Study

Climate Change, Energy and Environment

SUSTAINABLE TRANSFORMATION OF JORDAN'S ENERGY SYSTEM

Development of a Phase Model

Sibel Raquel Ersoy,Julia Terrapon-Pfaff
December 2021

By applying the Middle East and North Africa (MENA) energy transition phase model for the renewables-based energy transition in the MENA countries to Jordan, the study provides a guiding vision to support strategy development and the steering of the energy transition process.

Limited domestic fossil energy resources and the resulting dependence on energy imports are strong drivers for the transition to renewable energy (RE) in Jordan. Domestically generated RE can help to reduce the need for imports and increase energy security.

Given a stable and clear policy and regulatory framework, attractive incentives, and available competitive financing, Jordan is likely to become a regional energy hub with export potential.

FRIEDRICH EBERT STIFTUNG

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Content

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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 CO2 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 Jordan. The current state of development in Jordan is assessed and analysed against the phase 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 was collected for this study by local partners.

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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'.

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. 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 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.

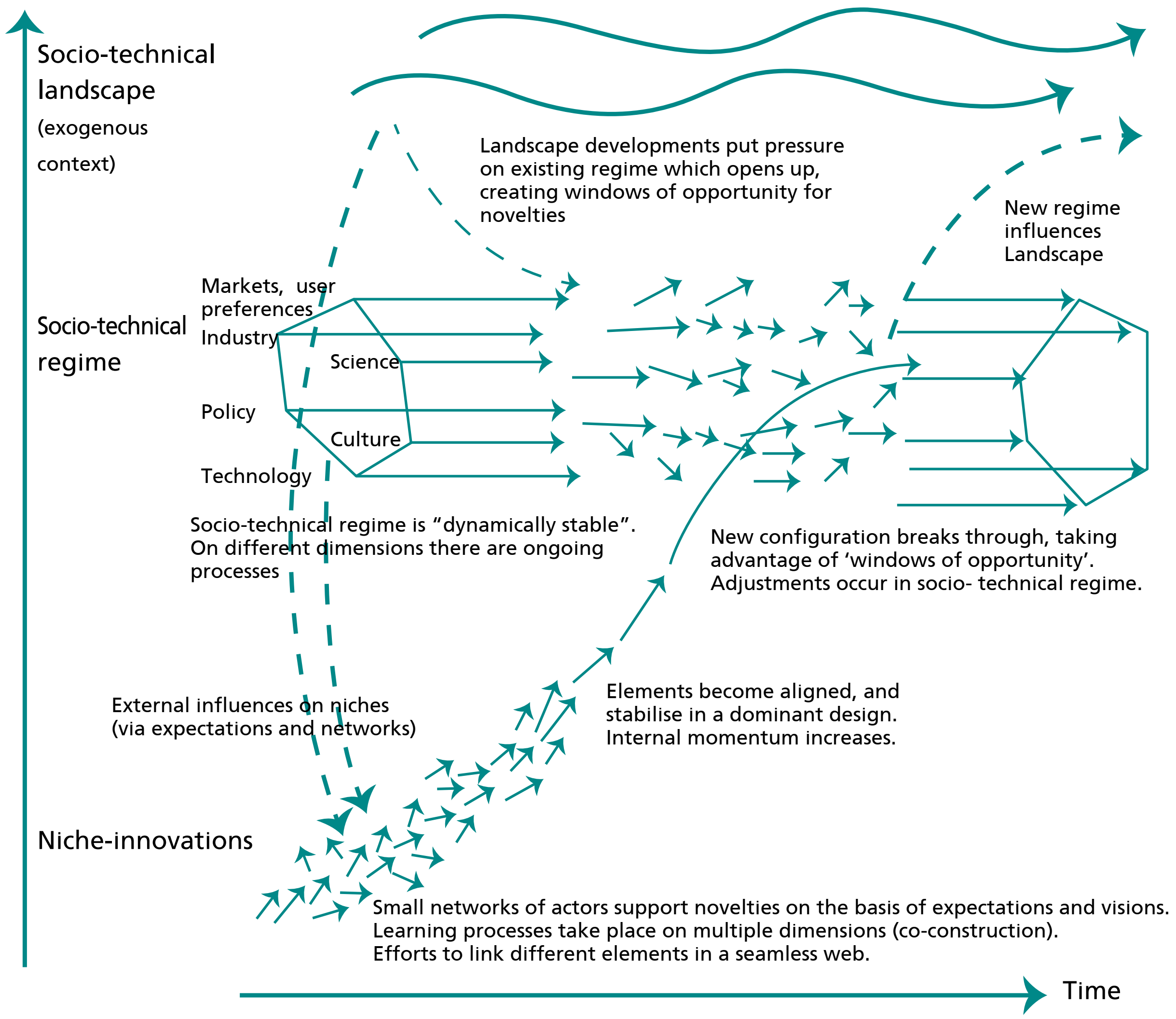
2.2 The Multi-Level Perspective and the Three Stages of Transitions

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

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

research. 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. The multi-level perspective (MLP) is a prominent framework that facilitates the conceptualisation of transition dynamics (Fig. 2-1).

Fig. 2-1
The Multi-Level Perspective



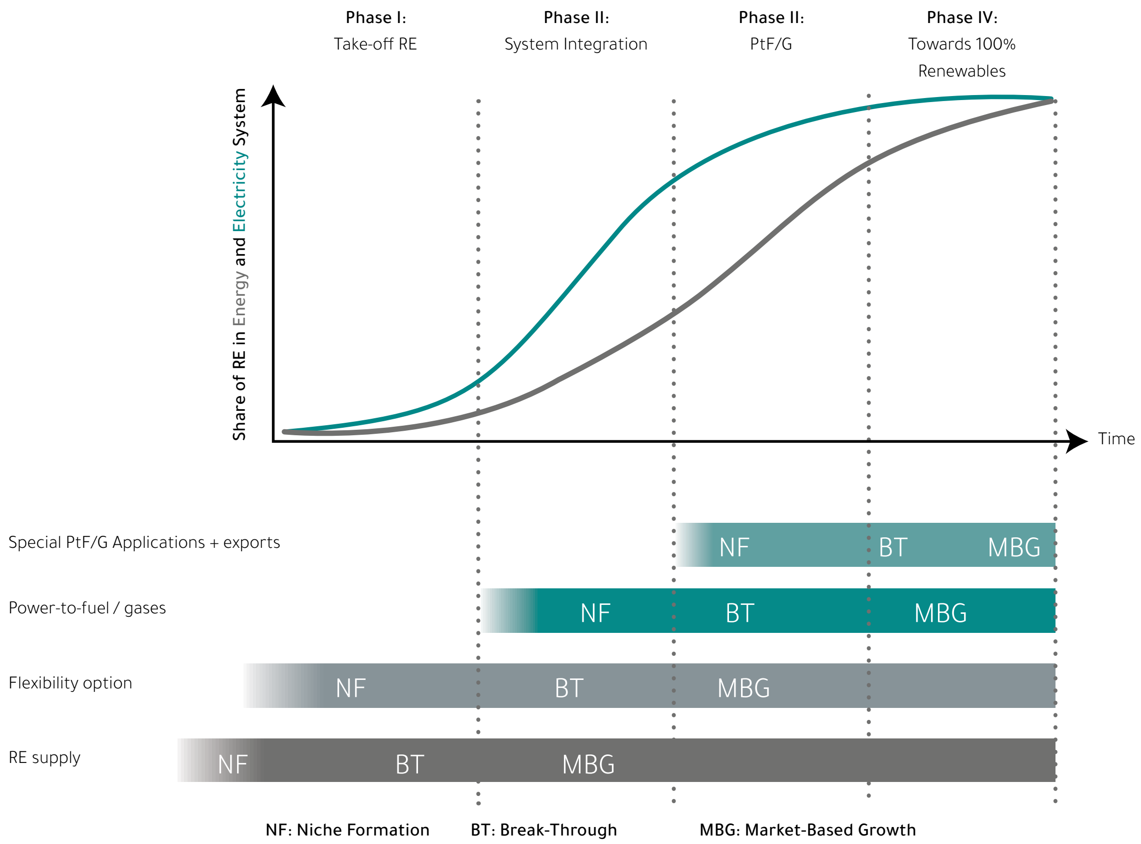
(Source: Geels and Schot, 2007)

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, innovations at the 'niche' level are incremental because they provide the fundamental base for systemic change (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. Within the transition phases, three stages can be distinguished: 'niche formation', 'breakthrough', and 'market-based growth'. In the 'niche formation' stage, a niche develops and matures. In the 'breakthrough' stage, the niche innovation spreads and 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. 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), power-to-fuel/gas 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. Consequently, the addition of the 'niche layer' creates a stronger emphasis on the processes that must occur to achieve the system targets (Fig. 2-2).

Fig. 2-2
Transition Phase Model for the MENA Region



(Source: Holtz et al., 2018)

3

The MENA Phase Model

3.1 Specific Characteristics of the MENA Region

One of the fundamental differences 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. 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.

Another 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.

