carbon neutrality. Actor networks create and share knowledge and skills in the field of PtF/G. Based on an assessment of the potentials for different PtF/G conversion routes, strategies and plans for infrastructure development are elaborated, and business models are explored.

The water-energy-nexus gains appropriate consideration in the framework of integrated approaches, as water is becoming even scarcer due to the consequences of climate change. This could result in shortages affecting the energy sector or competition from other uses, such as food production.

Phase 3 – »PtF/G«

At the »system« level, the share of renewables increases in the electricity mix, leading to intensified competition between renewables and fossil fuels and – temporarily – to high, negative residual loads. Green hydrogen and synthetic fuel production become more competitive due to the availability of low-cost electricity. PtF/G, supported by regulations including pricing schemes, enter the market and absorb increasing shares of »surplus« renewables during times of high supply. The mobility and long-distance transport sectors, in particular, contribute to an increase in the application of PtF/G. This, in turn, enables the replacement of fossil fuels and natural gas. The development of hydrogen infrastructure and the retrofitting of existing oil and gas infrastructure for the use of synthetic fuels and gases create dedicated renewable supply facilities for international exports. Price reductions and the introduction of fees and taxes on fossil fuels not only have a negative influence on their market conditions, but they also initiate the phase-out of fossil fuels. These developments stimulate changes in the business models. As PtF/G solutions provide long-term storage, considerable export market structures can be established.

At the »niche« level, experiments with PtF/G applications play an essential role in sectors that are difficult to decarbonise, such as heavy industry (concrete, chemicals, steel), heavy transport, and shipping. In addition, the potential to export hydrogen as well as synthetic fuels and gases is explored and assessed. Actor networks are established, initial learning is gained, and business models are studied.

Phase 4 – »Towards 100% Renewables«

Renewable-based energy carriers gradually replace the residual fossil fuels. Fossil fuels are phased out, and PtF/G is fully developed in terms of infrastructure and business models. As support for renewables is no longer required, price supporting schemes are phased out. Export market structures are expanded and constitute a crucial sector of the economy.

3.4 TRANSFER OF THE PHASE MODEL TO THE COUNTRY CASE OF LEBANON

The MENA phase model was exploratively applied to the case of Jordan in 2018 (Holtz et al., 2018). The model was discussed with high-ranking policymakers, representatives from science, industry, and civil society from Jordan. It proved to be a helpful tool to support discussions about strategies and policymaking for the energy transition; a tool which would also be appropriate for other MENA countries. Consequently, necessary adaptations were made, and the MENA phase model was applied to the country case of Lebanon. The results provide a structured overview of the ongoing developments in the Lebanese energy system and offer insights into the necessary steps to be taken to transform it into a renewables-based system. This, in turn, would improve Lebanon's energy security and reduce its import dependency on fossil fuels.

Lebanon's electricity system can be described as dysfunctional. It is a major contributor to the economic, fiscal, and financial crisis due to its high generation and operational costs, inefficiency, and weak governance. Situated at the nexus of regional conflicts, Lebanon is confronted with uncertainty about the development of regional conditions and the risk of potential spill-over effects (IRENA, 2020c). Electricity in Lebanon is heavily subsidised, and the economic depression puts additional strain on the public budget by contributing to a severe shortage in the foreign currency.

The dwindling of foreign currencies reserves threatens the fuel supply, seeing as most of the fuel demand has to be imported. This has led to operational challenges for the state-utility Electricité du Liban (EDL) as well as private diesel generators. Facing these challenges and reducing dependency on energy import are strong motives for the deployment of RE technologies. Yet, according to the International Energy Agency (IEA) (2020a), the RE share in the electricity production was only 2% in 2018, and the rest was produced by oil imports. In order to increase this share, the country must hasten the deployment of RE resources. However, a 46% debt ratio, the decline in dollar liquidity, and the current instability in the country present major hurdles to this development to be attained.

To reflect the specific challenges and opportunities for the energy transition faced by Lebanon, some additions to the criteria set of the MENA phase model were made, and additional factors at landscape level were analysed. These include the effects of the COVID-19 pandemic as well as global decarbonisation efforts in light of the Paris Agreement that have already affected (or will affect) international oil and gas prices and the development of the sector. Furthermore, details of the dominant role of fossil fuels in the energy system and the connected challenges for the development of the renewables sector have been assessed. Table 3-1 depicts the developments during the transition phases.

3.5 DATA COLLECTION

Detailed information on the status and current developments of the various dimensions was compiled in order to apply the phase model to individual country situations. In a first step, a comprehensive review of the relevant literature and available data was conducted. Based on the evaluation and analysis of the available data, information gaps were identified. The missing information was completed with the help of expert interviews and on-site research by local partner institutions. In addition, the local partner organisations helped to identify the country-specific challenges and barriers to unlocking the RE potential in the country. The interviewees included relevant stakeholders with experience in the energy sector or related sectors from public representatives, policy institutions, academia, international organizations, Civil Society Organizations (CSOs), and the private sector. The expert interviews were conducted according to guidelines for structured interviews. The quantitative data used is based on secondary sources, such as databases from the IEA and the International Renewable Energy Agency (IRENA). Secondary sources also include data either collected from local public and private institutions or calculated using available information. The subsequent results identify the current status and future trends.

In the Lebanese case study, the local research, interviews, analysis and data collection were conducted by the partner institution the IFI at the AUB.

Table 3-1
Developments During the Transition Phases

			Development before phase I	Phase I: »Take-Off RE«	Phase II: »System Integration RE«	Phase III: »Power-to-Fuel/Gas (PtF/G)«	Phase IV: "Towards 100% RE'
			* Niche formation RE	* Breakthrough RE * Niche formation flexibility option	* Market-based growth RE * Breakthrough flexibility option * Niche formation PtF/G	* Market-based growth flexibility option * Breakthrough PtF/G * Niche formation special PtF/G application and exports	* Market-based growth PtF/G * Breakthrough special PtF/G application and exports
Power Sector	Landscape level	* International frameworks on climate change * Decarbonisation efforts of industrialised countries (incl. green recovery programmes after COVID-19 pandemic) * Global and regional conflicts (affecting trade) * Long-term impacts of the COVID-19 pandemic on the world economy * Geographic conditions and natural resource distribution * Demographic development					
Power Sector	System level	Techno-economic layer		* RE share in energy system about 0%–20%	* RE share in energy system about 20%-50%	* RE share in energy system about 50%-80%	* RE share in energy system about 80%-100%
				* Market introduction of RE drawing on globally available technology and driven by global price drop	* Further grid extension (national and international)	* Extension of long-term storage (e.g., storage of synthetic gas)	* Large-scale construction of infrastructure for PtF/G exports
				* Extension and retrofitting of electricity grid	* ICT structures integrate with energy systems (e.g., introduction of smart meters)	* First PtF/G infrastructure is constructed (satisfying up-coming national/foreign demand)	* Phase-out of fossil fuel infrastructure and business models
				* Regulations and pricing schemes for RE	* System penetration of flexibility options (e.g., battery storage)	* Temporarily high negative residual loads due to high shares of RE	* Consolidation of RE-based export models
				* Developing and strengthening domestic supply chains for RE	* Direct electrification of applications in the buildings, mobility, and industry sectors; changing business models in those sectors (e.g., heat pumps, e-cars, smart-home systems, marketing of load shedding of industrial loads)	* Sales volumes of fossil fuels start to shrink	* Full replacement of fossil fuels by RE and RE-based fuels
				* No replacement of fossil fuels due to growing markets	* No replacement (or only limited replacement) of fossil fuels due to growing markets	* Existing fossil fuel-based business models start to change	* Stabilisation of PtF/G business models and production capacities (e.g. large-scale investments)
					* Development and extension of mini-grids as a solution for off-grid applications and remote locations	* Increasing volumes of PtF/G in transport, replacing fossil fuels and natural gas	
					* Progressing the energy transition in end-use sectors (transport, industry, and buildings)		
					* Progressing the energy transition in the industry sector, reducing the high carbon content of certain products and high emissions of certain processes		

			Development before phase I	Phase I: »Take-Off RE«	Phase II: »System Integration RE«	Phase III: »Power-to-Fuel/Gas (PtF/G)«	Phase IV: "Towards 100% RE'
			* Niche formation RE	* Breakthrough RE * Niche formation flexibility option	* Market-based growth RE * Breakthrough flexibility option * Niche formation PtF/G	* Market-based growth flexibility option * Breakthrough PtF/G * Niche formation special PtF/G application and exports	* Market-based growth PtF/G * Breakthrough special PtF/G application and exports
Power Sector	System level	Governance layer	* Fundamental recognition that energy efficiency is the second strategic pillar of the energy system transformation	* Support adoption of RE (e.g. feed-in tariffs), set up regulations and price schemes for RE	* Put pressure on fossil fuel-based electricity regime (e.g. reduction of subsidies, carbon pricing)	* Put pressure on system components that counteract flexibility (e.g. phase out base-load power plants)	* Put pressure on fossil fuels (e.g. phase out production)
				• Increasing participation of institutional investors (pension funds, insurance companies, endowments, and sovereign wealth funds) in the transition	* Withdraw support for RE (e.g. phase out feed-in tariffs)	* Withdraw support for flexibility options	* Withdraw support for PtF/G
				* Increasing awareness of environmental issues	* Measures to reduce unintended side-effects of RE (if any)	* Measures to reduce unintended side-effects of flexibility options (if any)	* Measures to reduce unintended side-effects of PtF/G (if any)
				* Provide access to infrastructure and markets for RE (e.g. set up regulations for grid access)	* Adaptation of market design to accommodate flexibility options	* Set up regulations and price schemes for PtF/G (e.g. transport, replace fossil fuels and natural gas)	* Access to infrastructure and markets (e.g. connect production sites to pipelines)
				* Moderate efforts to accelerate efficiency improvements	* Provide access to markets for flexibility options (e.g. adaptation of market design, alignment of electricity, mobility, and heat-related regulations)	* Reduce prices paid for fossil fuel-based electricity	* Support adoption (e.g. subsidies)
					* Support creation and activation of flexibility options (e.g. tariffs for bi-directional loading of e-cars)	* Provide access to infrastructure and markets for PtF/G (e.g. retrofit pipelines for transport of synthetic gases/fuels)	
					* Facilitate sector coupling between power and end-use sectors to support the integration of VRE in the power sector	* Support adoption of PtF/G (e.g. tax exemptions)	
					* Adaptation of market design to accommodate flexibility options		
					* Investments reallocated towards low-carbon solutions: high share of RE investments and reduce the risk of stranded assets		
					* Alignment of socio-economic structures and the financial system; broader sustainability and transition requirements		
					* Facilitate sector coupling between power and end-use sectors to facilitate the integration of VRE in the power sector		
					* Alignment of electricity, mobility, and heat-related regulations		

			Development before phase I	Phase I: »Take-Off RE«	Phase II: »System Integration RE«	Phase III: »Power-to-Fuel/Gas (PtF/G)«	Phase IV: "Towards 100% RE'
			* Niche formation RE	* Breakthrough RE * Niche formation flexibility option	* Market-based growth RE * Breakthrough flexibility option * Niche formation PtF/G	* Market-based growth flexibility option * Breakthrough PtF/G * Niche formation special PtF/G application and exports	* Market-based growth PtF/G * Breakthrough special PtF/G application and exports
Power Sector	Niche level	Techno-economic layer	* Assessment of RE potential	* Assessment of regional potential for different flexibility options	* Assessment of potential for different PtF/G conversion routes	* Experiment with PtF/G applications in sectors such as industry (e.g. steel, cement, and chemical sectors) and special transport (e.g. aviation, shipping)	
			* Local pilot projects with RE	* Experiment with flexibility options	* Local pilot projects with PtF/G generation based on RE hydrogen and carbon capture (e.g. CCU/CCS)	* Invest in business models for PtF/G exports	
				* Exploration of business models around flexibility options including ICT start-ups and new digital business models for sector coupling	* Exploration of PtF/G-based business models	* Pilot synthetic fuel exports	
					• Exploration of new DSM potentials (e.g. smart charging and vehicle-to-grid for EV, flexible heat pump heating and cooling, thermal storage fed by electricity)		
					* Tap into global experiences of PtF/G		
		Governance layer	* Development of shared visions and expectations for RE development	* Development of visions and expectations for flex-market and energy system integration (regional and transnational energy markets)	* Development of shared visions and expectations for PtF/G (e.g. strategy and plans for infrastructure development/adaptation)	* Development of shared visions and expectations for PtF/G exports (e.g. about target markets and locations for conversion steps)	
			* Support learning processes around RE (e.g. local projects)	* Support learning processes around flexibility (e.g. local projects)	* Support learning processes around PtF/G (e.g. local projects for PtF/G generation, tap global experiences of PtF/G, exploration of PtF/G-based business models)	* Support learning about PtF/G in sectors such as industry and special transport (e.g. experiments for using PtF/G products for glass smelting)	
			* Formation of RE-related actor networks (e.g. joint ventures)	* Formation of actor networks around flexibility across electricity, mobility, heat sectors (e.g. exploration of business models around flexibility including ICT start-ups and new digital business models for sector coupling)	* Formation of PtF/G-related actor network (national and international)	* Support learning around PtF/G exports (e.g. concerning market acceptance and trade regulations)	
			• Community-based engagement and involvement (e.g. citizen initiatives)	* Development of a shared knowledge base of integrated decarbonisation pathways to enable alignment and critical mass that can help shift the entire sector		* Formation of actor networks for creating large-scale synthetic fuel export structures (e.g. producers, trading associations, marketplaces)	
	* Continuing improvements in energy efficiency						
	* Continuing the reduction of material intensity through efficiency measures and circular economy principles						

(Source: Own creation)

4

APPLICATION OF THE MODEL TO LEBANON

Factsheet	
Paris Agreement ratified	✔
Green growth strategy	✗
RE targets set	✔
Regulatory policies for RE implementation established	✔
Energy efficiency strategy existing	✔
PtX strategy	✗

4.1 CATEGORISATION OF THE ENERGY SYSTEM TRANSFORMATION IN LEBANON ACCORDING TO THE PHASE MODEL

The Copenhagen conference on climate change in 2009 and the Paris Agreement from 2016 have endorsed the Lebanese government to move towards the energy transition and decarbonisation of the energy mix. Specifically, in 2009, Lebanon pledged to reduce the domestic fossil fuel usage through achieving a target of 12% renewables in the energy mix by 2020. However, it has been challenging to meet these targets in an environment of continuous political instability, a severe economic crisis that caused the local currency to lose around 85% of its value, and a social uprising as of October 2019. Today, RE represents only about 2% in the national electricity mix and around 2.9% in the overall energy mix. Yet, Lebanon has adopted another ambitious target to cover 30% of its primary energy consumption from renewables by 2030 (IRENA, 2020c). It has also ratified the Paris Agreement on March 29th, 2019 (Law 115/2019) and deposited the instrument of ratification in February 2020 at the United Nations (UNDP, 2021b). Through the latter, the country plans to reduce its GHG emissions by 30% as well as its power-demand by 10% through energy-efficiency measures. This is contingent upon the provision of international support. Furthermore, the country aims to unconditionally reduce its GHG emissions by as much as 20% and its power-demand by 3% all by 2030, relative to a business-as-usual scenario (UNDP, 2021a).

As a major oil importing country, the economic vulnerability to oil price fluctuations is severely endangering Lebanon's prosperity (Moore and Collins, 2020). Currently, imported fuels account for 98% of the energy supply, which puts a huge burden on the state's budget. The electricity generation sector is also almost entirely dependent on imported petroleum products, although significant potential for RE resources is given (Berjawi et al., 2017; Wehbe, 2021). Moreover, the demand for electricity cannot be met adequately today, and there are regular power cuts. The constant power outages occur due to the weak performance of the state's EDL that can meet only 63% of the electricity demand (Ahmad et al., 2020). The gap is extensively met by expensive and polluting private diesel generators that are mainly responsible for the electricity sectors' GHG emissions, which account for over 53% of the total emissions (Ahmad et al., 2020; Moore and Collins, 2020).