The MENA countries could benefit considerably from global advances in RE technologies. While the phase model for the German context assumed that RE technologies need time to mature, the phase model for the MENA context can include cost reductions. 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 photovoltaic (PV) and wind power plants, state-owned companies and large-scale projects take centre stage in most countries in the MENA region. 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 were adapted to correspond to the characteristics of the MENA region.

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. While in Germany imports play a considerable role in the later phases, 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

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. 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. 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 demand-side management (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.

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 information and communication technologies (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. 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.

Phase 3 — 'Power-to-Fuel/Gas (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.

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.

Table 3-1 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.

3.4 Transfer of the Phase Model to the Country Case of Jordan

The MENA phase model was exploratively applied to the Jordan case in Holtz et al. (2018) for the year 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 in regard to the energy transition that can also be applied to other MENA countries.

The current study updates the MENA phase model to the country case of Jordan after necessary adaptations were made to it. The results illustrate a structured overview of the continuous developments in Jordan's energy system. Furthermore, they provide insights into the next steps required to transform Jordan's energy system into a renewables-based system.

In order to reflect the specific challenges and opportunities for the energy transition in Jordan, some adaptations to the criteria set of the MENA phase model were made on the landscape level as well. These include factors such as the coronavirus disease 2019 (COVID-19) pandemic and global decarbonisation efforts in light of the Paris agreement. These aspects have either already affected or will affect the international oil and gas prices and the sector development. Furthermore, details about the dominant role of fossil fuels in the energy system and related challenges for the development of the renewable 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 (supply, demand, infrastructure, actor network, and market development) 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 that could hinder the unlocking of the RE potential in the country. The interviewees included relevant stakeholders with experience in the energy sector or related sectors from policy institutions, academia, 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 International Energy Agency (IEA) and the International Renewable Energy Agency (IRENA), or was calculated using available data to identify the current status and future trends. Local research and expert input was provided by Dr. Iyad Muslih.

Table 3-1

Developments During the Transition Phases

			Development before phase I	Phase I: 'Take-Off RE'	Phase II: 'System Integration RE'	Phase III: '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				
	System level	Techno-econom-ic 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

			Development before phase I	Phase I: 'Take-Off RE'	Phase II: 'System Integration RE'	Phase III: 'PtF/G'	Phase IV: 'Towards 100% RE'
				* 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	

			Development before phase I	Phase I: 'Take-Off RE'	Phase II: 'System Integration RE'	Phase III: 'PtF/G'	Phase IV: 'Towards 100% RE'
					* 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		
	System level	Govern-ance 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 (FiTs)), 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 FiTs)	* 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)

			Development before phase I	Phase I: 'Take-Off RE'	Phase II: 'System Integration RE'	Phase III: 'PtF/G'	Phase IV: 'Towards 100% RE'
				* 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		

			Development before phase I	Phase I: 'Take-Off RE'	Phase II: 'System Integration RE'	Phase III: 'PtF/G'	Phase IV: 'Towards 100% RE'
					* 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		
	Niche level	Techno-econom-ic 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)	

			Development before phase I	Phase I: 'Take-Off RE'	Phase II: 'System Integration RE'	Phase III: 'PtF/G'	Phase IV: 'Towards 100% RE'
			* 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)	

			Development before phase I	Phase I: 'Take-Off RE'	Phase II: 'System Integration RE'	Phase III: 'PtF/G'	Phase IV: 'Towards 100% RE'
			* 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 Jordan

4.1 Categorisation of the Energy System Transformation in Jordan According to the Phase Model

Jordan has made considerable progress over the last decade in terms of RE deployment. Consequently, in 2020, 20% of Jordan's electricity was generated from renewables. In view of the increasing share of REs in the energy mix, Jordan is updating its energy strategy, and this updated strategy reportedly includes green hydrogen and derivatives, among other aspects.

Factsheet

- ✓ Paris Agreement ratified
- ✓ Green growth strategy
- ✓ RE targets set
- ✓ Regulatory policies for RE implementation established
- ✓ Energy efficiency strategy existing
- ✓ Power-to-X (PtX) strategy

Jordan has been relying on imports, mainly from neighbouring countries, for a large proportion of its energy supply (Henderson, 2015). However, two major energy crises—the disruption of Iraq's oil supply in 2003 and Egypt's natural gas supply in 2011—have been important drivers for Jordan's energy transition towards a domestic RE supply. Hence, the country's abundance of RE sources could act as an alternative to imports. Still, Jordan continues to import as much as around 90% of its energy. In 2018, a significant amount of 10% of public funds was spent on securing electricity supply as a prerequisite for economic growth (Abu-Rumman et al., 2020). In addition, the ongoing conflicts in neighbouring countries have led to huge population displacement, with many refugees migrating to Jordan. These factors, combined with the growth of the

Jordanian population and an increase in industrial activities, present Jordan with major energy supply challenges. The COVID-19 pandemic has also been posing difficulties to Jordan's economy, making the use of domestic energy resources even more crucial (IRENA, 2021). Jordan, which is considered the most stable country in the region, has the potential "to become a regional energy and technology hub" (Abu-Rumman et al., 2020, p. 8). In order to reach that stage, the country must prepare and execute the necessary next steps for a full-fledged energy transition in the years to come. The uptake of RE has been facilitated through the successful implementation of targeted programmes, as well as financial incentives provided by the Jordanian government. Since 2021, Jordan has been at a point where it needs to focus on system integration and grid stabilisation.

Against this background, this report will assess Jordan's development and analyse its current status in terms of energy transition based on the proposed phase model.

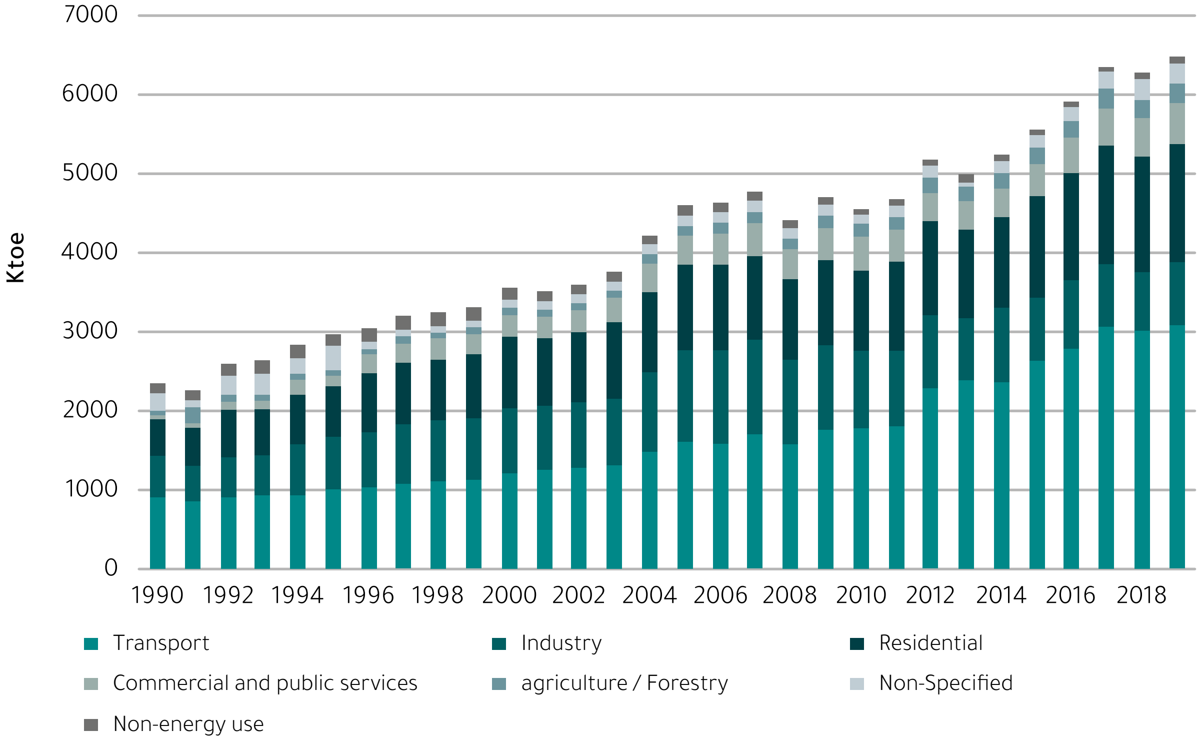
4.1.1 Assessment of the Current State and Trends at the Landscape and System Levels

This section discusses the current state and trends of Jordan's energy system in terms of supply, demand, RE, the fossil fuel sector, infrastructure, actor network, and market development.

Energy Supply and Demand

The energy demand is largely driven by industrial development, urbanisation, and demographic change. In particular, the arrival of a considerable number of refugees from Syria and Iraq has increased Jordan's energy needs and put pressure on public finances (Henderson, 2015). In 2019, Jordan's total final energy consumption amounted to 6,465 ktoe (IEA, 2020a). Broken down by sector, transport dominated the energy consumption (47%), followed by households (23%), industry (12%), the commercial and public services sector (8%), agriculture 4%, and others (5%) (Fig. 41) (IEA, 2020a).