Lebanon possesses advanced RE financing and regulatory mechanisms compared to many other MENA countries. However, a myriad of challenges ranging from economic, social, and geopolitical nature impede the sector's development. Especially, mismanagement and inefficiency in the electricity sector deprive Lebanon's citizens of a reliable and affordable electricity supply (Ahmad et al., 2020). The economic and financial crisis compounds the difficulties that the Lebanese state faces and is further exacerbated by the outbreak of the COVID-19 pandemic (The World Bank, 2020b). The shortage of foreign currencies reserves, which are needed to supply EDL with imported fuel supplies for its power plants, lead the country to experience complete blackouts.

Due to the significant energy supply-demand imbalance and the negative repercussions of the several crises the country is witnessing, the Lebanese state has formulated, in early 2020, that renewables and energy efficiency should be key to the country's recovery plans (IRENA, 2020c). To achieve the 2030 goals, enhance energy security, and support economic growth, large investments in the energy diversification strategy have to be made, and participation of the private sector needs to be encouraged.

Against this backdrop, the following sections will make a detailed assessment of the current status and development of Lebanon's energy transition along the energy transition phase model.

4.1.1 Assessment of the Current State and Trends at the Landscape and System Levels

This section discusses the current state and trends of Lebanon's energy system in terms of supply, demand, infrastructure, actor network, and market developments.

Energy Supply and Demand

Lebanon's total primary energy supply in 2018 was 8.57 Mtoe (IEA, 2020a). In terms of the energy consumption by sector, the transport sector dominated, accounting for 52%, followed by the residential sector (19%), and the industrial sector (14%) (IEA, 2020a) (Fig. 4-1). The energy mix was predominantly made up of oil (Fig. 4-2). In 2018, oil held a 95% share in the energy mix, coal accounted for 2% (mainly used by cement factories[2]), while REs held a share of around 2.95% (IEA, 2020a). Oil sources in the energy supply have always been the main fuel in the energy mix, varying between 92% and 95% since 1990.

According to the updated 2019 policy paper by the Ministry of Energy and Water (MEW) of Lebanon, the country's consumer peak was estimated at 3,669 MW in 2019. The total installed production capacity in Lebanon was around 2,600 MW (excluding the two power barges); thermal power plants added a capacity of 2,330 MW, while hydroelectric power plants accounted for 282 MW of the total capacity (MEW, 2019). However, as the effective generation capacity ranges between 1,800–2,000 MW over the year, an additional 1,500 MW would be needed to meet the overall demand. For instance, in 2018 EDL's power plants' contribution to electricity demand amounted to 1,884 MW (Ahmad et al., 2020). The daily load curve peaks in winter during the evening hours between 16 and 22 pm, while the summer day load is rather constant during the day and peaks between 18 and 21 pm as of 2016 (Berjawi et al., 2017). Although almost 100% of the population has electricity access in Lebanon, the country suffers from structured blackouts that average around 6 hours per day. In 2020, the blackouts lasted 22 hours per day during certain days (Azar, 2021; Harajli et al., 2020; Majzoub, 2020). Large companies, therefore, rely on their own private generators for electricity.

The capacity reserve margin reaches -27% and reflects the wide extent of the supply and peak demand gap. Constant blackouts are part of the daily life in Lebanon and vary highly geographically as a result of the state-utility EDL's insufficient electricity supply. This fact is represented by the low load factor of 73%, which measures the utilisation rate and efficiency of the electricity energy usage. Whereas in 2008 the percentage of unmet electricity demand was 22%, the unmet demand in 2019 amounted to 37%, totalling around 8.1 TWh (Ahmad et al., 2020). The gap is closed by expensive and polluting diesel generators, which, however, play a crucial role in assuring electricity supply (Fardoun et al., 2012). The shortage of supply is further exacerbated by the increasing electricity demand. The electricity demand has increased by an average annual growth rate of around 7.6% since 1990 reaching 19 TWh in 2018 (Fig. 4-3). The demand is induced by population growth that is partly driven by the large influx of refugees in the recent years (Berjawi et al., 2017).

The main electricity sources are fuel oil (54%) and gas or diesel oils (37.6%) (MEW, 2019). Most power plants are run by oil, while natural gas does not play an important role (Fig. 4-4). In total, seven thermal power plants are under operation, five hydroelectric plants, and two power ships are deployed, each of 195 MW generation capacity (MV Karadeniz Power-ship Fatmagül Sultan, MV Karadeniz Power-ship Orhan Bey, located in the Zouk and Jiyeh regions)[3]. The power barges that run on fuel oil contribute to 21% of the electricity generation, while the remainder of the total power generation is covered mainly by hydroelectricity (Farhat, 2019).

For the year 2018, Ahmad (2020) estimated the total electricity demand at around 22,000 GWh, EDL thermal power plants generated approximately 63% of the total power, while the remaining 37% was supplied by private diesel generators. In 2019, the total generated electricity equaled around 15,390 GWh (Farhat, 2019), leaving around 8,100 GWh unserved. The Government has tried, through the addition of several small power plants in 2016–2017, to close the gap between demand and in-stalled capacity (MEW, 2019), but the latter kept increasing due to several factors: technical and non-technical losses, operation and maintenance needs, shortage of USD, and consequently of fuel, among other aspects.

The COVID-19 pandemic has significantly impacted the energy sector, which has further slowed down the economy and the electricity sector, in particular. The poor power supply has affected the population. For example, difficulties in home schooling have ensued due to poor internet connectivity resulting from power cuts (Ahmad et al., 2020). Similarly, water supply has been hampered because water stations are suffering from inadequate power supply that, in turn, impedes water pumping through villages (Ahmad et al., 2020).

To summarise, the Lebanese electricity and energy supply is impacted by several factors: the supply-demand imbalance, the conventional energy system mostly relying on imports, and the uncertainties and fear of potential spill-overs related to the existing regional conflicts (IRENA, 2020c). There

2 UN ESCWA 2019 report: https://unstats.un.org/unsd/energystats/events/2019-Beirut/Lebanon%20Report%20Final.pdf

3 Sometimes, the generated power from the power barges drops to less than a half depending on fuel availability that the EDL is responsible for.

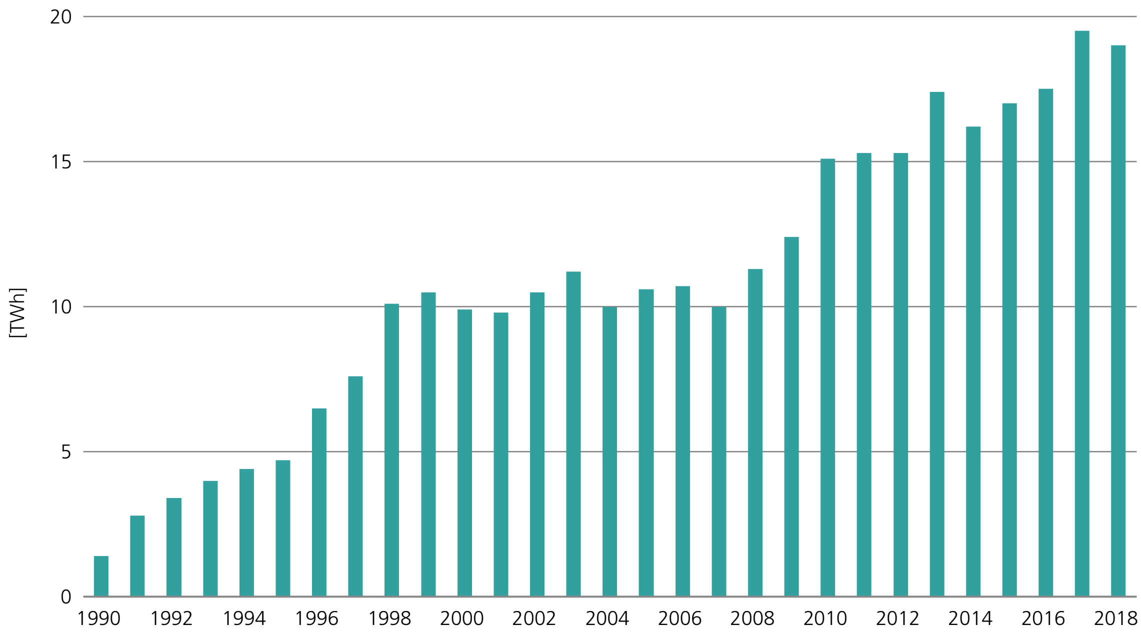
Figure 4-1
Total Final Energy Consumption (in ktoe), Lebanon 1990–2018

(Source: data based on IEA (2020a))

Figure 4-2
Total Energy Supply (in ktoe), Lebanon 1990–2018

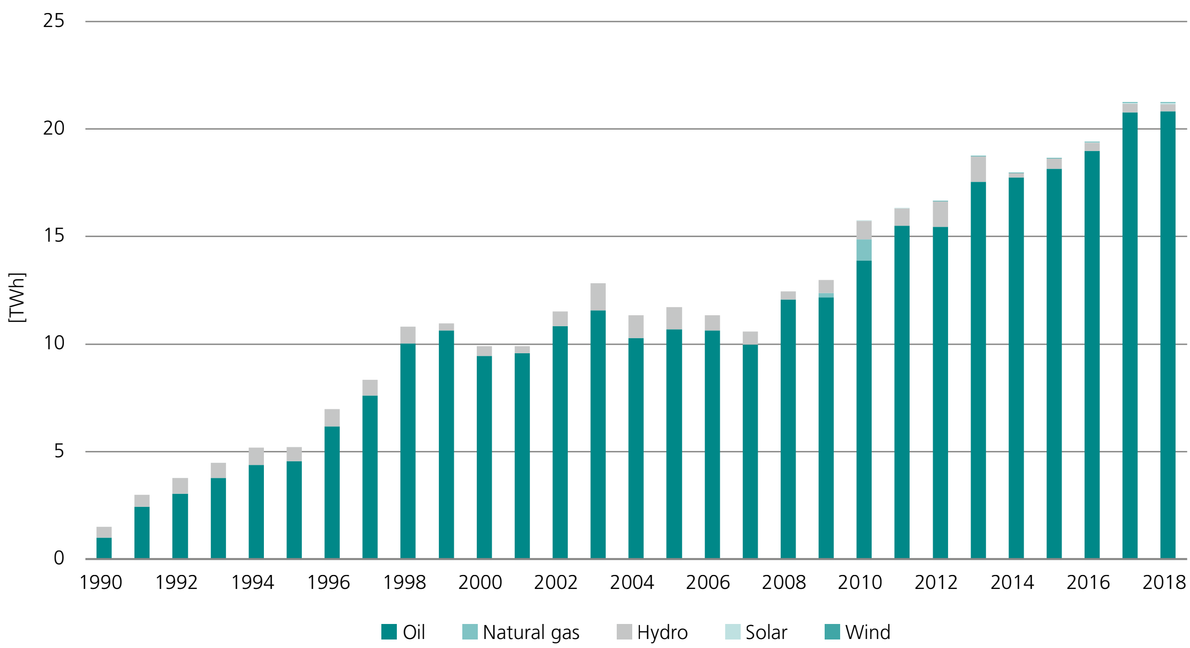
(Source: data based on IEA (2020a))

Figure 4-3
Electricity Consumption (in TWh), Lebanon 1990–2018



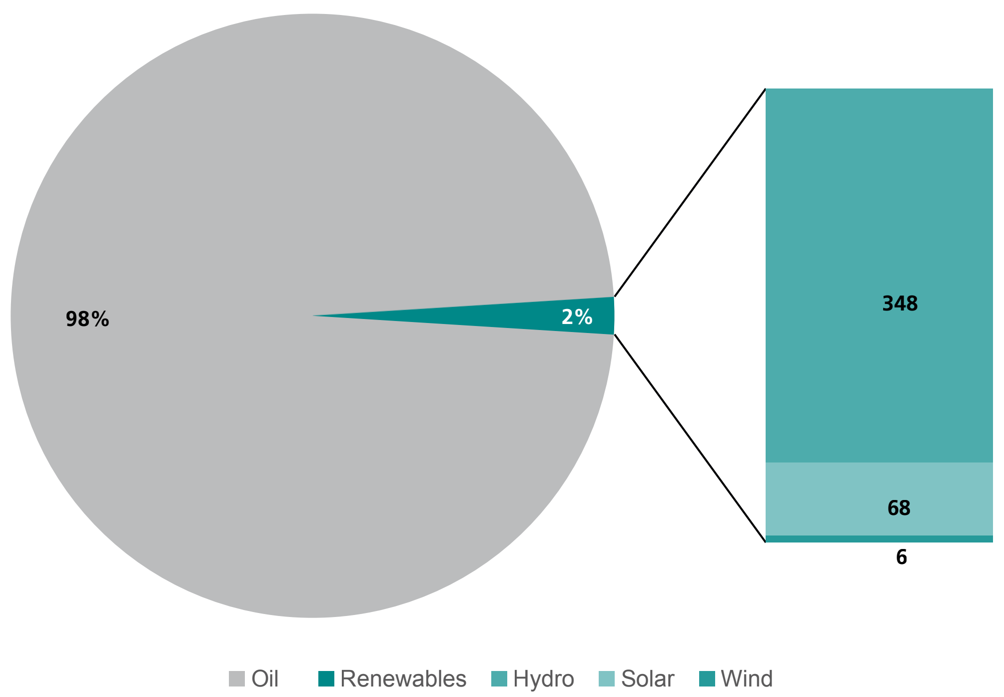
(Source: data based on IEA (2020a))

Figure 4-4
Electricity Generation by Source (in TWh), Lebanon 1990–2018



(Source: data based on IEA (2020a))

Figure 4-5
Electricity Generation Mix (in GWh), Lebanon 2018



(Source: based on data from IEA, 2020a)

is evidence of an increasing trend in conventional power generation over recent years. Lebanon's vulnerable energy supply condition has large implications on the Lebanese energy security. Based on this assessment, Lebanon can be classified, according to the MENA phase model, as being in the early stage of the first phase of the energy transition towards renewables, in which fossil fuels are still the dominating energy source.

Renewable Energy

Lebanon is one of the first Arab countries that developed an action plan to endorse RE deployment in 2010. This is due to the country's possession of abundant RE potential, such as wind, solar, and hydropower. With the *National Energy Efficiency Action Plan 2011–2015* (NEEAP), Lebanon pledged implementation targets in the field of energy efficiency and RE. However, the deployment of RE technologies remains limited to non-modern uses of biomass heating in rural areas and old, inefficient hydroelectric power plants (IRENA, 2020c). The recently added RE installations mainly consist of decentralised solar rooftop PV.

By the end of 2018, the installed capacity of renewables was 321 MW (IRENA, 2020b). Hydropower accounted for 286 MW, the cumulative PV power capacity reached around 56 MW, wind capacity 3 MW, and bioenergy 9 MW (ibid.). The year 2019 has witnessed the addition of 22.15 MWp of solar PV capacity, bringing the total installed capacity to 78.65 MWp. The number of new solar PV projects increased from 326 in 2018 to 360 in 2019, but remained below 387, which was a higher number of projects in year 2017 (Farhat, 2019). In an almost conventional power mix, the power generation from renewables held a share of 2% in 2018. Fig. 4-5 depicts the electricity generation mix for the year 2018, where hydropower produced 348 GWh, the solar power generation was 68 GWh, and wind 6 GWh, according to the IEA (2020a).

The most prominent RE technology in Lebanon is hydropower. Being a very mountainous country, the potential for both small- and large-scale hydropower stations is high (Kinab and Elkhoury, 2012). Today, a total of five hydropower plants are running, all of them installed between 1924 and 1967. The plants are located across country (Table 41). The major plant is the Litani power plant, located in the South of Lebanon at the river Litani, which is the longest river providing an annual flow of approximately 920 million m^3 (Kinab and Elkhoury, 2012). Hydropower plays a major role in the renewable electricity supply. However, due to its dependence on the irregular annual rainfall, the production is largely unstable. The generated electricity can vary extremely from 1,362 MWh in 2003 to 373 MWh in 2008 (Kinab and Elkhoury, 2012). In addition, low contracted prices and a lack of refurbishment of the power plants lead to a constant drop of hydropower generation (IRENA, 2020c). A further challenge is that most existing concessions are used exclusively for agricultural and irrigation purposes. The MEW is currently negotiating hydropower concessions to be consistent with the newly adopted electricity plan. The Lebanese government has expressed its interest to expand hydropower installations through this plan (ibid.).