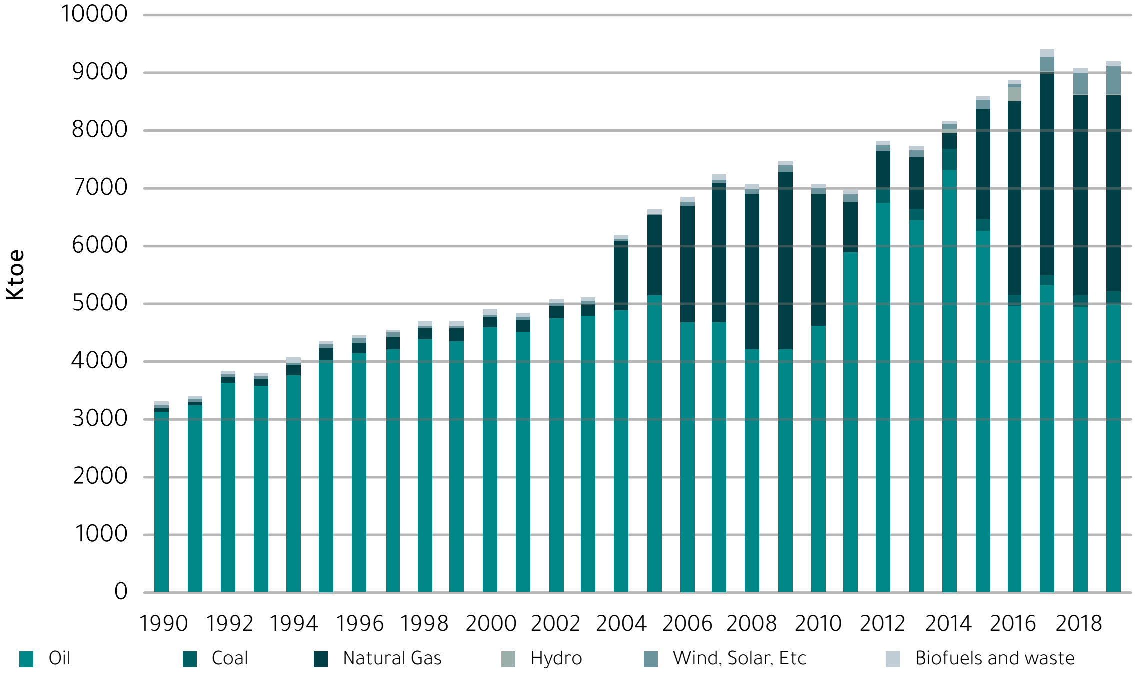
Fig. 4-1
Total Final Energy Consumption (in ktoe), Jordan 1990–2019



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

Also in 2019, the energy mix was dominated by fossil fuels; oil accounted for 54%, natural gas for 37%, and coal for 2%, while REs had a total share of 6% (Fig. 4-2) (IEA, 2020a).

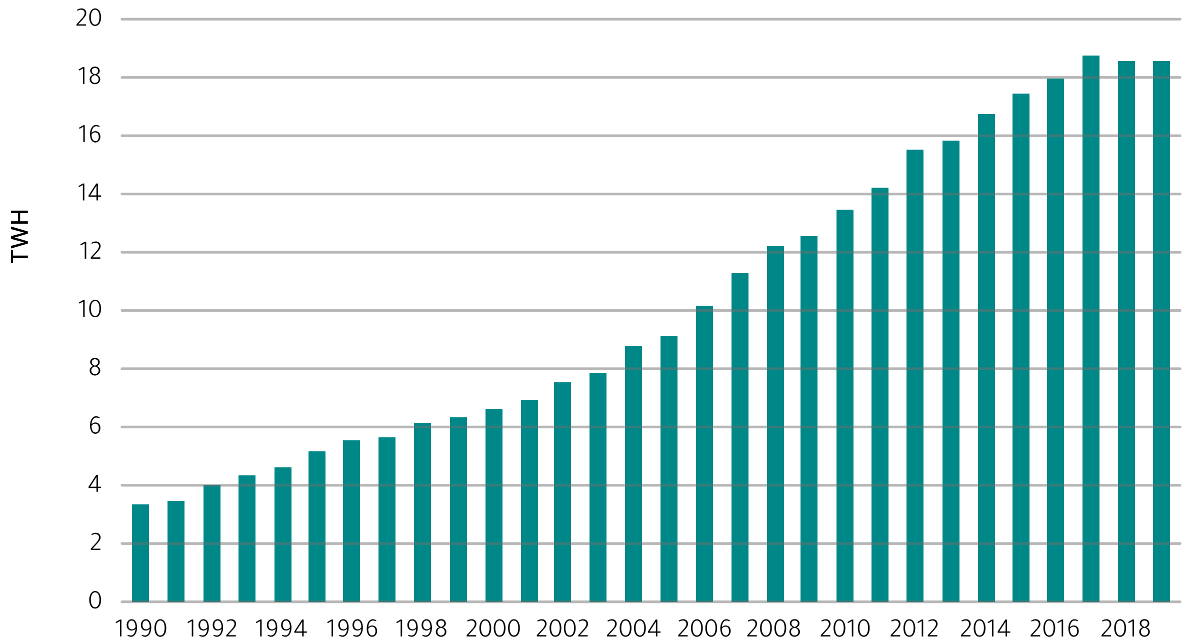
Fig. 4-2
Total Energy Supply (in ktoe), Jordan 1990–2019



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

Jordan's average growth in energy consumption between 1990 and 2019 was around 3.7%. Currently, 39% of primary energy is used for electricity generation, while the remaining 61% is used for the transport, heating, and industrial sectors (Kiwan and Al-Gharibeh, 2020). According to the National Electric Power Company (NEPCO, 2020), Jordan had a total available capacity of 5,424 MW in 2020. This indicates a growth in capacity of 3% compared to 2019. While capacity from conventional power plants reduced by 242 MW due to a few units going out of service, the available capacity from renewables increased by 411 MW. Also in 2020, the peak load for the interconnected system amounted to 3,670 MW, which represents an increase of 7.4% compared to the previous year. Around 19.1 TWh of electrical energy was purchased in 2020, and 18.8 TWh was sold (NEPCO, 2020). Also, NEPCO received around 66.6 GWh from wheeling projects, demonstrating an increase from 2019 of almost 90% (ibid.). Fig. 4-3 shows Jordan's overall electricity consumption profile from 1990 to 2019, using data from IEA (2020a).

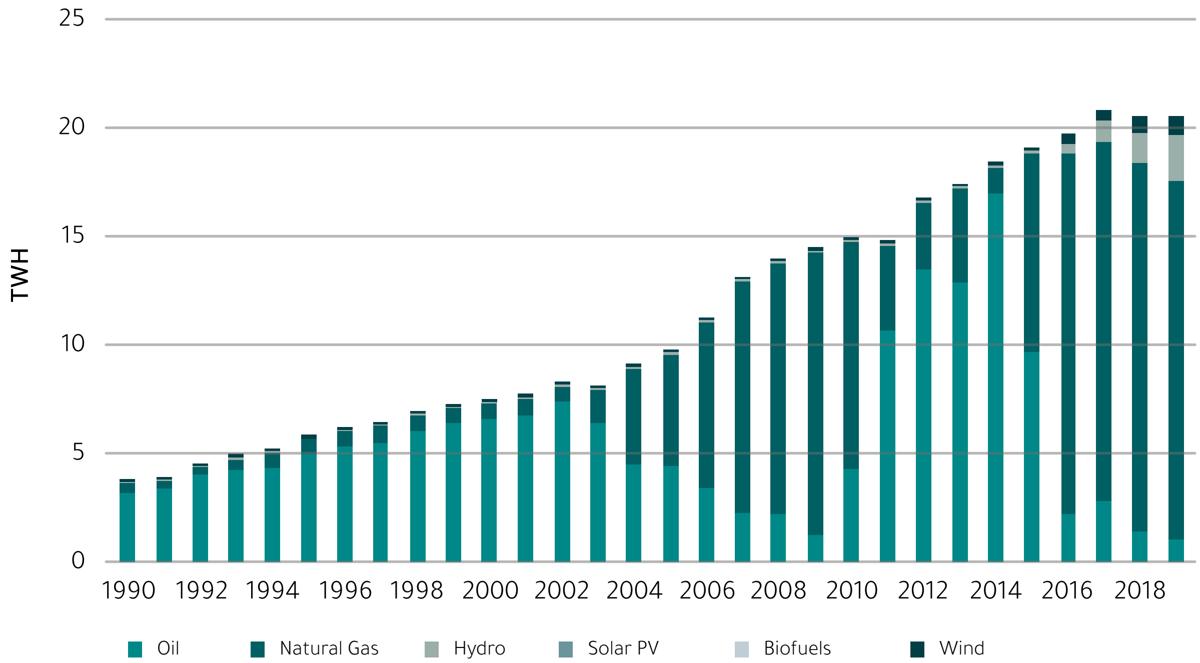
Fig. 4-3
Electricity Consumption (in TWh), Jordan 1990–2019



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

Jordan's energy supply underwent several changes. At first, it was dominated by crude oil imported from Iraq at below market prices (Kiwan and Al-Gharibeh, 2020). When the Iraq war started in 2003, this oil was progressively replaced (until 2010) by natural gas from Egypt. However, instabilities in Egypt in 2011 interrupted the natural gas flow to Jordan, which led Jordan to replace natural gas with crude oil once again (ibid.). After new gas agreements and the liquefied natural gas (LNG) port in Aqaba started operating, natural gas became once more the dominant source in Jordan's electricity generation by 2015, and the share of renewables also increased (Fig. 4-4) (IEA, 2020a). While the government abandoned the nuclear plans due to risk concerns, the Ministry of Energy and Mineral Resources (MEMR) signed an agreement to construct a power plant using coal and petroleum coke with a capacity of 30 MW in Al-Qatrana region. This would be the first coal power plant in Jordan.

Fig. 4-4
Electricity Generation by Source (in TWh), Jordan 1990–2019



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

According to NEPCO (2020), Jordan's peak power demand occurs during the evening hours between 5pm and 9pm. In 2020, the peak amounted to 3,670 MW in winter, while the minimum load (1,040 MW) occurred in spring. The winter and summer loads are almost identical, while the spring and autumn loads are similar to each other and slightly lower than the winter and summer loads. In 2020, combined cycle units accounted for 71% of the generating units in the system peak, whereas gas turbine units accounted for 1.5%, diesel units for 18.4%, and imports for 7%. Renewables contributed approximately 2% to meet peak demand (NEPCO, 2020).

The highest level of wind and solar power generation normally occurs between 8am and 6pm (this would vary according to the different seasons), which does not match Jordan's hours of peak demand.

These figures show that Jordan's energy sector currently suffers from excess generation capacity. The COVID-19 pandemic exacerbated this situation, with demand decreasing during the lockdown. Jordan also faces challenges surrounding its contracted fuel purchases and long-term commitments to purchase agreements, especially for natural gas (Komendantova et al., 2021).

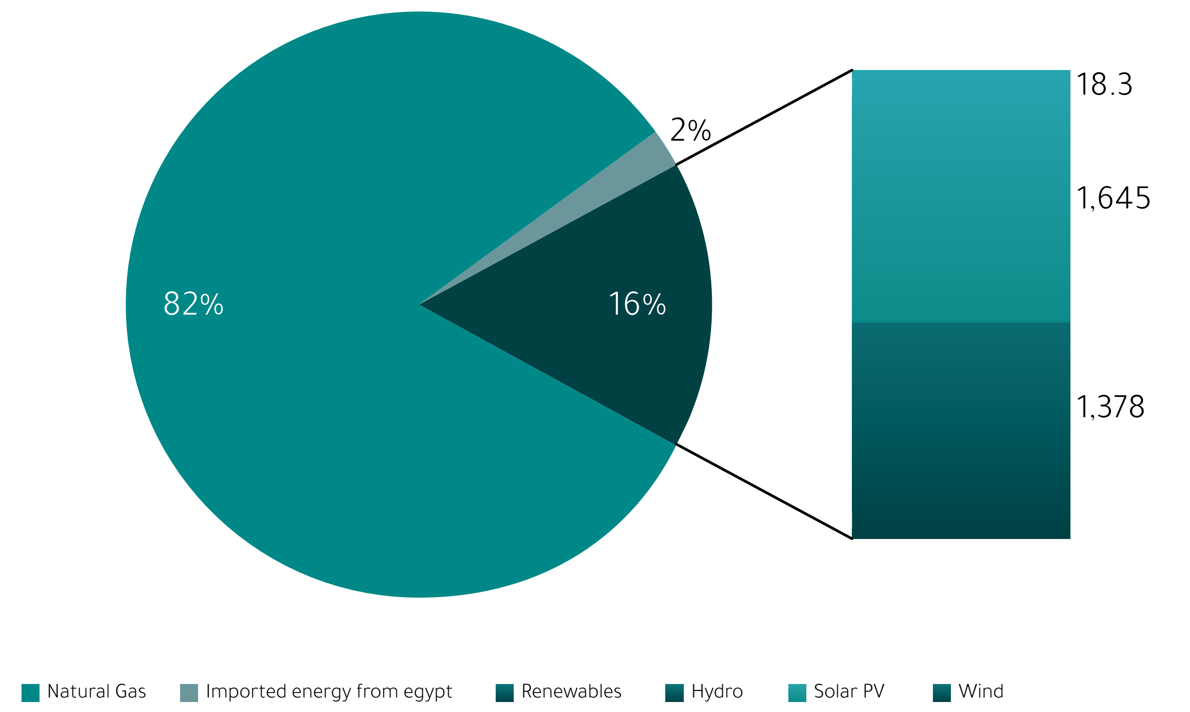
Jordan's energy demand is rising, and limited domestic resources are available to meet this demand. The contribution of renewables to the electricity generation mix has increased over the last few years, but fossil fuels are still dominant sources of energy. It is unlikely that renewables will be able to replace fossil fuels quickly enough to meet the growing energy demand. Moreover, plans to build a coal power plant prevail in the Jordanian strategy. Therefore, in the energy demand and supply category of the MENA energy transition phase model, Jordan falls under a later stage of the first phase.

Renewable Energy

The current installed and grid connected RE capacity in Jordan is 2,280.5 MW; solar energy accounts for 1,645 MW, wind energy for 625 MW, biogas amounts to 5.5 MW, and hydro power constitutes 5 MW. More than 35% of this renewable capacity is connected under the net metering and wheeling scheme (IRENA, 2021). For the distribution grid, the total capacity of operating PV systems was around 640 MW at the end of 2020, representing 213 MW under the wheeling scheme and 427 MW under the net metering regulation. Renewables accounted for 36% of the total installed electrical energy capacity and were expected to deliver 20% of Jordan's total electricity in 2021 (MENA-Fuels project, 2021). Forecasts and estimations predict that the installed capacity of renewables will reach 3,293.5 MW by 2030.

Based on data from NEPCO (2020), Fig. 4-5 shows that the on-grid renewables purchased by NEPCO accounted for 16% of electricity generation in 2020. Solar energy generated 1,645 GWh, wind energy generated 1,378 GWh, while hydro power produced 18.3 GWh.

Fig. 4-5
Electricity Generation Mix (in GWh), Jordan 2020



(Source: Data based on NEPCO (2020))

Jordan enjoys abundant RE resources. Located in the Sunbelt region, it receives around 2,900 hours of sunshine per year. The average annual irradiance ranges from 5 to 7 kWh/m2, with total annual irradiance (depending on the location) be-tween 1,800 and 2,700 kWh/m2 (Abu Hamed and Bressler, 2019; Azzuni et al., 2020). The southern region, from Aqaba to Ma'an, records the highest solar radiation val-ues with daily irradiation of 6 to 7 kWh/m2; thus, Jordan is highly suitable for the de-velopment of solar energy projects. Jordan has over 300 registered solar installation companies, some of which are effectively operating in the market (Abu-Rumman et al., 2020). A substantial number of stand-alone PV systems are operating in remote villages and rural areas; these are used for water pumping or domestic lighting. Currently, around 20% of households have solar water heating systems installed on the roof. Under the updated Energy Master Plan, the aim is to increase this percent-age (ibid.). Large-scale PV power plants are mostly located in the Ma'an region and have capacities of around 10 to 50 MW.

Moreover, a lot of the regions in the north-western and southern areas of Jordan are suitable for wind energy production, seeing as wind speeds in those locations range from 7 to 11 m/s (Abu-Rumman et al., 2020). Wind energy farms make a sig-nificant contribution to the share of Jordan's electricity generation. The first com-mercial wind farm was established in 1996 in Hofa, and Jordan's current highest ca-pacity wind power plant is located in Tafila with a capacity of 117 M (Abu-Rumman et al., 2020). The Tafila Wind Farm was developed by the Jordan Wind Project Com-pany, which is a partnership between InfraMed (50%), Masdar (31%), and EP Global Energy (19%) (Zarour, 2015, as cited in Holtz and Fink, 2015), and most of the exist-ing wind energy projects are based on power purchase agreements (PPAs). Also, the Jordanian Wind Atlas has existed since 1989 and is reviewed on a regular basis in order to provide the latest measurements (ibid.).

As for hydro power, the potential of this energy source is rather limited in Jordan due to scarce water resources. Just two small-scale hydro power plants are function-ing; one is in the King Talal Dam and the other is in the Gulf of Aqaba (Abu-Rumman et al., 2020). In 2017, these power plants together generated 38 GWh (Franceschini, 2019). Regarding biogas, until 2020, the Jordan Biogas Company operated until 2020 a 4 MW biogas power plant, the Rusaifeh Landfill (ibid.). This plant started operation in 1999 and processed around 60 tons of organic waste (from hotels, restaurants, and slaughterhouses in Amman) per day (ibid.). It is anticipated that Jordan's bio-mass potential will remain limited and will not be significant for the future energy strategy. Table 4-1 summarises the operational grid-connected large-scale RE projects in Jordan.