The solar potential in Lebanon is high with an annual average global horizontal irradiation (GHI) between 1,520 kWh/m^2 and 2,148 kWh/m^2 (IRENA, 2020c), while the yearly direct normal irradiation (DNI) exceeds 2,100 kWh/m^2 (IRENA and ESCWA, 2018). IRENA calculations estimate that the technical potential for utility scale solar PV is around 182 GW. However, more detailed estimates of practically useable capacity are between 5.5-10.5 GW.[4] At the end of 2019, the cumulative installed solar PV capacity reached 78.65 MW (Farhat, 2019). Most of these projects are at small-scale in the range of 50-1,000 kWp (Eslami et al., 2021)using Lebanon's capital, Beirut, as a case study, a methodology is proposed to assess the potential for solar photovoltaics (PV and consist of private or public PV systems. Small-sized projects, up to 50 kWp, dominate the market in terms of installed capacity (20%) with a total of 15.80 MWp. Beirut itself is estimated to have a rooftop solar PV capacity between 200 and 300 MWp (Ahmad et al., 2020). Between 30% and 80% of the total rooftop area in Beirut could potentially cover up to 34% of the electricity demand in the city (IRENA, 2020c). The two 1 MW projects are the Beirut River Solar Snake (BRSS) Project and the Zahrani Oil Installations Project that represent the large-scale projects in Lebanon. In 2018, the MEW and the Lebanese Centre for Energy Conservation (LCEC) launched an expression of interest (EoI) to install three 100 MWp PV facilities combined with a 70 MWh storage capacity each (IRENA, 2020c). While the required capacity was set to 300 MWp, the offered capacity by companies amounted to 4,268 MWp. In addition to the launched EoI, preparations for the launch of a 2nd round of PV auctions to install 24 PV farms with a total capacity of 240-360 MWp before the end of 2020 were in progress (ibid.). Yet, these preparations were halted due to the economic crisis. The top three governorates leading in solar PV installations in Lebanon are Mount Lebanon with 27.19 MWp at 35%, Beqaa with 20.44 MWp at 26%, and South Lebanon with 8.28 MWp at 10% (Farhat, 2019).

The industrial sector in Lebanon has contributed to the highest solar PV capacity growth rate lately and achieved an installed capacity of 25.54 MWp by 2019 (an increase from 18.4 MWp). About 20% of all rooftop PV systems are installed within the commercial sector and 13% each within the residential and agricultural sector (Farhat, 2019). The rest is distributed among the educational, medical, public and non-profit sectors. The peak demand occurs during the day when most of the solar power is available and the electricity is most needed for industrial processes. Therefore, industries have heavily invested in on-grid solar PV systems with around 45.74 MWp. The following factors explain this switch from diesel generators to solar PV: 1) available space at facilities, 2) access to financing (before the economic crisis), and 3) reliable constant electricity compared to the grid (ibid.). According to the United Nations Development Programme (UNDP) (2019), this reflects a crucial market development with economic benefits.

The residential sector leads in the use of solar water heating (SWH) systems. Within the NEEAP, private banks, initiated through the Central Bank of Lebanon (BDL), have granted five-years and interest free loans to support SWH installations (MEW and LCEC, 2019). The MEW contributed USD 200 to the capital costs. Projects that exceeded USD 5,000 were eligible to apply for a National Energy Efficiency & Renewable Energy Action (NEEREA) loan (Moore and Collins, 2020). By 2017, the installed systems comprised an area of approximately 608,529 m^2. Between the years 2010 and 2017, 85,060 systems with a capacity of 27,733,366 liters were installed, accounting for an overall investment of USD 153,650,283. Currently, the market is at a steady state, installing about 50,000 m^2 annually (MEW and LCEC, 2019). Due to the NEEREA incentive, the SWH systems, which were partially manufactured in Lebanon, have gained momentum in the Lebanese market (Moore and Collins, 2020). The solar business landscape is, in general, characterized by over 100 competitive PV companies with the potential of growth (ibid.). Since 2008, at least 670 jobs have been created just in the solar PV sector (UNDP, 2019).

Regarding the wind energy potential in Lebanon, different studies indicate that the wind capacity in the country is between 1,500 MW and 6,100 MW, while the recently conducted assessment by IRENA presents a higher potential of 6,233 MW (IRENA, 2020c). As of today, there are three micro-wind projects of 2 kWp installed capacity. Currently, the first utility-scale projects consisting of three wind farms are under development, but the process has been halted due to the economic crisis. The wind farms will be situated in the Akkar district close to the Syrian border and will have 54 turbines with a total capacity of 226 MW (NCEA, 2019). The projects will be run by three private developers who have signed a power purchase agreement (PPA) back in 2018 (UNDP, 2019).

Bioenergy has not been developed significantly in Lebanon. However, the country has a great potential from various sources. The UNDP-CEDRO (2012) published a study which aimed to formulate a bioenergy strategy for Lebanon considering all bioenergy sources. However, the development of sustainable bioenergy is still lagging despite the intense use of traditional biomass in rural areas. Another major source of bioenergy is biodegradable fraction of municipal waste that is dumped into landfills. According to the UNDP report, it is estimated that around 863,000 tons of biodegradable waste is generated in Lebanon per year. This equals a total energy potential of 743 GWh steam and 278 GWh of methane. The biggest sanitary controlled landfill that serves the Greater Beirut Area (GBA) and the Mount Lebanon area is the Naameh landfill, which accounts for 60% of this total. It is estimated that the Naameh landfill has a potential to produce 14,413,583 m^3 of methane and 143.3 GW of energy (UNDP-CEDRO, 2012). In the city of Sidon, located in south Lebanon, anaerobic digestion is used to produce energy from waste (GIZ, 2014). The biogas produced is refined and generates 1,700 kWh that are used to power the plant itself and the nearby recycling plant. The 150 kWh electrical

4 AUB/IFI-LFRE-Strategy&. (2019). *Lebanon's electricity sector – Leapfrogging to higher penetration of renewables*. https://static1.squarespace.com/static/5d80f7c51d0ebc135e8dfd66/t/5e5c324d55dd0836544463ec/1583100556399/Strategy-AUB-LFRE+final+report+Leapfrog+May+2019.pdf

Table 4-1
Operational and Planned Renewable Energy Projects in Lebanon

Operational hydro power plants					
Site	Markaba, Awali, Joun	Chouane, Yahchouch, Fitri	Bechare, Mar Licha, Blaouza II, Abu-Ali	Al Bared 1, Al Bared 2	Richmaya-Safa
River	Litani/Awali rivers	Nahr Ibrahim river	Kadisha valley	Nahr Al Bared	Safa spring
Installed Capacity (MW)	199	32	21	17	13
Operational solar power plants (CSP and PV)					
Site	Beirut River Solar Snake (BRSS) project	Zahrani Oil installations	Other distributed projects in the regions of less than 1 MW		
Type	PV	PV	PV		
Installed Capacity (MWp)	1.08	1	≈ 75		
Planned solar power plants (CSP and PV)					
Site	BRSS project (second phase)	Zahrani Oil installations	12 distributed farms of 15 MW each	3 utility-scale farms with storage	
Installed Capacity (MW)	7	3	180	3*100 MWp and 70 MWh of storage	
Status	Launched		Launched	Launched	
Planned wind power plants					
Site	Akkar (3 wind farms)				
Installed Capacity (MW)	226				
Status	under development				

(Source: data based on IRENA (2020a); Khalil (2017); NCEA (2019))

surplus is given to the municipality of Sidon free of charge to power street lights at night (IBC, 2015).

Lebanon's current operational and planned RE projects are listed in Table 4-1.

To summarise, the implementation of REs in Lebanon could yield significant benefits like addressing the high deficits of the power sector, meeting the growing demand, reducing the import dependency, thereby increasing the energy security and providing various health benefits (Ayoub and Boustany, 2019). However, in comparison to its significant potential, Lebanon's share of renewables is negligible. Due to the current economic crisis, geopolitical challenges, and the effects of the COVID-19 pandemic, the implementation is further slowed down. Thus, based on the MENA phase model, Lebanon is classified as being in an early stage of the first phase of the renewable implementation.

Legal Framework for RE and Efficiency in the Electricity Sector

Until the Conference of the Parties (COP) meeting in Copenhagen in 2009, Lebanon never had a tangible commitment to invest in its RE sector. However, after the meeting, the Lebanese Government had set a target to achieve 12% renewables in the national energy mix by 2020, which has been recently updated to 30% by 2030 (IRENA, 2020c). This commitment is an important part of the policy papers for the electricity sector issued by the MEW in 2010 and 2019. The first policy paper was adopted by the government as the national strategy in June 2010. This paper included several initiatives: infrastructure (generation, transmission, and distribution), supply and demand (fuel sourcing, RE, DSM, energy efficiency, and tariffs), and was then supported by a legal framework through law 181/2011. The MEW along with the World Bank worked on developing the second policy paper, which was approved by the parliament in April 2019. The aim of this policy paper was to reduce the inefficiencies in the electricity sector with a special focus on EDL's financial deficit and the shortage in electricity supply. The policy papers were associated with plans developed and adopted by the Lebanese government, namely the action plans prepared by the LCEC that contained initiatives related to energy efficiency.

The LCEC developed the NEEAP for Lebanon for the years 2011–2015, which has set a roadmap for Lebanon's goal to reach energy efficiency (MEW and LCEC, 2012). The NEEAP was approved by the MEW in November 2011 (Decision #26). Fourteen initiatives related to energy efficiency and RE, including supporting the UNDP's national projects, were introduced. The two major projects led by the UNDP were the following:

1. the Country Energy Efficiency and Renewable Energy Demonstration Project for the Recovery of Lebanon (CEDRO), funded by the European Union (EU)
2. the Global Solar Water Heaters Project (GSWH), funded by the Global Environment Facility (GEF) (MEW and LCEC, 2012)

The most successful initiative (no. eleven) was the cooperation between the EU, the UNDP, and the BDL to introduce the NEEREA. The NEEREA was created to promote the financing of RE or energy efficiency projects. Nevertheless, large-scale projects from independent power producers (IPPs) have been limited, as under the NEEREA incentive, only projects for individual consumption have been approved (Moore and Collins, 2020). Besides the NEEREA, the

Lebanon Energy Efficiency and Renewable Energy Finance Facility (LEEREFF) and the Green Economy Financing Facility (GEFF) provide favourable loan schemes for the promotion of distributed PV and SWH markets (IRENA, 2020c).

After the evaluation of the NEEAP 2011–2015, many gaps have been identified. The missing baseline and the orientation towards energy efficiency led to an amendment of the plan. The MEW adopted an updated NEEAP for the years 2016–2020, which includes initiatives targeting different sectors in Lebanon. The NEEAP 2016–2020 is divided into two major sections (MEW and LCEC, 2016):

1. the first section constitutes the power sector measures, which focuses on energy efficiency in the generation, transmission, and distribution of electricity.
2. the second section tackles end-use measures that include horizontal end-use measures, end-use measures in the building sector, end-use measures in industry and agriculture, measures in mobility and transport, and end-use measures in the public sector.

Furthermore, the gaps mentioned previously are met through setting 2010 as base year scenario and developing a new incentive that focuses only on REs: the *National Renewable Energy Action Plan* (NREAP). The NREAP, in collaboration with the League of Arab States (LAS) and Regional Centre for Renewable Energy and Energy Efficiency (RCREEE), aimed to produce 12% of the projected electricity and heating demand from RE by 2020 (Mahmoud & Habib, 2019). The LCEC believed that the target would be achievable if the policies and activities set in the NREAP would be implemented. The full deployment of the NREAP 2016–2020 would have resulted in saving more than USD 225 million on a yearly basis, starting in 2020 (MEW and LCEC, 2016). The LCEC is currently in the process of updating this action plan and aims to launch the NREAP 2021–2025 to achieve its targets in both energy efficiency and RE. During this improvement, the LCEC takes into account the current economic downturn.

Moreover, in collaboration with the LCEC along with the MEW, IRENA has provided a 2030 outlook that frames a roadmap for RE development in Lebanon. According to this roadmap, upscaling the integration of RE in Lebanon will help to meet the national energy demand, support growth of the economy, and save Lebanon annually around USD 249 million. Individual target capacities for each technology have been identified in order to achieve the target of 30% renewables by 2030:

Table 4-2
Individual Target Capacities for Each Technology

Target capacities of RE technologies	
Wind	1,000 MW
Hydro	601 MW
Centralised Solar PV	2,500 MW
Decentralised Solar PV	500 MW
Biogas	13 MW

(Source: data based on IRENA (2020))

Law 462/2002 currently governs the Lebanese electricity sector. This law established a new structure for the energy sector and has set a legal framework for its unbundling. It divided the sector into three entities: production, transmission, and distribution, where production and distribution become partially privatized. Nonetheless, Article 5 of Law 462/2002 kept EDL the sole institution responsible for electricity transmission. Moreover, this law initiated the appointment of the Electricity Regulatory Authority (ERA), which would be responsible for ensuring competition in the sector, adjusting non-competitive tariffs, and issuing long-term licenses for IPPs to generate electricity and feed it into the grid. Although Law 462 came into force in 2002, it was never implemented, and no licenses were granted at that stage, as the ERA has not been established yet. Clearly, this represents an obstacle to the RE development (Berjawi et al., 2017). In addition, private diesel generators operate outside the legally authorised mechanism. Yet, they are tolerated by policy makers, for they tackle the challenge of power under-supply (Ahmad et al., 2020).

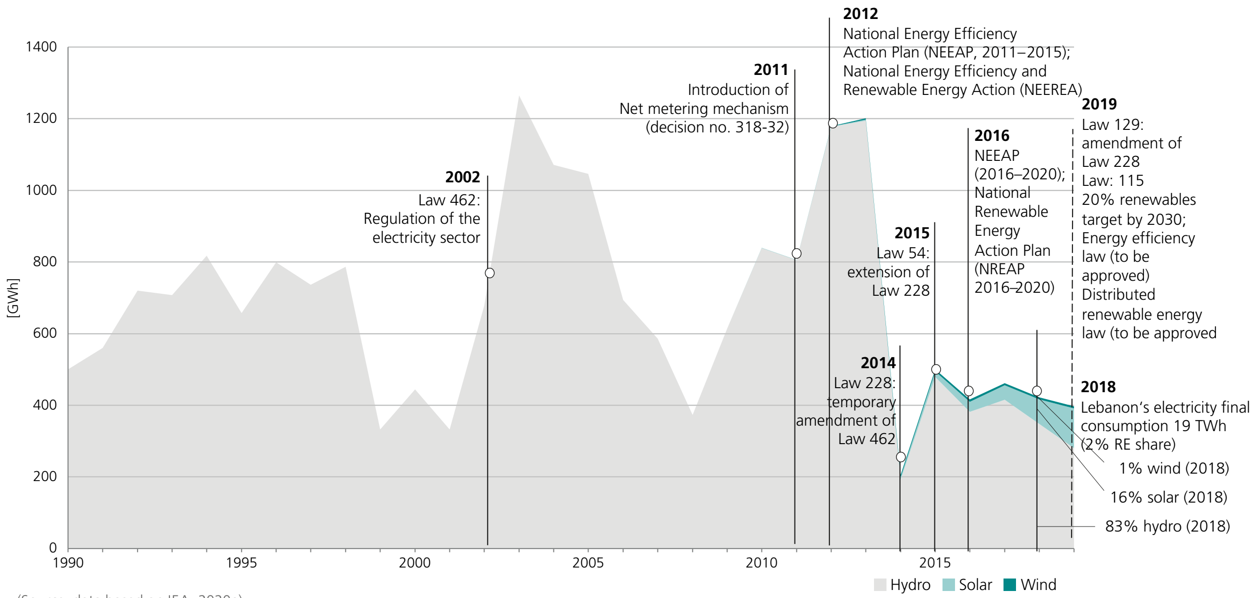
Law 288 (2014) was enacted to temporarily amend Law 462/2002. Under Law 288, exceptional licenses for PPAs indicated by the Council of Ministers (CoM) upon recommendations from the MEW and the Ministry of Finance (MoF) have been allowed. This law was expected to be applied between 2014 and 2016 until the ERA was appointed. The government did not grant any permits under Law 288. Thus, the amendment of Law 288 (under Law 54/2015) was extended for the period until April 2018. Under Law 54/2015, one PPA for three wind farms in Akkar has been signed, combining a capacity of 226 MW (EBRD, 2019). Hence, Law 54/2015 was seen as a milestone for the private sector to access the Lebanese electricity generation market.