Table 4-1

Operational Large-Scale Renewable Energy Projects in Jordan

Operational wind power plants											
Site	Tafila Jordan Wind Farm	Tafila Mass Energy	Tafila Abour Energy Company OSC (Xenel)	Tafila Daehan (KOSPO)	Al-Hussein Elecnor/ Ma'an	Ma'an Green Watt (Alrajif)	Ma'an KEPCO (Alshobak)	Ma'an Alcazar (Alshobak 2)			
Installed Capacity (MW)	117	100	51.75	51.75	80	86.1	89	45			

Operational solar power plants or PV											
Site	Saqr Ma'an Solar Energy Company	Ma'an Enera Company	Shams Ma'an Company	Ma'an Anwar Al Ardh Company	Ma'an Al-Zanbaq Company	Ma'an Zahrat Al-Salam Company	Ma'an Al-Ward Joury Company	Ma'an Ard Al Amal Company	Jordan Solar One (Al-Mafraq)	Ma'an Scatec Solar Company	Shamsuna Power Company (Aqaba)
Installed Capacity (MW)	20	10	52.5	20	10	10	10	10	20	10	10
Site	Ma'an SunEdison italia	Almafraq PV 1/FRV	Almafraq PV 2/ FRV & Hareon Swiss	Almafraq PV 3/ ACWA	Alsafawi PV/ FRV & ATC	Philadelphia Solar/ Alhusainiyah	Baynona/ MASDAR	Alrisha PV / ACWA	AM solar/ Amman east	Alquaryrah PV	
Installed Capacity (MW)	20	50	50	50	50	50	200	50	40	92	
Operational hydro power plants											
Site	King Talal Dam	Gulf of Aqaba (currently not in operation)									
Installed Capacity (MW)	5	7									

(Source: Data provided by expert Dr. Iyad Muslih)

The regional capacity distribution of the PV systems connected to the distribution grid can be found in Table 4-2.

Table 4-2

PV Systems Connected to the Distribution Grid Under the Net Metering and Wheeling Scheme

DISCO	Net Metering (MW)	Wheeling (MW)
Middle	321.8	162
North	184.8	36.3
South	84.4	64.5
Total	591	262.8

(Source: Data provided by expert Dr. Iyad Muslih)

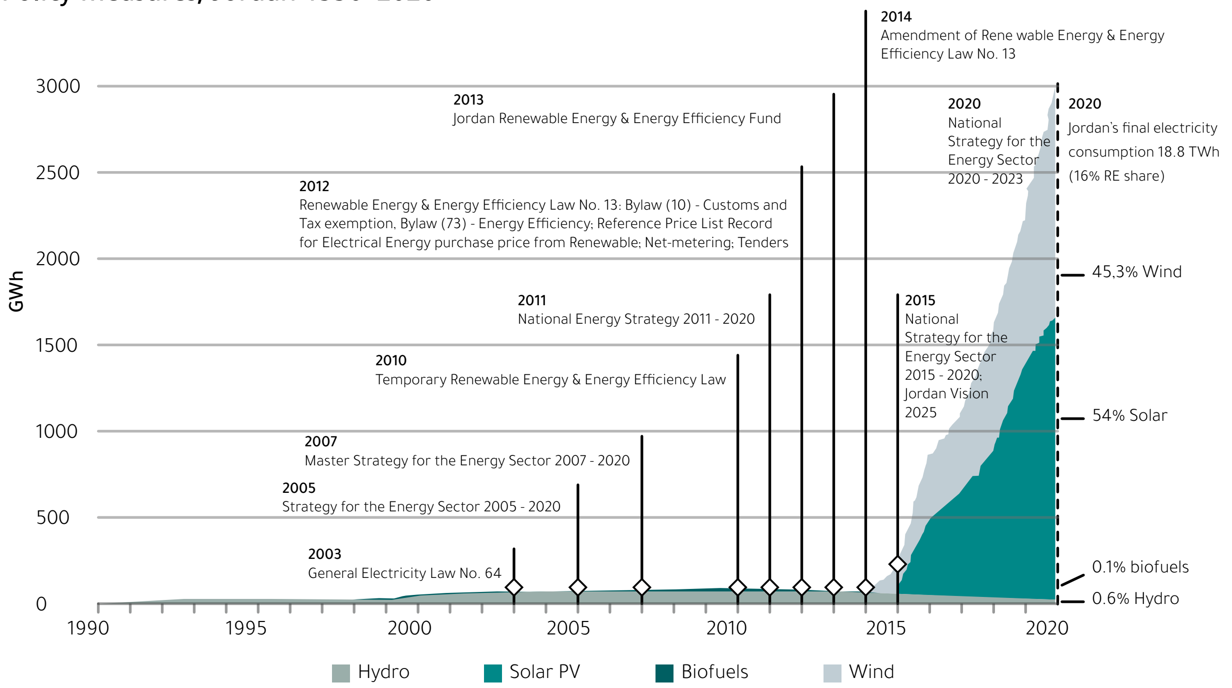
A number of initiatives and policy measures have been introduced in Jordan's ener-gy market to drive the uptake of renewables. The policy and regulatory frameworks are considered to be among the most advanced in the MENA region. These measures are guided by the political will to improve Jordan's energy security, to reduce its dependence on energy imports prone to political risks, and to mitigate climate change. The need for energy security and the increasing cost of energy im-ports have impelled the government to update and amend its energy strategy on a regular basis. Moreover, frequent revisions to the bylaws are based on lessons learnt since the introduction of Law No. 13 (IRENA, 2021) in 2012.

The main law governing the electricity sector is the General Electricity Law No. 64 of 2003, which liberalised the market to guarantee efficiency, reliability, and development (LSE, 2020). Also, the Strategy for the Energy Sector 2005–2020 was released in 2005 and was then updated in 2007 and became the Master Strategy for the Energy Sector 2007–2020. To achieve its RE plans, the Jordanian government launched a temporary RE law in 2010 and issued the Law No. 13 for Renewable Energy and Energy Efficiency in 2012. The law endorses energy management and efficiency measures in the service and industrial sectors. It aims to further encourage investments in renewables "by simplifying the investment procedures" (MEMR, 2013, as cited in Abu-Rumman et al., 2020, p. 7). Furthermore, a 'one stop shop' of-fice at the Energy and Minerals Regulatory Commission (EMRC) was established to attract new investment, and independent power producers (IPPs) can implement power projects under the build, own, and operate (BOO) financing mechanism and then enter into a PPA with NEPCO to sell the energy they produce. Projects can be developed through three main methods: "direct proposal submission ([BOO] projects offered through competitive bidding), government-owned (offered as engineering, procurement and construction (EPC) contracts for the private sector) and self-consumption (wheeling and net metering projects)" (IRENA, 2021, p. 40). The direct proposal submission method has been identified as a strong driver for the up-take of renewables (IRENA, 2021). The wheeling and net metering projects have also attracted significant interest; however, this has resulted in rapid capacity deployment, which has caused overload situations for the distribution companies. In addition, the companies that usually review the project applications are unable to cope with the high volumes of applications (IRENA, 2021). In 2019, the MEMR set a cap on renewables projects above 1 MW due to the technical limitations of the electricity grid (Franceschini, 2019). However, projects under 1 MW are frequently not ap-proved or are only approved for partial capacity due to the limitations of the grid (IRENA, 2021). The Jordan Renewable Energy & Energy Efficiency Fund (JREEEF) was also formed to facilitate investment. JREEEF is financed from the governmental budget, foreign investments, and grants from the European Union (EU) and the Gulf Cooperation Council (GCC) (IRENA and ESCWA, 2018). Additionally, Bylaw (10) pro-vides tax incentives and customs exemptions to further boost investments. Other mechanisms to incentivise renewables include competitive bidding processes, direct proposal submissions to MEMR, energy net metering schemes, electric power wheeling applications, and self-generation applications (Abu Hamed and Bressler, 2019; FES, 2015). FiTs for households vary according to the technology and the size of the power systems, and they range between 10 and 15 Eurocents (dena, 2014). The operator receives a 15% bonus if the RE system is of Jordanian origin. These measures support the development of small-scale projects and also provide incen-tives to use domestically produced systems.

In 2020, the National Master Strategy of the Energy Sector for 2020–2030 was updated, and it targets a significant number of domestic energy sources, such as oil and renewables, by 2030 (IRENA, 2021). It foresees an increase in the installed capacity of 3,200 MW, with renewables accounting for 31% of total electricity genera-tion and 14% of the total energy mix by 2030 (ibid.). According to the new plan, nat-ural gas will have a 53% share in electricity production, while oil shale will account for 15%, and only 1% of electricity will be produced through oil (Sandri et al., 2020). The new strategy has abandoned the former nuclear plans, and methods to include the production and use of green hydrogen in the next updated strategy are being discussed. The published strategy from 2020 is to be further updated; however, this has been delayed due to the COVID-19 pandemic and disagreements within the Jor-danian government (Komendantova et al., 2021). Moreover, the primary national development strategy, Jordan Vision 2025, concentrates on improving the energy sector while also calling for the development of the green economy in the transport, water, waste, agriculture, and tourism sectors. Several other strategies have been created to enhance the RE and energy efficiency deployment in Jordan. For exam-ple, the Energy Sector Green Growth National Action Plan 2021–2025 (GG-NAP) rep-resents a green growth framework and outlines actions for the sector. The strategy is aligned with the National Green Growth Plan, Jordan Vision 2050, and the coun-try's NDCs (Ministry of Environment, 2020). The five national green growth objec-tives are as follows: enhancing natural capital, sustainable economic growth, social development and poverty reduction, resource efficiency, and climate change adap-tation and mitigation (ibid.).