Law 129/2019, which is another extension of Law 288, was granted until April 2022 to allow IPPs to generate electricity and feed it to the grid via PPAs.

Based on the aforementioned, Decree 16878 Article 4 indicates that natural and legal persons are eligible to produce electricity for their consumption and to cover their personal needs only. In 2011, based on decision No. 318-32 of EDL's board of directors, net metering was introduced to inject excess power produced on consumer's premise into EDL's grid credited against their monthly bills. Due to the novelty of the net metering scheme, EDL has established a Net Metering Committee for supervising the implementation process. On one hand, the net metering scheme supported the expansion of solar energy. On the other hand, as EDL lacks of meters, net amounts must be calculated manually, which strongly limits the effectiveness of this policy scheme (Berjawi et al., 2017; Moore and Collins, 2020).

In 2019, the parliament approved Law 115 and Lebanon's Nationally Determined Contributions (NDCs), which commits Lebanon to reduce significantly its GHG emissions and to achieve 30% target of renewables from the total energy mix by 2030. Given that distributed renewables could play a major role in achieving the government's target and would

Figure 4-6
Development of Renewable Electricity Generation by Source (in GWh) and Introduction of Energy Policy Measures, Lebanon 1990–2019



(Source: data based on IEA, 2020a)

significantly benefit the economy and the environment, several draft laws are currently being proposed and discussed. This will help establish the legal basis for future renewable investments in Lebanon. Those are mainly the Distributed Renewable Energy Law and the Energy Efficiency law that will be explained in chapter 4 of this report.

Fig. 4-6 depicts all energy policy measures by year and the development of renewables-based electricity generation.

Essentially, despite the described efforts that have been made so far to provide a legal and regulatory framework for REs, the integration of renewables in Lebanon still faces major barriers. On the policy level, the Lebanese RE resources have not been prioritised over fossil resources. Several conflicting laws still prevent the private sector's investment and its participation in the electricity sector. Other laws that have entered into force have never been implemented, which has impeded the achievement of targets that were intended to be met by 2020. The successful large-scale deployment of the RE technologies will, therefore, require major adjustments in Lebanon's legal framework. Thus, Lebanon remains in a very early stage of the energy transition, classified as the first phase in the MENA phase model.

Financial Incentives for Renewables

In November 2011, as an implementation process to the government's NEEAP 2011–2015, the NEEREA loans supported the growth of renewables. The loans start from USD 2,000 up to USD 20 million, making the NEEREA the only green financing mechanism in the Arab region with high loan ceilings. The NEEREA supports the private sector, such as individuals, small and medium enterprises (SMEs), or corporate bodies, in applying for subsidised loans for any RE and energy efficiency projects. The interest rates for these loans were 1.075% and reached as low as 0.3% with a 14-year repayment period and two-years grace period for new projects (MEW and LCEC, 2016). All private sector entities are allowed to apply for these subsidised loans. These green loans are given by any of the commercial banks, as it is easier to reach end-users. However, funds for loans do not get allocated until the LCEC studies, reviews, and gives its technical approval for the final execution of the projects.

Investments in the solar PV sector have increased from USD 2.29 million in 2010 to USD 125.83 million in 2019. The NEEREA benefited from a EUR 15 million grant between 2011–2014 for SMEs. Part of the grant was dedicated to financing the technical unit in the LCEC and to launching nationwide marketing campaigns to boost the use of the NEEREA green loans in the country (MEW and LCEC, 2016). Despite the economic situation, the investments reached USD 20.72 million in 2019 for NEEREA and non-NEEREA investments (Jabbour, 2021).

Under the NEEAP 2016–2020, the financing mechanism of the NEEREA has been extended until 2020. However, a new credit line signed between the European Investment Bank (EIB), the Agence Française de Développement (AFD), and the Lebanese government was introduced under the name of LEEREFF. In total, EIB and AFD provided an EUR 80 million global loan to support small-scale investment in energy efficiency and RE projects specifically for SMEs. Unfortunately, after 2019, there were no loans distributed due to the economic crisis.

The LEEREFF is part of the BDL subsidised scheme for companies that are willing to invest in renewables, green building, and energy efficiency in businesses and industries. The LEEREFF is related to the NEEREA but with stricter performance criteria and transparent calculation methods against targets. The LEEREFF loans are supported through the EIB and AFD, with interest rate subsidies provided by the BDL, and free technical assistance provided by an international team of engineers, financed by the EU. There are two types of loans under the LEEREFF that aim to meet varying companies' needs. On one hand, there is the standard loan which is designed for clients with projects that need simple energy efficiency and RE measures. The amount of this type of loan varies between EUR 40,000 and EUR 250,000 for projects such as thermal insulation and windows, HVAC (heating, ventilation and air conditioning) systems, monitoring and control systems, SWH and others. On the other hand, there is the type of non-standard loans offered by the LEEREFF. This loan is for general energy efficiency investments in industrial and commercial companies as well as for investments in commercial green buildings. Its amount varies between EUR 250,000 and EUR 15 million. The LEEREFF covers up to 80% of the investment costs, while the rest of the amount can be supplemented by companies' own funds, a NEEREA loan, or a conventional bank loan (LEEREFF, 2019).

In 2018, the European Bank for Reconstruction and Development (EBRD) and Bank Audi signed the first GEFF to provide funding for Lebanon's sustainable development. The EBRD and Bank Audi joined forces to provide a total of USD 200 million for financing green energy projects. The EBRD provided USD 90 million, which was complemented by USD 10 million from the Taiwan International Cooperation and Development Fund (ICDF). The programme provides loans for investments in RE, improving energy efficiency (LED lighting, HVAC –, roof-tiling, stone cladding, landscaping), efficient resource usage, including water, materials and other resources, waste management, emission reduction, and green buildings, which contribute to lowering pollution levels and improving the environment. These loans are eligible for individuals investing in residential projects, private businesses, service providers, and vendors providing supply or sale equipment. The EBRD will provide technical assistance for the GEFF. The GEFF will receive support from specialised experts in several fields, who will offer Bank Audi and its clients assistance and guidance throughout the whole green project lifecycle. Moreover, interest rates are set based on the credit assessment of the borrower. The structure of repayment is flexible, as it depends on the project's expected cash flow with the borrower's choice of monthly or quarterly payments. The grace period is contingent upon the credit approval and the project's expected cash flows. However, according to interviewed experts and due to the current economic situation, projects under the GEFF and other green financing schemes and projects have been halted.

Fossil Fuel Sector

Lebanon's energy system depends largely on imported heavy fuel oil and diesel oil to fuel conventional power plants and private diesel generators. The imported fuels account for 93% of the total electricity produced (Salameh and Chedid, 2020). Fossil fuel imports reached around 8.6 Mtoe of energy products in 2018, most of which were oil products as well as small quantities of coal, electricity, and solid biofuels. The imported oil products are grouped as follows: liquefied petroleum gas (LPG), gas/diesel oils, fuel oil, jet kerosene, and asphalt (UNSD and ESCWA, 2019). Additionally, coal and petroleum coke are imported by the cement industries (ibid.). Electricity was imported from Syria, before ceasing in 2012. Egypt also exported electricity to Lebanon (ibid.).

Fig. 4-7 presents data on the historical net energy imports of Lebanon from 1990–2018 by year. Plotted on the graph, the energy imports peaked by 2017 with 9.2 Mtoe, dropping slightly in 2018.

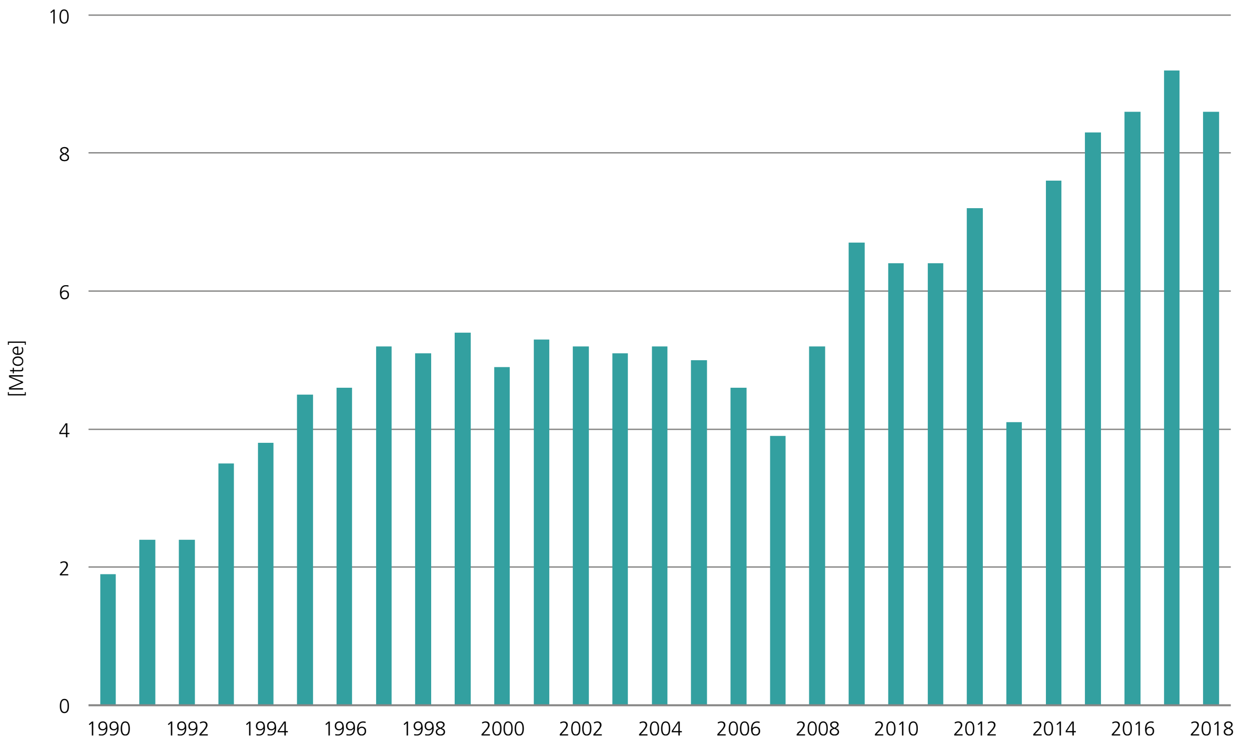
The Lebanese energy strategy is, however, at a turning point, as the country cannot continue relying on imported fossil fuels that are bought via the dwindling foreign currencies reserves at the BDL (UNSD and ESCWA, 2019). As a result, Lebanon is exploring the potential for fossil energy extraction in the country. The United States Geological Survey (USGS) estimates that the Levant Basin Province accommodates 1.7 billion barrels of recoverable oil and 122 trillion cubic feet of recoverable natural gas (ibid.). Comparing the projected future demand of Lebanon with the local reserves, Lebanon has the potential to become a natural gas supplier. Yet, extracting oil and gas and assessing the commerciality of the discovery is a long-lasting and time-consuming process (LOGI, 2021). According to experts in the oil and gas field, Lebanon did not yet benefit from its existing wealth due to the absence of a national strategy and visionary policy-making. Additionally, an oil cartel has been controlling different aspects of the downstream sector.

Still, in January 2018, two Exploration and Production Agreements (EPAs) for block 4 and 9 were signed between the Republic of Lebanon and the consortium composed of Total E&P Liban s.a.l. (Right Holder Operator), Eni Lebanon B.V., and Novatek Lebanon (Right Holders Non-Operators) (LPA, 2018). Completed drilling activities in block 4 during 2020 have shown the availability of traces of gas, confirming the presence of a hydrocarbon system, but no reservoirs were encountered in the formation that was the main target of this exploration well (Total, 2020).

Due to an ongoing conflict between Lebanon and Israel on the maritime borders' delimitation, no drilling activities were conducted in southern block 9, a potentially gas-rich area. Continuous disputes led to indirect negotiations mediated by the US and launched in October 2020 in the UN base in southern Lebanon. Seeing as an equitable resolution to this dispute according to maritime laws was not possible, security concerns will remain the top priority of licensed International Oil Companies (IOCs) from both sides. This, in turn, will delay drilling activities and wealth exploitation.

On the one hand, the regional dispute over the legal rights around the potential oil and gas reserves is expected to last for a long period of time, which could encourage the Lebanese to switch more quickly to renewables (Ayoub et al., 2013). On the other hand, the private diesel generators' industry is powerful and is deemed to already influence lawmaking in the fraught political landscape, impeding any

Figure 4-7
Net Energy Imports (in Mtoe), Lebanon 1990–2018



(Source: based on data from IEA, 2020a)

mobilisation against the current supply policy (Moore and Collins, 2020). According to the MEW's 2019 plan, several natural gas power plants were to be constructed in Salaata, Zahrani, Jiyeh, Zouk, Hraycheh, and Deir Ammar (MEW, 2019). However, the implementation of these power plants was halted due the economic and monetary crisis.

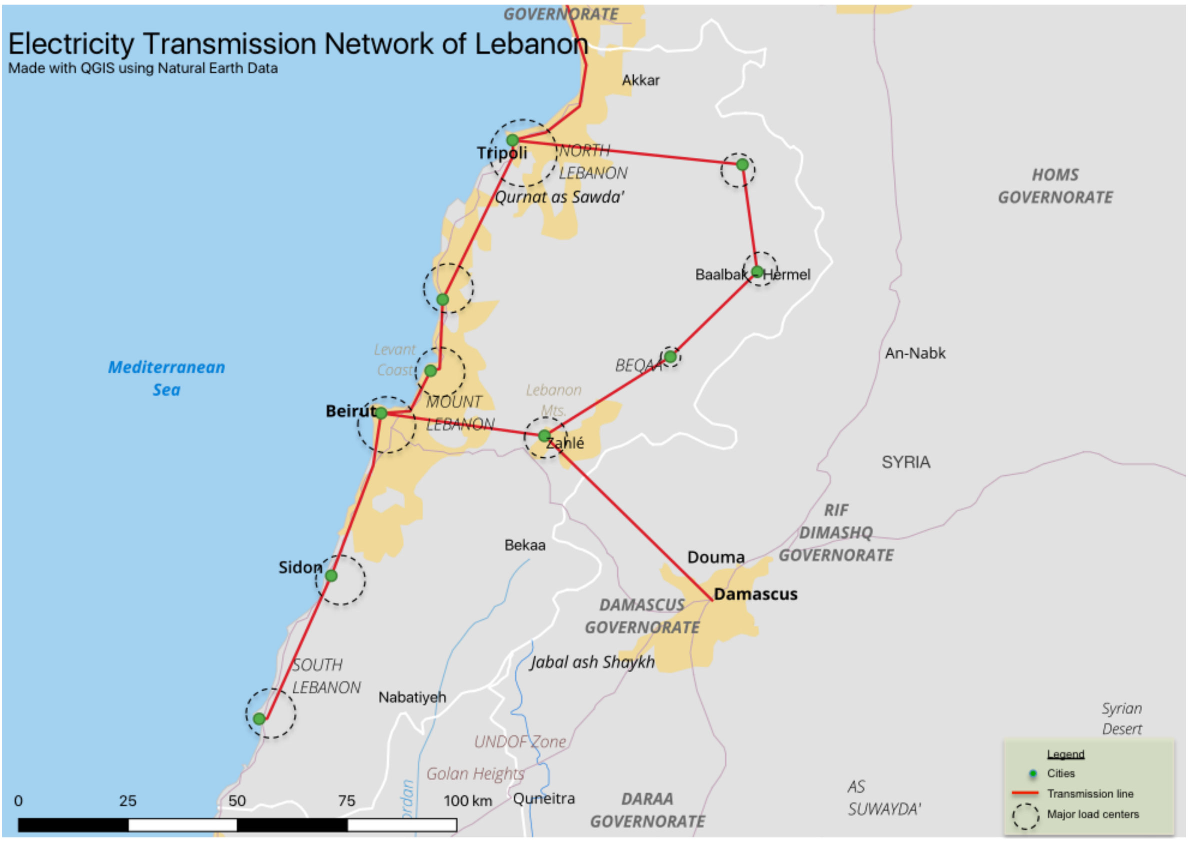
Furthermore, supporting the development of an oil and gas sector can create technological lock-in effects and ultimately lead to stranded investments, for at the global level more and more countries are striving towards a carbon-neutral economy. For example, while Lebanon aims for the EU to become a potential customer for its projected gas, the EU Green Deal and associated climate policies can counteract these ambitions. Even IOCs are taking the rising risks into consideration as they try to deal with the energy transition worldwide. This could also become an incentive for Lebanon to transition its energy system towards renewables instead of producing natural gas. Yet, until a clear strategy is developed, the Lebanese pathway is certainly classified, in terms of the transition phases, to be in the very early stage of the first phase.

Infrastructure

Lebanon's transmission network is part of the eight-country regional interconnection project (EIJLLPST), which was initiated in 1988 and comprises of the following countries: Egypt, Iraq, Jordan, Libya, Lebanon, Palestine, Syria, and Turkey. Although the interconnection project aims to upgrade the electricity systems to regional standards and to trade electricity, these goals, however, exist mainly on paper (ESMAP, 2013). As under-supply, unsynchronised interconnections, unsolid regulatory frameworks, and the bundled electricity market structure in most of the countries persist, trade has been only modest among the EIJLLPST countries. For instance, when Syria exports energy to Lebanon, some parts of the Lebanese grid network have to be disconnected from the main grid to prevent major disruptions. While Egypt and Jordan currently have an over-supply in electricity, political engagement is still missing. Thus, it is not possible to activate a trading framework through Syria to sell the over-supply to Lebanon (The World Bank, 2020b).

The state-utility EDL is responsible for the transmission network in Lebanon. The network consists of country-wide 66 kV lines, some 150 kV transmission lines in the central coastal area around Beirut, and newer 220 kV network lines that stretch from the north to the south coast and the northern zone of the Beqaa valley. EDL plans to switch from the 150 kV voltage network to 66 kV and 220 kV as standard sub-transmission/transmission voltages by retrofitting and expanding the grid (The World Bank, 2020b). This will help to accommodate a broader technology mix into the grid and facilitate the regional grid integration. Under the law 181/2011, several projects were approved by the parliament as Lebanon's electricity emergency plan. The first of these projects were new heavy-fuel-oil-fired plants in Zouk and Jiyeh that started operation in 2017 and led to an increase in electricity supply. Other projects are related to substations and their transmission lines, which provide a stable electricity supply. These projects include six 220 kV substations, in

Figure 4-8
Electricity Transmission Network of Lebanon Showing Major Load Centres



(Source: own creation data based on Energydata (2017))

addition to the 66 kV substation in Bednayel, and three mobile substations at Aassoun (Donnieh), Jezzine and Batroun (MEW, 2019).

There is a significant number of losses on a technical and a non-technical level that weigh largely on the financial performance of the electricity sector. This results in load shedding throughout the year. The transmission and distribution losses of EDL's grid reach approximately 40%, of which 15% are technical losses (Ahmad et al., 2020; Fardoun et al., 2012; UNDP et al., 2019). The causes for this loss include several problems on the voltage network, such as overloading in load centres or high voltage transformers operating at high load factors that result in low standby capacity and impact the network (Fardoun et al., 2012). Next to the EDL are two concessions, which are Electricité de Zahlé (EDZ) and Electricité de Jbeil (EDJ) that are currently operational in the country. A recent School of Oriental and African Studies (SOAS) publication[5] has shown that these concessions have gained wide public support within their respective territories due to their track record of good service provision and their ability to navigate the local political context. They also have much better technical and management performance, such as lower losses and higher collection rates, which ultimately translates into better commercial performance. Yet, these have been used over the years to extract rents and continuously weaken central institutions, such as EDL (Ahmad et al., 2020).

Fig. 4-8 shows Lebanon's electricity transmission network, including major load centres.

To improve the situation, the MEW has specified in its transmission master plan three main objectives (MEW, 2019):

1. reducing technical and non-technical losses from 34% in 2019 to 11% in 2021,
2. improving the generation system, including efficiency and extension of fuel mix, and
3. increasing the tariff to cover the costs on generation, transmission, and distribution level.

Six new power plants of around 3,000 MW capacity between 2019 and 2026 should be added, while the temporary power plants will be gradually removed (MEW, 2019). The plan foresees the expansion and stabilisation of the grid until 2030. From a current installed capacity of 2,449 MW in 2019, a total installed capacity of 5,695 MW by 2030 is envisaged, while the projected peak demand will amount to 4,672 MW, fully covering the electricity demand over 24 hours (ibid.). Yet, due to the economic crisis, the 2019 plan and the goals announced seem to be challenged with the lack of the needed investments and Lebanon's default on its debt. Therefore, a review and assessment of the planned power

5 More information: https://www.aub.edu.lb/ifi/Documents/publications/policy_briefs/2020-20/20210511_models_for_tackling_lebanon_electricity_crisis_policy_brief.pdf

plants is envisaged. Earlier in 2020, the World Bank commissioned Electricité de France (EDF) to prepare a Least Cost Generation Plan for Lebanon following the IRENA report and the Bank's 2020 emergency action plan for Lebanon's electricity sector. This study is the first of its kind in 30 years, as it evaluates how Lebanon can optimise its energy production, minimise costs, and reduce pollution from fossil fuels, based on technical, economic, and environmental grounds, without political interferences (Kulluna Irada et al., 2020).

In essence, the current electricity network is unstable, and insufficient generation capacities reflect the outdated condition of the energy assets. There is a need to rebuild and extend the network. Advanced systems, such as smart grids, are still a long way off for Lebanon, but in order for Lebanon to reach its 2030 goals, it needs to, at least, start exploring non-trivial short-term solutions and strengthening institutional involvement. Furthermore, extending international transactions of electricity or gas will require stronger cooperation and coordination at the political level (The World Bank, 2020b). The current state of the grid infrastructure shows that it is reasonable to classify Lebanon as being at an early stage of the first phase of the applied MENA energy transition model.

Institutions and Governance

The Lebanese energy policy is directed by the MEW, which formulates policy targets for the electricity, fuel, and water sectors (Moore and Collins, 2020), while the CoM holds the overall responsibility. The MEW has three main directories: 1) the General Directorate of Electricity and Water Resources, 2) the General Directorate of Investment, and 3) the General Directorate of Oil. The power sector can be considered a monopoly of generation, production, and distribution governed by the EDL, under the MEW's supervision (ESMAP, 2013). The EDL was founded by Decree 16878 (10 July 1964) and is a public organisation responsible for the generation, transmission, and distribution of electricity in Lebanon (EBRD, 2019). The MoF is also a major participant in controlling EDL by assessing the feasibility of projects. Over 90% of the Lebanese electricity sector is monopolised by EDL (Fardoun et al., 2012). Other sector actors are the public Litani River Authority that owns hydroelectric power plants, the private Ibrahim and Al Bared companies that run hydropower plants and sell their electricity to EDL, and the distribution concessions in Zahlé and Jbeil, and previously in Aley, Kadisha and Bhamdoun (ibid.).

In 2010, and through the approved electricity policy paper, the government allowed the cooperation of public-private partnerships via distribution service providers (DSPs), generation rental agreements, and net metering (IRENA, 2020c).

As a joint project between the MEW and the UNDP, the LCEC was established in 2011. The LCEC, in affiliation with the MEW, is the national energy agency, and it offers technical expertise for topics related to energy efficiency and RE. The LCEC was funded by the UNDP until 2013. Currently, it is mainly funded by a variety of national and international institutions and partners, namely the EU, the Italian Ministry for the Environment, Land, and Sea, and the BDL. The LCEC works on a 5-year plan basis that is continuously updated to support the government in implementing its national plans regarding the energy policy. For instance, the LCEC is responsible for the NEEAP's and the NREAP's implementation and monitors the targets set in the plans (UNSD & ESCWA, 2019).

The Lebanese electricity sector represents a clear case of a mismanaged publicly owned monopoly that has existed since the civil war. It was also rapidly reconstructed in the years afterwards (EBRD, 2019). Its performance is hampered by challenges in its governance structures, which is based on a sectarian governance system. Stemming from this, the Lebanese electricity sector is characterised by power under-supply with chronic shortages, bankrupt power utilities, power thefts, high network losses, low power tariffs due to high subsidisation and high emissions (ibid.). Although Law 462/2002 mandates an unbundled electricity market and the establishment of an independent national ERA, the law exists only on paper, leaving the Lebanese electricity sector highly dysfunctional.

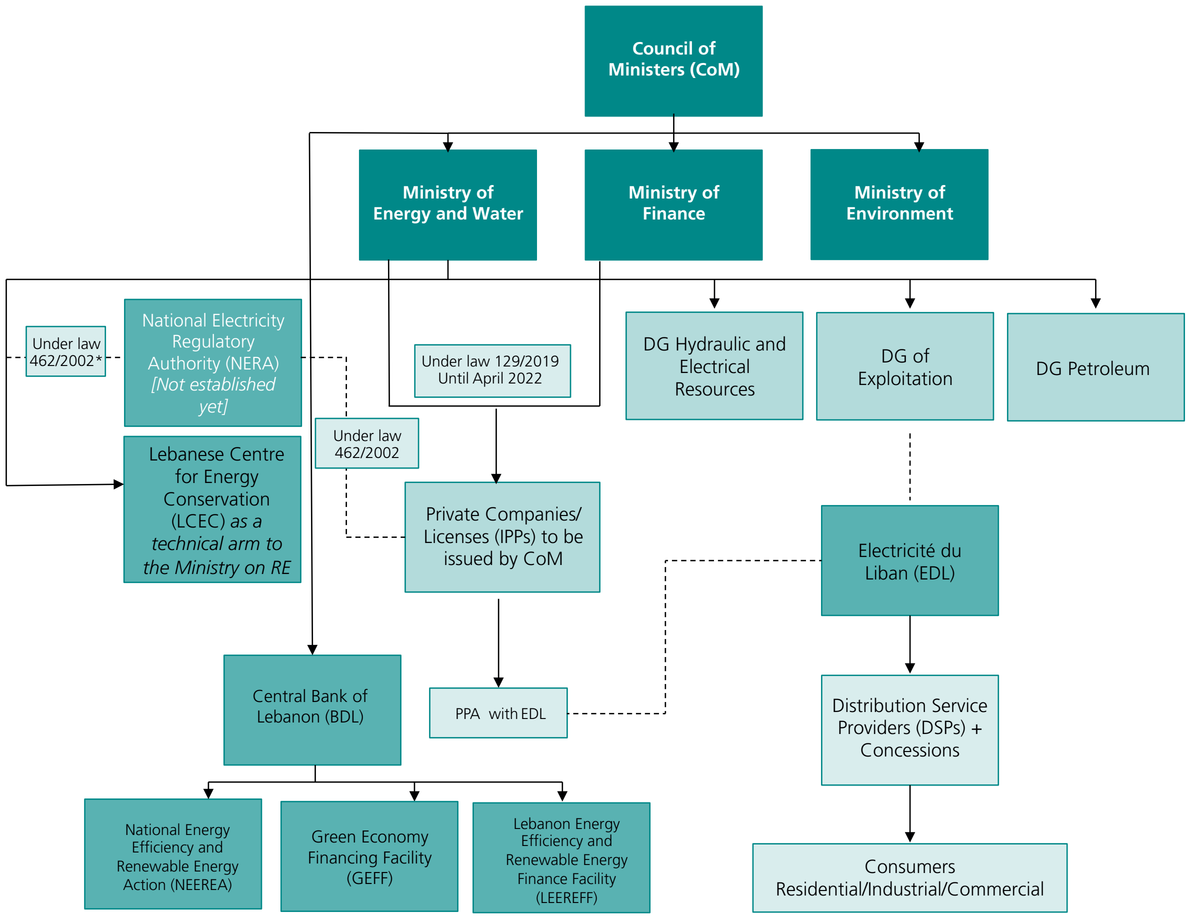
This situation underpins Lebanon's classification as being in the first transition phase, but in a very early stage, according to the applied MENA phase model.

Energy Market and Economy

The electricity sector in Lebanon presents a constant financial burden to Lebanon's public finances. More than 40% of the public debt can be attributed to the electricity sector's spending and subsidies since 1992 (Eslami et al., 2021)using Lebanon's capital, Beirut, as a case study, a methodology is proposed to assess the potential for solar photovoltaics (PV. The electricity tariff has not changed since 1994 when the average oil price reached USD 23 per barrel (Moore and Collins, 2020). Nowadays, tariffs are much lower than the actual cost of produced electricity. For instance, the average cost of one kWh electrical production has been around 0.23 US-cents in 2014, while the average bill per kWh within the inclining block tariff was 0.085 US-cents (Berjawi et al., 2017; Dagher and Ruble, 2011; Moore and Collins, 2020). The more hours EDL supplies electricity, the more financial losses it makes. In 2018, EDL made operating losses amounting to USD 1.8 billion (MEW, 2019). The sector subsidies between 2008 and 2017 have aggregated to almost half of Lebanon's overall external debt (Moore and Collins, 2020). Although the sector is heavily subsidised, the supply cannot cover the demand. As a consequence, constant power outages occur that are estimated to reach 1.5 GW.

Although diesel generators have become important in maintaining basic require-ments for households and businesses, they are more expensive (around 0.30 US-cents per kWh), which increases the energy costs for households (Ahmad et al., 2020; Eslami et al., 2021). Also, due to the current economic meltdown, the generators' monthly prices keep increasing. In 2017, around 66% of the households de-

Figure 4-9
Electricity Market Structure with Relevant Authorities and Companies



** Law 462/2002 is the umbrella law for regulating Lebanon's electricity sector and when implemented, law 129/2019 will not exist anymore, as the latter is an amendment of law 462/2002.*

(Source: own creation data)

pended on diesel generators to back-up power supply. This costing approximately 10% of their income (Farhat, 2019). The diesel generator business is backed by poli-ticians, and no competition is in place that can influence the pricing. Additionally, new buildings already get a space for generators, leaving residents no choice but to support illegal generators (Moore and Collins, 2020).

Furthermore, bad investments into new open cycle gas turbines (OCGT) instead of combined cycle gas turbines (CCGT) in power plants have increased the financial losses. Uncollected bills and electricity thefts from political leaders are tolerated, which adds to the public debt. Illegal connections are also responsible for a financial burden of USD 330 million per year (Moore and Collins, 2020). Moreover, the lack of an internal auditing system increases the institutional financial problem, and the lack of a computerised accounting system impacts the institution's financial accuracy (Fardoun et al., 2012).

All in all, the Lebanese electricity system fails due to deep-rooted political-economic challenges (Ahmad et al., 2020). The economic crisis stems mainly from the mismanagement of the electrical sector. Its weak financial performance can no longer be maintained as the sector adds directly to foreign currency shortages in the BDL and commercial banks (Eslami et al., 2021) using Lebanon's capital, Beirut, as a case study, a methodology is proposed to assess the potential for solar photovoltaics (PV.

According to Ahmed (2020), by phasing out diesel generators, the Lebanese public could save around USD 800 million per year. Even if EDL's tariff would increase twice, the savings could reach around USD 400 million. Taking into consideration that RE systems offer a reliable supply and are economically more viable than the current Lebanese energy system, the government should seize the opportunity and incentivise renewables at all levels (Eslami et al., 2021).