Fig. 4-6 depicts the introduction of energy policy measures and their impact on re-newable electricity generation by year.

Fig. 4-6
Development of Renewable Electricity Generation by Source (in GWh) and Introduction of Energy Policy Measures, Jordan 1990–2020



(Source: Data based on Franceschini (2019); IEA (2020a); IRENA (2018b); NEPCO (2020); Sandri et al. (2020); Zawaydeh (2018))

Also in 2020, the Solar Heating Arab Mark and Certification Initiative (SHAMCI) for solar thermal systems was introduced, providing regional compliance regulations for policy, industry, and end users (IRENA, 2021). In the same year, the Jordanian-German Energy Partnership was established to strengthen the cooperation between the two countries on energy related topics. This partnership aims to encourage the energy transition of both countries through political, economic, regulatory, and technological exchange. Jordan also intends to collaborate with Israel in a joint project to build a 600 MW solar facility for export to Israel (Rabinovitch et al., 2021). In return, Israel will provide Jordan with 200 million m3 of desalinated water. The declaration of intent for this water-for-energy deal was signed in November 2021 between the two countries and the United Arab Emirates. However, this deal has already attracted serious objections from Jordanian society (Bilanceri, 2021).

Despite the advancements made for the uptake of renewables, Jordan's RE sector has been negatively affected by the COVID-19 pandemic. When electricity consumption decreased during lockdown, RE continued generating electricity. This negatively affected the network stability (IRENA, 2021). Thus, NEPCO reduced the consumption of state-owned renewables facilities to alleviate the impact on the grid. Subsequently, all renewables which were disconnected are gradually being reconnected (ibid.).

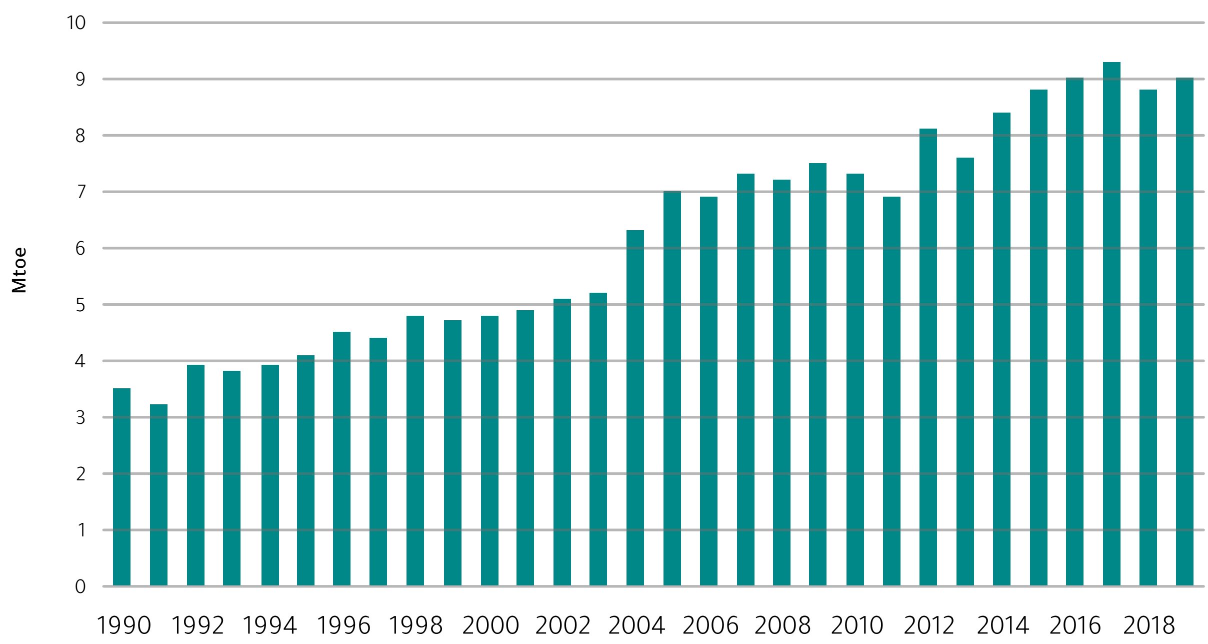
Jordan has successfully opened its energy and electricity market to private producers in order to boost investment in renewables, which is a pivotal step for the take-off of renewables. Stable and clear policy frameworks, attractive incentives, and the availability of financing mechanisms have contributed to a significant rise in the implementation of RE technology in Jordan (Franceschini, 2019). However, unexpected changes and the lack of a long-term strategy beyond 2030 are still barriers to the rapid upscale of investments in renewables. Although Jordan possesses high RE potential, the share of natural gas and oil shale in the energy mix is still an important component of its energy strategy. Overall, regarding REs, Jordan can be classified as having largely achieved the first phase of the MENA phase model. Yet, hurdles to progress remain, such as the renewables project cap of 1 MW, which is expected to be lifted with the next update of the energy strategy.

Fossil Fuel Sector

Other than the recent exploration of shale oil, Jordan has nearly no natural re-sources of its own; therefore, it imports almost all of its energy resources. This causes large budgetary deficits. In the last decades, the supply of energy has been challenging for Jordan due to different geopolitical aspects. Prior to 1990, Jordan was supplied with oil from Saudi Arabia, but this ended when

Jordan supported the Iraqi invasion of Kuwait (Henderson, 2015). Until the end of Saddam Hussein's re-gime in 2003, Jordan was supplied with Iraqi oil. Afterwards, this was replaced with Egyptian and Syrian gas, but the pipelines became prone to regular sabotage attacks due to the Arab Spring in Egypt and the political turmoil in Syria. Jordan then bought heavy fuel oil and diesel from the global market to supply its power plants (ibid.). In 2015, Israel and Jordan signed an agreement for natural gas to be supplied from the Leviathan fields to Jordan for the next 15 years. Although there has been some anti-Israeli resistance, this deal will provide Jordan with 45 billion m3 of natural gas an-nually (Abu Hamed and Bressler, 2019). Earlier in 2014, a separate gas deal with Is-rael was signed to supply Jordan with natural gas from the Tamar fields (Times of Is-rael, 2016). Based on data from IEA (2020a), Fig. 4-7 provides an overview of the net energy importing profile of Jordan from 1990 to 2019.

Fig. 4-7
Net Energy Imports (in Mtoe), Jordan 1990–2019



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

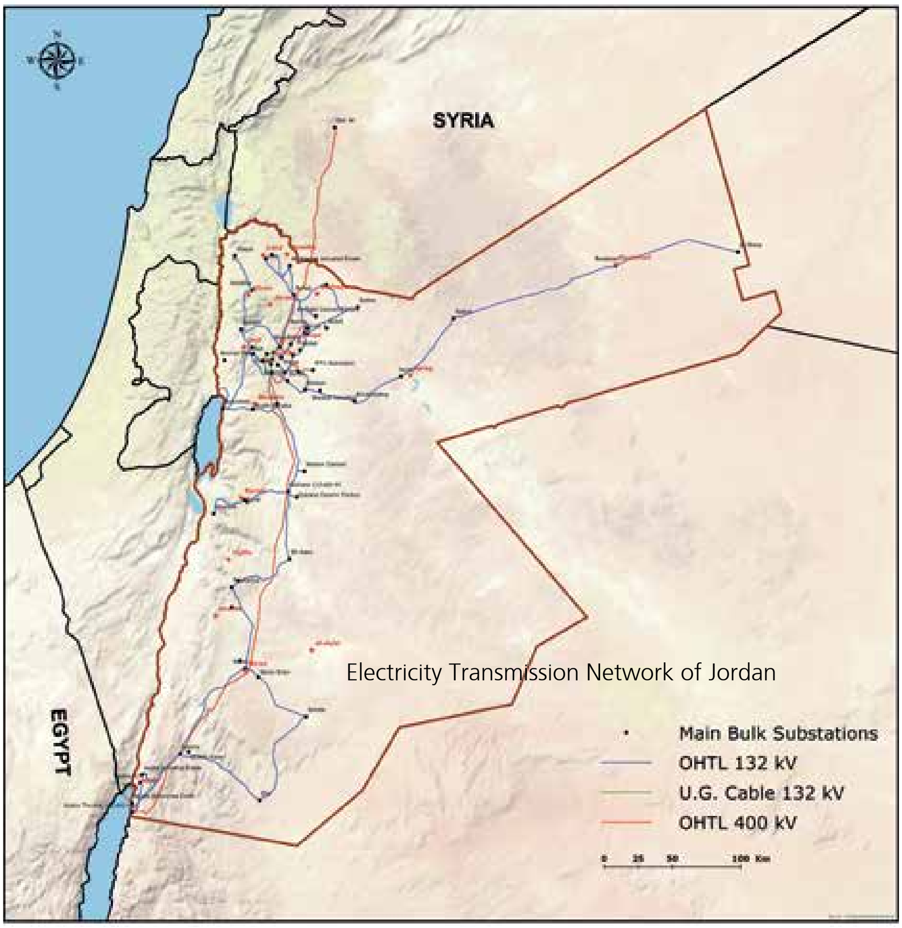
Egypt currently provides Jordan with daily quantities of natural gas of 1 to 2 million m3 (MENA-Fuels project, 2021). Jordan depends on this Egyptian gas to generate 10% of its electricity. Through the LNG port in Aqaba, which has been operating since 2015, LNG gas is imported to Jordan and is used to generate more than 87% of Jordan's electricity. Currently, around 90% of Jordan's energy supply is imported, creating high costs for the economy (around 10% of the Gross Domestic Product (GDP)) (IRENA, 2021). This problem has been exacerbated by the rapid increase in energy demand in recent years, which is expected to continue growing. Consequent-ly, domestic oil shale resources have been exploited (Abu Hamed and Bressler, 2019). The Jordanian government has signed several memoranda of understanding (MoUs) for investments in domestic oil shale production. The largest private sector oil shale facility worldwide (implemented by a coalition of Chinese, Malaysian, and Estonian companies) is located in Attarat, with a capacity of 470 MW. The plant has come online in 2021, operating on the basis of direct oil shale burning. In addition, Jordan has increased its natural gas supply by signing LNG contracts between NEPCO and Shell International. These contracts would secure natural gas supplies for power plants and industry (Abu Hamed and Bressler, 2019).