The net-metering scheme, introduced in 2011, encourages citizens to reduce their electricity consumption by using private RE installations. This, in turn, reduces the individual electricity bill. This arrangement enables customers to subtract the produced electricity from the bill and balance out the production surpluses with the consumption surpluses. This scheme, however, has not succeeded due to a lack of meters and qualified staff to install the equipment. Yet, it

Table 4-3
EDL's Deficit from 1992-2020 (based on Audi Bank (2021))

Year	Yearly Deficit (USD million)	EDL Cumulative Deficit (USD million)	Cumulative Deficit incl. Interest Cost (USD million)	EDL Cumulative Deficit incl. Interest (USD bn)	Public Debt (USD bn)	EDL Cumulative Deficit / Total Debt
1992				–	4	0%
1993				–	4	0%
1994	50	50	50	0	7	1%
1995	70	120	123	0	9	1%
1996	90	210	221	0	13	2%
1997	110	320	346	0	16	2%
1998	120	440	488	0	19	3%
1999	140	580	660	1	22	3%
2000	386	966	1,089	1	25	4%
2001	188	1,154	1,347	1	28	5%
2002	202	1,356	1,637	2	31	5%
2003	274	1,630	2,017	2	33	6%
2004	383	2,013	2,532	3	36	7%
2005	646	2,659	3,342	3	39	9%
2006	909	3,568	4,468	4	40	11%
2007	981	4,549	5,740	6	42	14%
2008	1,612	6,161	7,725	8	47	16%
2009	1,499	7,660	9,726	10	51	19%
2010	1,192	8,852	11,550	12	53	22%
2011	1,742	10,594	14,043	14	54	26%
2012	2,261	12,855	17,217	17	58	30%
2013	2,027	14,882	20,363	20	64	32%
2014	2,094	16,976	23,781	24	67	36%
2015	1,135	18,111	26,461	26	70	38%
2016	927	19,038	29,108	29	75	39%
2017	1,328	20,366	32,328	32	80	41%
2018	1,756	22,122	36,185	36	86	42%
2019	1,505	23,627	40,042	40	92	44%
2020	1,000	24,627	43,645	44	94	47%

shows that Lebanon is willing to shift towards renewable-based systems.

Efficiency

Energy efficiency in Lebanon is recognised by the government as a fundamental second strategic pillar of the energy system transformation. The Lebanese government has, therefore, developed the NEEAP 2011–2015 and its follow-up strategy the NEEAP 2016–2020 in order to reach its target of 12% renewables in the energy mix by 2020. The NEEAPs include a number of energy efficiency initiatives that target different sectors of the Lebanese economy (Fakhoury and Al Achkar, 2020; MEW and LCEC, 2012):

- increasing the use of compact fluorescent lamps (CFL),
- increasing the use of energy saving public lighting,
- developing a building code,
- increasing awareness and capacity building,
- supporting energy audits for energy service companies (ESCOs), and
- promoting energy efficient equipment.

The NEEAP 2016–2020 amends the first NEEAP and focuses on primary energy saving measures. For example, it dictates a yearly energy saving of 302.9 GWh, defines energy efficiency savings by sector, completes a cost analysis for each measure, and formulates quantifiable, time-bounded targets (MEW and LCEC, 2016). Yet, while Lebanon supports the energy efficiency measures, the realisation of these measures remains often limited and is impeded due to manifold reasons that can be traced back to institutional weakness. This assessment supports the classification of Lebanon as being at the first stage according to the applied energy transition model.

Greenhouse Gas Emissions

GHG emissions are caused in Lebanon mainly by the electricity generation (60%) and transportation sector (32%), followed by the industry and residential sector (each 4%). While in 2005 the CO_2 emissions amounted to 14 Mt CO_2, in 2018 they reached 25 Mt CO_2, representing an increase of 78% (Fig. 4-10). 15.3 Mt CO_2 emissions from the electricity and heat generating sector were caused by the combustion of oil (Fig. 4-11). In general, the emissions intensity has shown an overall declining trend in CO_2 emission per unit of gross domestic product (GDP), while the CO_2 emission per capita increased (Table 4-4).

Almost 40% of the overall electricity GHG emissions in 2018 can be attributed to diesel generators (Ahmad et al., 2020). As these generators are mostly located in dense residential areas, environmental impacts endanger the public health (Ahmad et al., 2020). Another major polluter is EDL's thermal power fleet. Power facilities are usually located close to very densely populated areas (ibid.). Although the Lebanese government has shown concerns regarding the increased GHG emissions, there is no active attempt to decrease the use of generators (Kinab and Elkhoury, 2012).

Lebanon's emissions are increasing and a concrete roadmap to reduce emissions seems to be lacking. This supports Lebanon's classification as being in a very early stage of the first energy transition phase in the applied phase model.

Society

To assess the elements supporting the process of the energy transition, including social awareness, social acceptability, and active support, the local team at the AUB administered an online survey specifically tailored for this study to reveal the level of awareness of the Lebanese society on issues related to RE, energy efficiency, and climate change. The survey followed a random sampling approach with around 100 local citizens of several backgrounds across the country, 70% of whom were below the age of 35, and 71% of all participants were females. The geographical distribution varied across regions; 46% of the respondents were located in Beirut area, followed by Baabda (13%), Tripoli (7.6%), and the remaining distributed across the other districts. As for the interviewees' educational background, 47% completed their master's degree, while 32% obtained at least a university bachelor's degree.

Surprisingly, 96% of the respondents confirmed that they have acquired prior knowledge on RE from different sources, mainly articles and newspapers (31%). In addition, 28% have acquired their knowledge from school and 22% from university. The citizens' know-how was focused mainly on solar energy, wind power, and hydropower. Despite this high knowledge in RE technologies, 97% of participants felt the need for more awareness campaigns. However, only 30% of the respondents currently use RE, 88% of which are using solar PV for either producing electricity or as SWHs at their workplace or at home. Nonetheless, all participants confirmed that they would be definitely using solar PV if prices were cheaper.

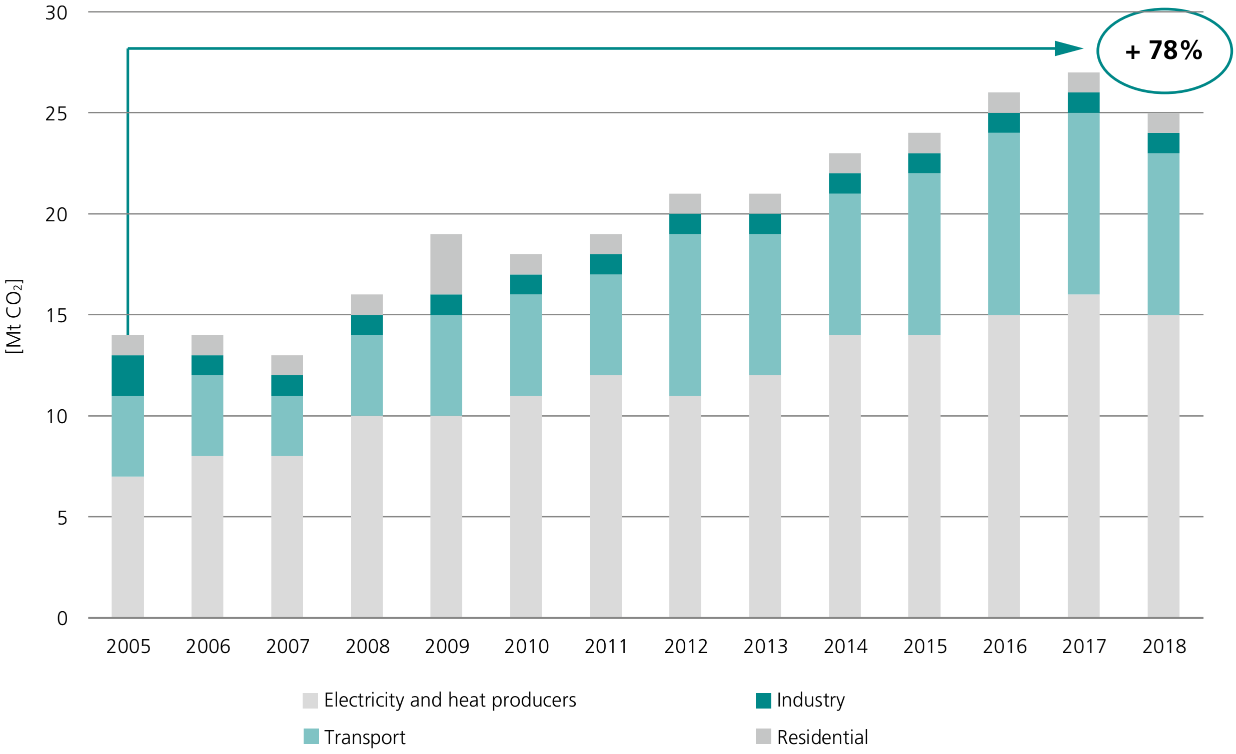
When asked about future considerations, 96% confirmed that they would be willing to install RE technologies if they were accessible. 50.6% believed that during this transition period, diesel generators will remain part of the citizens' daily lives or would be partially phased out. Around 69% also believed that this transition will affect the communities at all levels and the country at large. At the energy efficiency level, only 21% of the respondents were aware of energy efficiency standards; 36% indicated their use of electrical appliances in their homes, which conform with efficiency standards. The survey also shows that 72% of the respondents were willing to pay initial capital costs from their own pockets to install RE technologies. However, the main barriers to implementing those measures included the high upfront costs (79%), maintenance costs (72%), space requirements (45%), and technical problems (39%), as shown in Fig. 4-12. Moreover, the main challenges of implementing community-level energy efficiency standards were capital expenditure costs (89%), technology availability (59%), lack of needed know-how (74%), and lack of needed expertise (55.5%) (Fig. 4-13).

The survey also tackled issues directly linked to climate change; 71% of the respondents stated that they felt climate change's impact on the country, and most of them confirmed the importance of climate change topics for their daily life.

On a more national level, when asked about the situation in Lebanon regarding the RE sector, all participants noticed that the current energy situation is poor. Moreover, only 7% were aware of the announced RE targets for 2020 and 2030, and only 3% were aware of the laws and action plans towards the issues of climate change and RE. Most importantly, 81% believed that the current unstable political situation heavily impacts decisions towards RE transition. In addition, 58% did not yet believe that CSOs are aware of RE technologies or that they are well-prepared to participate in the transition.

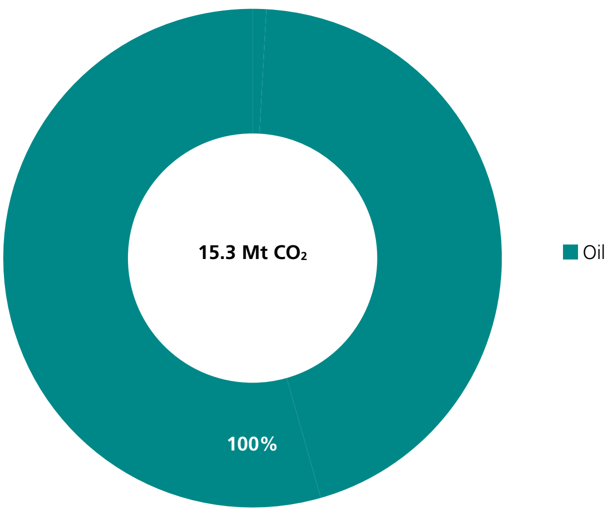
In comparison to previous studies which concluded that the general population in Lebanon and also parts of the elite are not well informed about the benefits of RE technologies (UNDP-CEDRO, 2015), the results of this survey paint a more positive picture. Yet, a lack of data and information still seem to impede the development of renewables. One reason for the absence of information could be that many projects are being realised in a narrow circle of stakeholders; thus, renewables do not receive much public attention (Ayoub et al., 2013) even though awareness raising campaigns and capacity building measures are part of the NEEAP. As a consequence, chances to influence people's mentality and behaviour regarding environmental and energy topics have been limited (Elmustapha et al., 2018). Even the number of installed SHW and solar home systems is small. Yet, according to El Mustapha (2018), demonstration projects that were piloted, have the potential to increase awareness and trust

Figure 4-10
CO_2 Emissions by Sector (in Mt CO_2), Lebanon 2005–2018



(Source: based on data from IEA, 2020)

Figure 4-11
CO_2 Emissions from Electricity and Heat Generation by Energy Source (in Mt CO_2), Lebanon 2018



(Source: based on data from IEA, 2020a)

Figure 4-12
Barriers to Switching to Renewable Energy (Survey Results)

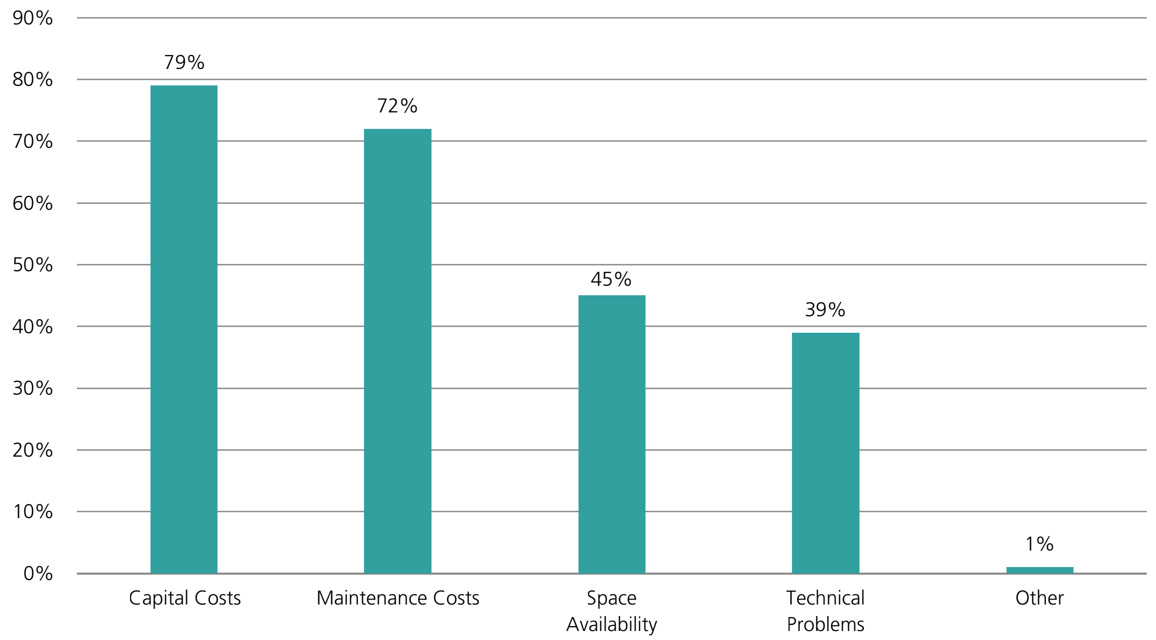
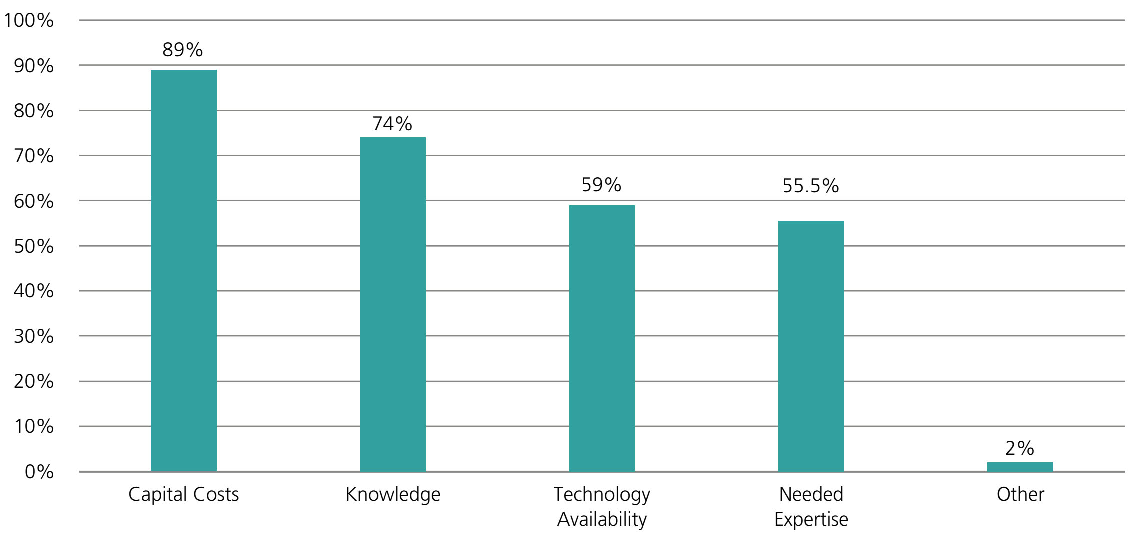


Figure 4-13
Barriers to Implementing Energy Efficiency Standards (Survey Results)



among the public. In addition, they can help to spread the positive word-of-mouth (ibid.).

This situation is aggravated by the fact that many policy-makers, bankers, and other decision-makers also lack skills and knowledge on renewables (Elmustapha et al., 2018; UNSD and ESCWA, 2019). In addition, many skilled engineers prefer working abroad, where the salaries are higher (Elguindy et al., 2020). Still, there is growing evidence that the educational sector in Lebanon is providing better offers in RE education. Some RE system graduate programmes are already running or are being planned in Lebanese universities (UNDP-CEDRO, 2015). In 1998, the education reforms added environmental studies among others in their curricula, offering more programmes in this field.

When renewables were introduced to the Lebanese market in the beginning of the last decade, the private sector started to create certain demand for knowledge and expertise. As a result, some associations and industry networks were established: the Lebanese Association for Energy Saving and for Environment (ALMEE), Lebanese Solar Energy Society (LSES), and Lebanon Green Building Council (LGBC). Through industrial ventures, some testing facilities have been established, which engage the Industrial Research Institute (IRI) and develop the National Standards through the Lebanese Standards Institute (LIBNOR) (UNDP-CEDRO, 2015). Moreover, they aim at offering specialised training programmes in the field of renewables.

To summarise, the Lebanese society is, in general, not yet fully informed about environmental issues and REs, which is a paramount requirement for succeeding in the energy transition. Although climate change is felt to have an impact by a large number of the citizens, only few currently use RE sources. More campaigns and demonstration projects could support the wider uptake of REs, energy efficiency, and conservation measures. Moreover, the survey results indicate that a large number of the participants are willing to actively use RE technologies in the future when they are accessible, but this is mainly hindered by high initial capital costs. Another factor for the uptake of renewables is the availability of qualified staff. The introduction of pertinent training programmes for decision-makers and employees could, therefore, support the larger uptake of renewables. Hence, Lebanon's classification as being at the early stage of the first phase, according to the MENA phase model, is also validated for the society dimension.

Summary of the Landscape and System Level Developments

Energy and electricity supply security are Lebanon's main concerns. Thus, the country's interest in adopting REs has increased, for it is an approach to reduce import dependency and increase electricity production. Environmental concerns are probably only a secondary motivation for switching to renewables. Alongside REs, Lebanon is also exploring the options of exploiting natural gas deposits off the Lebanese coast. Natural gas imports or Floating Storage and Regasification Units (FSRUs) are also being explored. These developments could hinder a transition towards a renewable-based energy system. In addition, on the landscape level, the economic crisis and the COVID-19 pandemic have severely impacted the energy and power sector, limiting the capacity and willingness to invest in the RE sector.

On the system level, the Lebanese electricity sector is affected by three key challenges that affect the energy transition, at least in the short-term but potentially also in the long term:

1. weak governance
2. underinvestment in the supply
3. lack of financial stability (The World Bank, 2020b).

EDL holds a monopoly on the Lebanese electricity sector. Its performance is crucially hampered by challenges in its governance structures. Seeing as it operates based on a sectarian governance system, adequate competences for monitoring the utility's performance are absent. Limited investments in new generation capacities have caused an increasing supply shortfall during the last years. Lebanon tries to meet the demand by using power barges and illegal private diesel generators. Compared to all other MENA countries, Lebanon has the largest gap between electricity cost and end-user tariffs, which induces the sector's financial deficit. The lack of financial viability stems particularly from the low, unchanged, subsidised electricity tariffs, the high network losses, and the problems to collect the bills.

Next to the weak utility performance, regulatory challenges impact the energy transition at the system level. Although Law 462/2002 governs the electricity sector, it fails to unbundle the sector. Without political consensus and the actual establishment of the ERA, the successful reform of the sector is difficult to achieve.

In summary, several factors can be identified at the system level that currently challenge Lebanon's progress in the energy transition: the tense regional and geopolitical situation resulting in serious energy security issues, the current COVID-19 pandemic, and the institutional set-up hamper Lebanon's ability to move forward with the energy transition. Nevertheless, with the introduction of the NEEAP, the NREAP, and the latest IRENA 2030 outlook, which all create a systematic plan for the RE uptake, Lebanon has demonstrated the political will to increase the use of RE. This represents a milestone to diversify the energy system. Accordingly, Lebanon can be classified as being at the early stage of the first phase in the energy transition phase model. The following table (Table 4-4) summarises important energy transition indicators in Lebanon and compares them across several years.

4.1.2 Assessment of Trends and Developments at the Niche Level

Developments at the niche level during each phase are crucial for reaching the subsequent stages of the energy transition (see Table 3-1). Lebanon has already made some progress in some fields. However, it displays very limited progress in the majority of the following relevant dimensions: supply, demand, infrastructure, markets/economy, and society.

■ Renewable Energy

While small-scale solar PV projects reached a capacity of up to 78.65 MW in 2019 (MEW, 2019), the development of utility-sized renewable plants is still in its starting phase. Thus far, only a number of pilot projects were initiated over the past decade. The most advanced attempt has been the first EoI for wind power, which was launched in 2012 by the MEW, after the development of the Wind Atlas of Lebanon by the UNDP through the CEDRO project in 2011 (UNDP-CEDRO, 2011). The tender process and negotiations phase lasted from 2014 till 2017. As a result, three companies were awarded the licenses to develop three wind farms in Akkar, northern Lebanon, with a total potential capacity of 226 MW (MEW, 2019). These farms will be producing electricity and selling it to EDL at 10.45 cents/kWh for the first three years and for 9.6 cents/kWh for the remaining 17 years, according to the PPA signed with the MEW and MoF on behalf of the CoM under law 54/2015. Despite receiving financial approvals from several international financing institutions, the project has not yet progressed and has been halted due to the economic downturn and Lebanon's default on its debt in March 2020.

Table 4-4
Current Trends and Goals of the Energy Transition

Category	Indicator	2005	2010	2015	2018	2020	2030	2050
Carbon Emissions (Compared to 1990)	CO_2 emissions per unit of GDP	–38%	–47%	–41%	N/A	N/A	–20% (NDC)	–
	CO_2 emissions per capita	+55%	+85%	+90%	+85%	N/A		–
RE	Installed and planned capacity (MW)	N/A	282	298	321	N/A		–
	Share in final energy use	3%	2.7%	1.4%	1.2% (2017)	N/A		–
	Share in electricity mix (existing and planned)	9%	5%	3%	2%	N/A		–
Efficiency	Total primary energy supply (TPES) (compared to 1990)	+159.5%	+229.2%	+326.2%	+339.5%	N/A	–	–
	Energy intensity of primary energy (compared to 1990)	+10.4%	–3.3%	+6.8%	N/A	N/A	–	–
	Total energy supply (TES) per capita (compared to 1990)	+57.1%	+85.7%	+85.7%	+85.7%	N/A	–	–
	Electricity consumption per capita (compared to 1990)	+360%	+520%	+420%	N/A	N/A	–	–
Buildings	Residential final electricity consumption (compared to 2005)	0%	+34.9%	+52%	+69.5%	N/A	–	–
Transport (Compared to 1990)	Total final energy consumption	+117.1%	+170.9%	+339.6%	+328.7%	N/A	–	–
	CO_2 emissions in transport sector	+100%	+150%	+300%	+300%	N/A	–	–
Industry	Carbon intensity of industry consumption (compared to 1990)	–28.6%	–55%	–48.8%	–52.5%	N/A	–	–
	Value added (share of GDP, compared to 1991)	14.7%	13.8%	15.7%	14.24%	12.7 (2019)	–	–
Supply Security	Natural gas imports (TJ/gross)	N/A	9,867	N/A	N/A	N/A	–	–
	Oil products imports (compared to 1990)	+163.7%	+226.6%	+342.9%	+362.1%	N/A	–	–
	Electricity imports (compared to 2005)	N/A	+174.4%	–41%	–97.4%	N/A	–	–
	Electricity access by population proportion	99.6%	99.8%	100%	100%	N/A	–	–
Investment	Decarbonisation investments (USD million)	N/A	1.59	35.13	N/A	N/A	–	–
Socio-economy	Population (2019)				6,855,713	–	–	
	Population growth	2.7%	2.8%	4.2%	0.5%	N/A	N/A	–
	Urbanisation rate	88.6%	87.3%	88.1%	88.4% (2017)	N/A	–	–
	GDP growth	2.6%	7.9%	0.2%	–1.9%	–6.7% (2019)	–	–
	Jobs in low-carbon industries	N/A	N/A	N/A	N/A	22,000 (2019)	–	–
Water	Level of water stress (compared to 2005)	0%	+35.5%	+47.1%	+58.7%	N/A	–	–

(Source: based on data from BP (2020); FAO (2020); IEA (2020a); IRENA (2020a); Statista (2020); The World Bank (2020a))

At the solar PV level, in 2017, the MEW launched EoIs to install 12 solar PV farms in four main regions (North and Akkar, South, Bekka, and Mount Lebanon) with capacities ranging between 12 to 15 MW. Two hundred and sixty five companies have shown interest in the project, and after the evaluation phase in 2019, only 28 companies qualified to the final phase. The lowest bid showed a very competitive price at 5.7 cents/kWh in the Bekaa region. However, due to the economic crisis, the process was interrupted (MEW, 2019). Moreover, the LCEC and the MEW launched an EoI in 2018 for the installment of three 100 MW PV farms with 70 MWh of storage. This was considered a milestone towards the development of the RE sector, but this project has also stopped at this phase.

At the governance level, a sufficient regulatory framework for RE is still missing. Currently, however, a draft law for distributed RE generation is being prepared to provide a basis for establishing projects that promote net metering in all its forms, trading through direct PPAs and/or RE equipment leasing. All what was previously mentioned would be effective immediately once ratified by the parliament and announced in the official newspaper. Similarly, the draft of the energy efficiency law aims at promoting behavioural changes and the usage of more efficient appliances and equipment through a combination of economic policies and incentives.

Transportation Sector

According to the IEA's statistics, Lebanon's 2018 oil consumption in the transport sector constituted more than 84% of total oil consumptions (IEA, 2021). The Minis-try of Interior and Municipalities estimates a total of 1.58 million registered vehi-cles in Lebanon in 2012 with a population of 4,425,000. Forty percent of Lebanon's population is concentrated in the GBA, which is characterised by a high rate of con-gestion for the majority of the day (Haddad et al., 2015). Up to now, Lebanon has been neglecting the role of its transport sector in reaching its commitments of re-ducing GHG emissions. Accordingly, there has not been any mentionable niche de-velopment in terms of sector coupling and electrification of the transport sector. There are two main mitigation options for the transportation sector of the GBA, which are to deploy an efficient mass transit system and to renew the passenger car fleet with fuel-efficient and hybrid electric vehicles. According to a study con-ducted by the Lebanese American University (Haddad et al., 2018), the most feasi-ble mitigation options in Lebanon between 2020 and 2040 consist of 3 measures: (1) increasing the share of fuel-efficient conventional vehicles (FEVs), (2) increasing the share of hybrid electric vehicles (HEVs), and (3) increasing the share of mass transport (Mansour and Haddad, 2017). The study calls for increasing the share of FEVs to 35% of all vehicles in 2040, in addition to the introduction of HEVs to the market. The study concludes that if all options were functioning optimally, this will lead to a 63% reduction in GHG emissions achieved by 2040, compared to the baseline year of 2010.

Grid Network

According to interviewed experts, Lebanon's energy system is still in the expansion phase. Before the crises in Egypt and Syria (2011), there was a plan to increase the transformation capacity by adding a transformer in Ksara substation 400/220 kV (300 MW). The plan also included building a second 400 kV line in Syria to connect the second unused line in Lebanon on this voltage level (currently only one line exists), hence increasing the interconnection capabilities. Unfortunately, this plan is still pending due to the conflicts in the region. The system stability is handled by EDL, through the Lebanese Electricity National Control Centre (LENCC), using high-quality ICT tools. Unfortunately, the LENCC was destroyed during the Beirut blast on 4 August 2020.

4.1.3 Necessary Steps for Achieving the Next Phase

Fossil fuels are the predominant source of energy in Lebanon. REs with a total installed capacity of less than 350 MW still play a very minor role in the energy system. Deep-rooted political economy challenges have heavily weighted on the energy and electricity demand and supply over the past years (UNDP-CEDRO, 2011). Electricity reform efforts do exist mainly on paper without being implemented. Based on the applied MENA phase model, the Lebanese energy system transformation can be classified as being in a very early stage of the first phase. Although some aspects of the first transition phase have started to develop, the RE share is negligible, and any further development of renewables is currently hampered by the economic crisis and the current COVID-19 pandemic.

The Lebanese electricity sector faces three main challenges: an unreliable power supply, a distorted subsidy system, and a weak financial stability at utility level. Despite the economic crisis in Lebanon, the primary energy demand has increased. It is steadily being accelerated due to the high influx of Syrian refugees, among other factors. The expansion of generation capacity has not taken place at the same pace as the energy peak demand, leading to unreliable electricity supply with daily power cuts. As a consequence, investments in diesel generators have increased, making the Lebanese electricity sector even more dependent on fossil fuel imports. EDL's financial performance has been further declining steadily due to theft, high technical losses, and the widening gap between costs and tariffs. To improve the situation and introduce opportunities for investments in REs, the government needs to develop a clear action plan to reform the tariff structure in a way that protects the poor (The World Bank, 2020b).

A successful transition to a more open and competitive power market that supports the renewable take-off will further depend on a robust institutional and regulatory framework. Despite the existing visions, plans, and Law 462/2002, the structural challenges persist because these mechanisms have not taken into account the Lebanese reality. According to interviewed experts, market regulation efforts are mostly driven by the international community and lack the support of local politicians to move forward. The institutional architecture, shaped around a monopolistic and mostly publicly controlled power market, does not only impede the participation of the private sector but is the reason as well for the mismanagement of the entire sector's performance. Robust regulations need to be implemented to improve the quality and degree of the private sector's participation. A first step should be the actual establishment of the independent ERA. Furthermore, roles and responsibilities of the institutions need to be defined. However, wider structural reforms are also needed to put Lebanon on a more integrated and sustainable path. This entails concrete actions and political commitment. For example, a long-term vision for the energy sector with a clear roadmap that includes quantified sector targets is needed. In this regards, Lebanon should update the electricity plan from 2019 and commit to leapfrogging into a green energy transition (Kulluna Irada et al., 2020).

A transition towards a more resilient energy system further requires the diversification of the energy supply and energy demand management. RE presents a chance for Lebanon to address the aforementioned challenges. With the launch of the IRENA 2030 outlook, the Lebanese government has expressed its interest and motivation to officially increase the share of renewables in the country's energy mix to 30% by 2030. A significant volume of RE could reduce the import dependence and the carbon footprint of the power production at the same time. Harnessing domestic RE will reduce Lebanon's vulnerability to international oil prices and ease its burden on the public budget. Decentralised power generation should be considered as an option to increase the reliability of supply and the participation of the private sector. Community ownership (of neighbourhoods and households) should also be investigated as an option (Eslami et al., 2021)using Lebanon's capital, Beirut, as a case study, a methodology is proposed to assess the potential for solar photovoltaics (PV. To this end, adequate business models should be developed for small-scale and decentralised RE systems, such as peer-to-peer contracts. Therefore, it is advisable to put into practice the developed Distributed Renewable Energy Generation and Energy Efficiency laws.

Expanding and rehabilitating the transmission capacity is equally important for coping with the growing demand and the variability of supply from renewable sources in the future. Several factors, including technical and non-technical losses, are responsible for the unreliable transmission network. The higher the RE share in the electricity mix, the more unstable the transmission network will become. According to interviewed grid experts, the distribution network has been developed intensely in the past years, filling a major gap between the load demand and the network capacity. However, the grid is still not redundant for the injection of additional large quantities of power and requires more development to attain stability. While the major load centres are located in the coastal area, Lebanon's high RE potential is given in the interior of the country in the North and in the Bekaa region. Connecting the eastern interior regions with the coast through a capable high voltage network is a precondition to develop renewables on a large-scale, which can transport the electricity to the demand centres. Therefore, high investments in the transmission capacity are needed in the future to guarantee the electricity dispatch, while securing grid stability. This should include smart grid developments to prepare for a larger amount of variable renewable electricity and increasing shares of e-mobility.