Recent political debate has come out in favour of importing natural gas, while simultaneously producing domestic oil shale in Jordan. Although the phase model advocates replacing the use of fossil fuels with renewables, Jordan is likely to continue to expand its fossil fuel use in the light of growing markets and demand. As a result, the current structure of the energy supply regime will probably remain in place for years to come.

Infrastructure

The transmission network in Jordan is operated by NEPCO. The grid runs along the north–south corridor, from Aqaba in the south to Irbid (close to the Syrian border) in the north (Holtz and Fink, 2015). The grid is connected to both Syria via a 230 to 400 kV power line with a capacity of between 300 and 800 MW and to the Egyptian grid via a 400 kV power line with a capacity of 550 MW (Abu-Rumman et al., 2020; NEP-CO, 2020). Moreover, Jordan supplies the Palestinian network through an intercon-nection in Jericho via a 132 kV transmission power line with a capacity of 20 MW (NEPCO, 2020). By 2020, there were approximately 5,400 km of overhead transmis-sion lines with voltages of 400 kV, 230 kV, 132 kV, and 66kV, and there was an addi-tional 62 km of 132 kV underground cables (ibid.). Power stations are connected (via 132 kV and 400 kV lines) to the transmission network that supplies the load centres (Shalalfeh et al., 2021), and around 13% to 14% of generated electricity is lost dur-ing transmission and distribution (Kiwan and Al-Gharibeh, 2020). Furthermore, the distribution system is separated into three regional systems that are managed by different distribution companies (Shalalfeh et al., 2021). These distribution companies are as follows: (1) The Jordan Electric Power Company (JEPCO), which supplies central Jordan (including Amman) around 64% of the electricity consumed (ibid.), (2) The Electricity Distribution Company (EDCO), which serves the southern and western regions via an 8,396 km distribution network, and (3) The Irbid District Electricity Company (IDECO), which supplies the north via a 13,148 km network (ibid.). Based on Energydata (2017a), Fig. 4-8 depicts Jordan's electricity transmission network.

Fig. 4-8
Jordan's Electricity Transmission Network



(Source: National Electric Power Co. 2021)

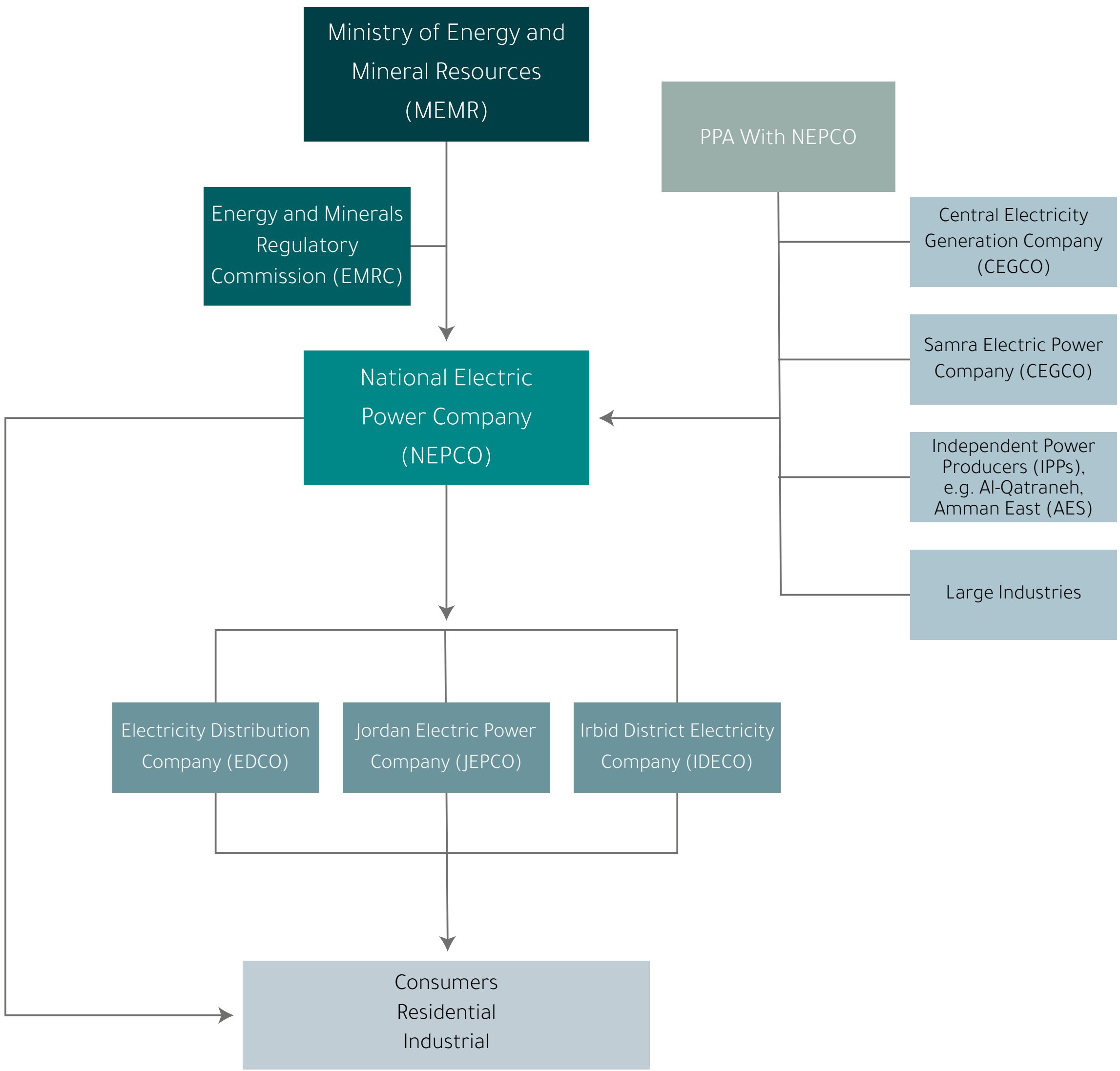
The current Jordanian grid capacity is limited, which constrains the upscaling of electricity generation from renewables. NEPCO developed the 'Green Corridor' project to upgrade and extend the power grid by building several sub-stations and new connection lines in the southern region of Jordan. It aims to accommodate more electricity from renewables and to transfer it to major load centres (Jordan Times, 2017). In addition, the development of several interconnection projects to improve the existing infrastructure is currently being discussed. Accordingly, the Egyptian-Jordanian Electric Interconnection (Submarine Cable) is being renewed to increase the capacity up to 1,100 MW, the Jordanian-Syrian Electric Interconnection will be reconstructed with a 150 MW capacity, an upgrade up to 80 MW of the Jordanian-Palestinian Electric Interconnection is under discussion, an upgrade of the Jordanian-Iraqi connection to reach 150 MW is under development, and the construction of the Jordanian-Saudi Electric Interconnection (127 km and 400 kV voltage) is planned for 2026–2027 (NEPCO, 2020). Additionally, an agreement for the Jordanian-Iraqi Electric Interconnection has been signed while a feasibility study is being undertaken for the Jordanian-Gulf-Egyptian Electric Interconnection (ibid.).

The RE sector in Jordan is currently constrained by the limited grid capacity. Although Jordan guarantees priority grid access for renewables and gives dispatch priority, technical challenges remain (RCREEE, 2019). In addition, the surplus of renewable and conventional energy means that storage options are becoming increasingly important for Jordan. Storage projects, such as grid expansion at interconnection points, battery storage systems for PV, and pumped storage projects, are being considered as solutions to overcome the fluctuations in the electricity grid. Thus, the development of the electricity infrastructure for the integration of renewables according to phase one of the phase model has been initiated in Jordan but is not yet complete.