The citizens' awareness is needed in order to sustainably switch to a democratic and just participation in the energy transition. Promoting RE technology through awareness campaigns is vital for the development of renewables. Social media and information centres are critical to sensibilise the people on environmental topics. Social and cultural factors are important for the successful deployment of technologies in the local context and should also be considered in the Lebanese context (Eslami et al., 2021)using Lebanon's capital, Beirut, as a case study, a methodology is proposed to assess the potential for solar photovoltaics (PV. Education and training for installers, engineers, bankers, developers and decision-makers are equally important. It is crucial to offer adequate training programmes for employees in the renewables' sector in order to improve the project's implementation, the risk assessment, and the familiarity with RE projects.

The uptake of RE can make an important contribution in increasing the energy security in Lebanon, the most pressing concern in Lebanon's electricity sector. In order to move towards a renewables-based energy system, the country needs to become active in many different areas. It must implement regulations, focus on the market development, invest in grid retrofitting, and adopt energy efficiency measures, all of which are currently lacking.

4.2 OUTLOOK FOR THE NEXT PHASES OF THE TRANSITION PROCESS

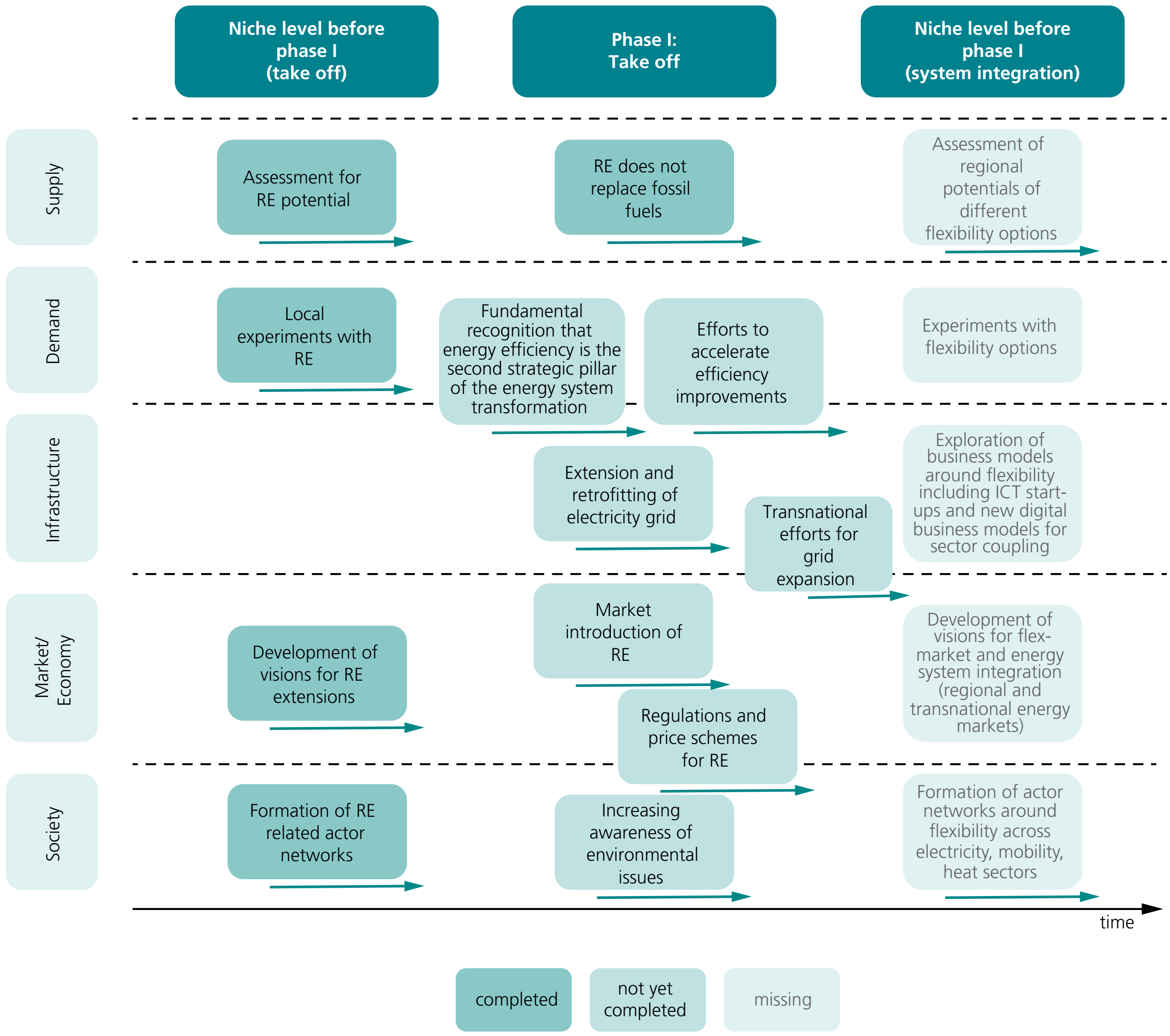
The analysis carried out provides ample evidence that Lebanon has developed certain frameworks and mechanisms to support the uptake of REs, but it fails to fully implement them. Despite the encouraging and ambitious strategic national targets, the energy transition has displayed decreased momentum due to multiple reasons that are deeply rooted in political-economic drawbacks. Lebanon's power and energy sector struggles are the result of the fundamental policy inaction that reigns over decades. The barriers to solve the electricity crisis lie mainly in the nature of governance, as all decisions taken by policymakers related to the energy sector seem to be driven by political motives as opposed to national interests. Building a long-term future energy vision requires an understanding of the nature of these structural challenges and their interlinkages. Energy security and stability of electricity are, indeed, Lebanon's major concerns. Adopting RE has the potential to combat these problems. Therefore, both policymakers and citizens need to understand the benefits that renewables can offer. They must recognise how global cost reductions make this technology an interesting alternative to natural gas explorations as well as diesel power generation.

While the need to secure the national energy supply could become a main driver for the greater deployment of renewables, environmental factors are currently not primary motives for Lebanon's energy transition. Still, this could change in the long-term, seeing as Lebanon will be affected by the increasing consequences of climate change. Instead of relying on potential offshore discoveries, the focus should be placed on updated and cost-efficient plans. The global decarbonisation efforts will, in the long-term, also affect Lebanon. Therefore, a timely switch to producing fuels from RE sources has the capability to offer new economic opportunities. Furthermore, the adoption of environmentally sound technologies prevents technological lock-in effects and stranded investments. Although it will be a challenge to overcome political and institutional barriers, the transition to RE could have the following positive effects on the economy and the environment: job creation along the energy value chain, reduced air and environmental pollution, thereby reducing health hazards, and increased energy security levels that are a prerequisite for economic growth (IRENA and ESCWA, 2018).

Several steps are crucial for advancing the transition towards renewables. First, appropriate institutions and structures with clear roles must be created. It is of extreme importance that, in the Lebanese case, the institutions work independently and have the power of autonomous decision-making. In addition, R&D is essential for the creation of local value chains. The measures for the development plans need to be linked to concrete time frames and realistic milestones. Furthermore, the introduction of better participatory tools and channels in the energy transformation process could foster acceptance and contribute to fair power dynamics and energy policies.

Against this backdrop, a long-term and integrative approach that takes into account the entire energy system and builds on the benefits of a transition towards a fully renewables-based energy system is needed. Policymakers must understand that the early adoption of RE systems can result in multiple benefits both in the short term (by increasing the security of supply) and in the long term (as an opportunity for economic development). Fig. 4-14 summarises Lebanon's status in the energy system transition and provides an outlook for future steps to be taken.

Figure 4-14
Overview of Lebanon's Status in the Energy System Transition Model



(Source: data based on IEA, 2020a)

5

CONCLUSIONS AND OUTLOOK

A clear understanding and structured vision are prerequisites for fostering and steering a transition towards a fully renewables-based energy system. The MENA phase model was adapted to the country case of Lebanon in order to provide information to support the energy system's transition towards sustainability. The model, which built on the German context and was complemented by insights into transition governance, was adapted to capture differences between general underlying assumptions, the characteristics of the MENA region, and the specific Lebanese context.

The model, which includes four phases (»Take-off RE«, »System Integration«, »PtF/G«, and »Towards 100% Renewables«), was applied to analyse and determine where Lebanon stands in terms of its energy transition towards renewables. The application of the model also provides a roadmap detailing the steps needed to move forward on this path. The drivers for Lebanon to shift to a sustainable energy system are primarily the need to secure a reliable and affordable electricity supply as well as the need to create economic development opportunities. Situated in an unstable region, Lebanon's energy sector is affected by neighbouring conflicts, especially as Lebanon is largely dependent on imported oil. At the same time, the country has high debts and declining foreign exchange liquidity. Hence, it is imperative for the country to explore alternatives in the form of domestic RE (Kulluna Irada et al., 2020). To this end, the government should develop a long-term strategy for the future of the energy sector that focuses on decarbonisation and supports the growth of RE.

To move forward in this direction, renewables must »take-off« and become an integral part of the Lebanese energy system. This requires the support and implementation of regulations, ranging from tariff adaptations and tax revisions to grid extensions and reinforcement. Increasing the tariffs and reducing electricity subsidies may encourage public and private investments towards RE projects and allow for the spread of renewables through small and medium-scale deployment (Ayat et al., 2021). A sound institutional framework to stimulate diversification, together with greater transparency will increase efficiency. This will simultaneously increase awareness among stakeholders and the population.

While the transition towards REs is still at an early stage in Lebanon, the country would be well advised to invest in a more sustainable energy system that benefits its citizens and the economy as a whole both in the short-term and the long-term. Taking this path is better than continuing to rely on fossil-based energy supply structures. The results of the analysis along the transition phase model towards 100% renewables should stimulate and support the discussion about Lebanon's future energy system by providing an overarching guiding vision for the energy transition and the development of appropriate policy strategies.

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LIST OF ABBREVIATIONS

AFD	Agence Française de Développement
ALMEE	Lebanese Association for Energy Saving and for Environment
AUB	American University of Beirut
BDL	Central Bank of Lebanon (Banque du Liban)
BRSS	Beirut River Solar Snake
CAS	Central Administration for Statistics
CCGT	Combined cycle gas turbine
CCS	Carbon capture and storage
CCU	Carbon capture and use
CEDRO	Country Energy Efficiency and Renewable Energy Demonstration Project for the Recovery of Lebanon
CFL	Compact fluorescent lamp
CoM	Council of Ministers
COP	Conference of the Parties
COVID-19	Coronavirus disease 2019
CSO	Civil Society Organization
CSP	Concentrated solar power
DNI	Direct normal irradiation
DSM	Demand-side management
DSP	Distribution service provider
EBRD	European Bank for Reconstruction and Development
EDF	Electricité de France
EDJ	Electricité de Jbeil
EDL	Electricité du Liban
EDZ	Electricité de Zahlé
EIB	European Investment Bank
EIJLLPST	Eight Country Interconnection Project
EoI	Expression of interest
ERA	Electricity Regulatory Authority
ESCO	Energy service company
EU	European Union
EV	Electrical vehicle
FEV	Fuel-efficient conventional vehicle
FiT	Feed-in tariff
FSRU	Floating Storage and Regasification Unit
GBA	Greater Beirut Area
GDP	Gross domestic product
GEF	Global Environment Facility
GEFF	Green Economy Financing Facility
GHG	Greenhouse gas
GHI	Global horizontal irradiation
GSWH	Global Solar Water Heaters Project
HEV	Hybrid electric vehicle
ICT	Information and communication technologies
IEA	International Energy Agency
IFI	Issam Fares Institute for Public Policy and International Affairs
IOC	International Oil Company
IPP	Independent power producer
IRENA	International Renewable Energy Agency
IRI	Industrial Research Institute
LAS	League of Arab States
LCEC	Lebanese Centre for Energy Conservation
LEEREFF	Lebanon Energy Efficiency and Renewable Energy Finance Facility
LENCC	Lebanese Electricity National Control Centre
LGBC	Lebanon Green Building Council
LIBNOR	Lebanese Standards Institute
LPG	Liquefied petroleum gas
LSES	Lebanese Solar Energy Society
MENA	Middle East and North Africa

MEW	Ministry of Energy and Water of Lebanon
MLP	Multi-level perspective
MoF	Ministry of Finance
NDC	Nationally determined contributions
NEEAP	National Energy Efficiency Action Plan
NEEREA	National Energy Efficiency & Renewable Energy Action
NREAP	National Renewable Energy Action Plan
OCGT	Open cycle gas turbine
PPA	Power purchase agreement
PtF	Power-to-fuel
PtG	Power-to-gas
PtX	Power-to-X
PV	Photovoltaic
R&D	Research and development
RCREEE	Regional Centre for Renewable Energy and Energy Efficiency
RE	Renewable Energy
SDG	Sustainable Development Goals
SME	small and medium enterprise
SWH	Solar Water Heating system
UNDP	United Nations Development Programme
USD	US-Dollar
USGS	United States Geological Survey
VRE	Variable renewable energy
WTE	Waste-to-energy

LIST OF UNITS AND SYMBOLS

%	Percent
CO_2	Carbon dioxide
GW	Gigawatt
GWh	Gigawatt hour
kgoe	Kilogramme of oil equivalent
ktoe	Kilotonne of oil equivalent
kV	Kilo Volt
kW	Kilowatt
kWh	Kilowatt hour
m^2	Square Metre
m^3	Cubic Metre
m/s	Metre per second
Mt	Megatonne
Mtoe	Millions of tonnes of oil equivalent
MVA	Megavolt-ampere
MW	Megawatt
MWh	Megawatt hour
MWp	Megawatt peak
tCO_2e	Tonne of CO_2 equivalent
TWh	Terawatt hour
W/m^2	Watt per square metre

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ABOUT THIS STUDY

This study is conducted as part of a regional project applying the energy transition phase model of the German Wuppertal Institute to different countries in the MENA region. Coordinated by the Jordan-based Regional Climate and Energy Project MENA of the Friedrich-Ebert-Stiftung, the project contributes to a better understanding of where the energy transition processes in the respective countries are at. It also offers key learnings for the whole region based on findings across the analysed countries. This aligns with FES's strategies bringing together government representatives, civil society organisations along with supporting research, while providing policy recommendations to promote and achieve a socially just energy transition and climate justice for all.

The views expressed in this publication are not necessarily those of the Friedrich-Ebert-Stiftung or of the organisations for which the authors work.

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SUSTAINABLE TRANSFORMATION OF LEBANON'S ENERGY SYSTEM

Development of a Phase Model

A clear understanding of socio-technical interdependencies and a structured vision are prerequisites for fostering and steering a transition to a fully renewables-based energy system. To facilitate such understanding, a phase model for the renewable energy (RE) transition in the Middle East and North Africa (MENA) countries has been developed and applied to the country case of Lebanon. It is designed to support the strategy development and governance of the energy transition and to serve as a guide for decision makers.

Lebanon's energy transition towards REs stands at a very early stage of the first transformation phase. Although abundant solar and wind energy potential does exist, the pathway towards a 100% renewables energy seems very challenging for Lebanon, as a consequence of highly unstable political conditions. The most pressing concern for Lebanon's electricity sector is combating the country's fiscal imbalance, while providing secure and reliable electricity supply. At the operational level, Lebanon's grid network requires significant investments to rebuild, retrofit, and expand the overall capacity and energy efficiency improvements.

The need to strengthen the energy system after the political turmoil of the civil war is likely to offer several long-term opportunities, such as developing the economy, reducing environmental pollution, and increasing the energy security. In order to move forward into the first phase, Lebanon needs to improve the framework conditions for REs and implement its visions. It needs to support the market development in a realistic timeframe, where structural reforms represent the highest priority.

The results of the analysis along the transition phase model towards 100% renewables energy are intended to stimulate and support the discussion on Lebanon's future energy system by providing an overarching guiding vision for the energy transition and the development of appropriate policies.

For further information on this topic:
https://lebanon.fes.de
https://mena.fes.de/topics/climate-and-energy

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