Institutions and Governance

In Jordan, there are several institutions that oversee the electricity and energy sector. The MEMR is the key actor in this sector and is responsible for the strategic development of energy policies and targets in the national energy system (Franceschini, 2019). The EMRC, which is financially and administratively independent, is the electricity market regulator. According to the General Electricity Law, EMRC sets the electricity tariffs and grants licences to IPPs and distributors. The electricity sector is a single-buyer market with competition between power producers. Thus, power generation and distribution are privatised sectors, but NEPCO is the only authorised energy off-taker at wholesale level, and it manages the interconnections with neighbouring countries (Franceschini, 2019). Furthermore, all PPAs are held with NEPCO. At the distribution level, there are three companies responsible: JEPCO, EDCO, and IDECO. These companies receive all RE project applications and have the authority to approve and reject them. Additionally, these companies conduct grid impact studies and are in charge of net meter installation (Zawaydeh, 2018). Based on data from FES (2011), Fig. 4-9 depicts Jordan's institutional framework of the electricity and energy market and shows the relevant authorities and companies.

Fig. 4-9
Electricity Market Structure with Relevant Authorities and Companies



(Source: Own creation based on FES (2011))

After restructuring the electricity sector in 1996 (which was also when NEPCO was established), the sector was progressively opened up to private investors to allow for market competition. NEPCO replaced the former Jordan Electricity Authority, which was divided into three companies: the transmission company NEPCO, the generation company Central Electricity Generation Company (CEGCO), and the distribution company EDCO (Sandri et al., 2020). In addition to CEGCO, the Samra Electric Power Company (SEPCO), IPPs, and large industries are currently producing electricity in the Jordanian sector. Thus, there are a number of institutions responsible for the electricity market. However, cooperation between these institutions is limited, which results in poor performance and efficiency losses. The financial challenges faced by the electricity sector are concentrated at NEPCO as the single buyer. By in-creasing electricity tariffs, NEPCO wants to decrease operating losses, but this is on-ly succeeding to a limited extent (Sandri et al., 2020). The strong development of REs contributes to these losses, seeing as NEPCO is obliged to purchase renewable electricity when new IPPs for REs enter the market, regardless of demand.

To sum up, the electricity market in Jordan has been rather liberalised after the re-structuring of the electricity sector in 1996. Nevertheless, it remains a single-buyer market, with NEPCO, the state-owned utility, as the only off-taker. Despite Jordan's market liberalisation efforts and the introduction of EMRC, companies in the energy sector still need to tackle bureaucratic and lengthy processes, and communication between institutions and ministries must be improved (Sandri et al., 2020). There-fore, the current state of development and effectiveness of the institutional frame-work places Jordan at the beginning of the second phase towards a renewables-based energy system according to the MENA phase model.

Energy Market and Economy

The electricity tariff structure in Jordan varies for industrial consumers according to the time of the day; it consists of a peak load bulk supply tariff, a day energy tariff, and a night energy tariff. These tariffs differ between the three distribution companies JEPCO, EDCO, and IDECO (NEPCO, 2021). The retail tariff follows an inclining block model, with seven different blocks according to the monthly unit kWh consumption. With each block, the tariff increases and ranges between 4 and 33 Eurocents. The public and commercial sectors, banks, telecommunications, small and medium industries, hotels, and agriculture each have a different tariff and all are based on different consumption blocks. The tariffs range between 6 and 35 Eurocents. Large industries, such as mining and quarrying, only pay the peak load bulk supply tariff, day energy tariff, and night energy tariff. These range between 13 and 29

Eurocents (ibid.). A new electricity tariff will replace the existing structure, which will reduce costs for households as well as for the business, industry, tourism, agriculture, and healthcare sectors. The new tariff structure that will be implemented in the beginning of 2022 will be partly subsidised for some consumer groups, and the peak demand tariff for all sectors will be removed. Consumers that can make use of the subsidised tariff will pay 50 fils (around 6 Eurocents) per kWh for a consumption between 1 and 300 kWh, while a consumption between 301 and 600 kWh will cost 100 fils (around 12 Eurocents) per kWh, and more than 600 kWh will cost as much as 200 fils (around 25 Eurocents) per kWh. In the unsubsidised tariff, the costs of a kWh will range between 120 and 150 fils (around 14–19 Eurocents), depending on the consumption (Jordan Times, 2021a).

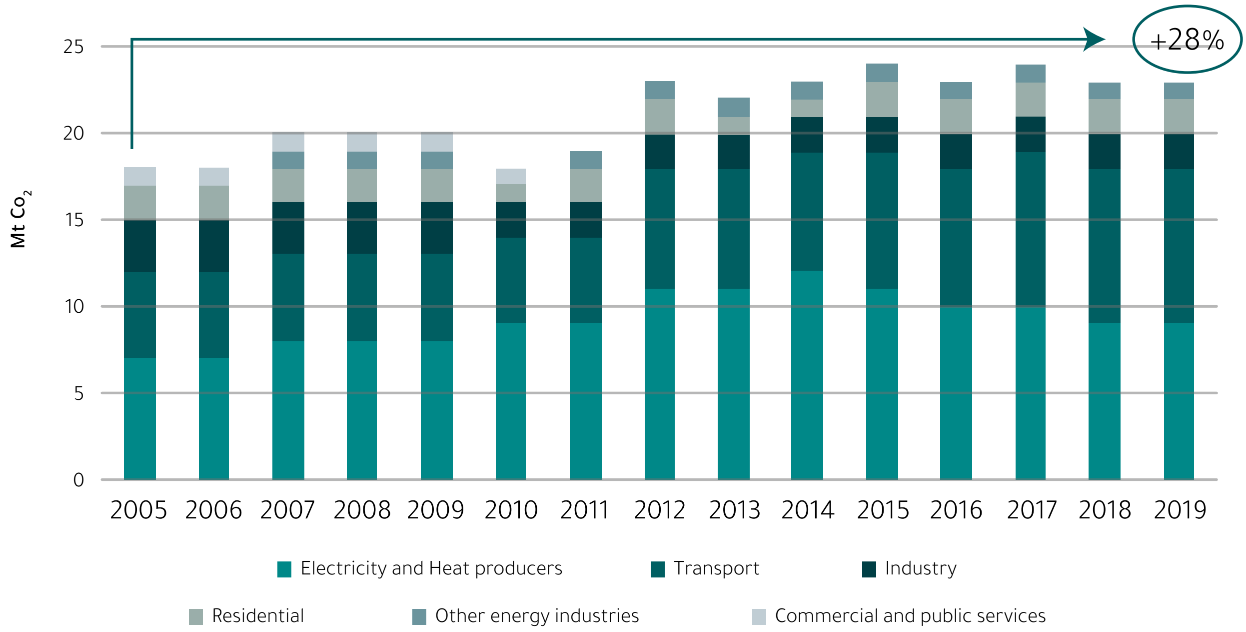
Until 2017, distribution costs did not match production costs. This difference was compensated for by governmental subsidies that caused budgetary deficits of around USD 1.22 billion (Abu-Rumman et al., 2020). To reduce the governmental subsidy, the electricity tariffs were adjusted and electricity subsidies were completely lifted in 2017.

In summary, the withdrawal of state subsidies for electricity has led to an improved financial situation for NEPCO since 2017. Moreover, many households have switched to their own residential net metering systems due to the increase in electricity tariffs and decrease in the cost of renewables. This has contributed to the wider deployment of small-scale RE systems (Holtz and Fink, 2015). Overall, regarding the energy market, Jordan can be classified as having accomplished phase one of the transition phase model.

Greenhouse Gas Emissions

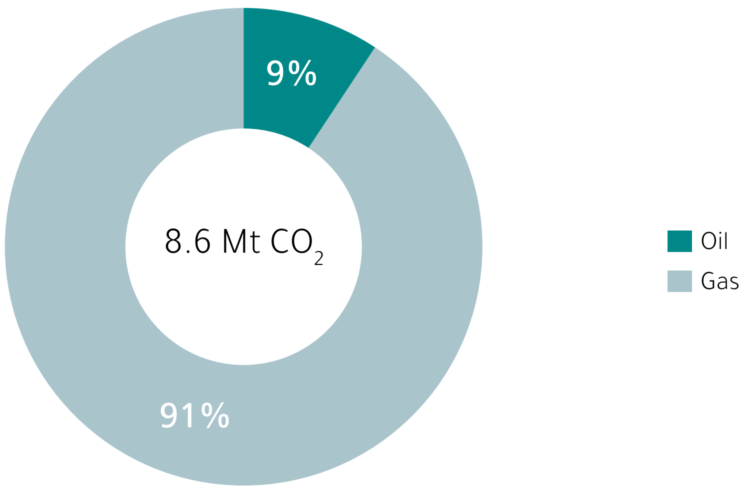
The use of fossil fuels in the energy sector significantly contributes to the level of GHG emissions per capita (Baniyounes, 2017). In 2018, CO2 emissions per capita amounted to 2.28 metric tons (The World Bank, 2020a). In total, Jordan emitted 23 Mt of CO2 in 2018. The transport sector and the electricity and heat generation sec-tor were each responsible for 39% of the CO2 emissions, followed by the industrial and residential sectors, each of which released 8% of the CO2 emissions). From 2005 to 2019, CO2 emissions increased by 28% due to changing demographics, industrial development, and impacts of climate change (Fig. 4-10) (IEA, 2020a) . Based on in-formation from IEA (2020a), Fig. 4-11 illustrates the resulting emissions from heat and electricity generation by source for 2019; it shows that more than 90% of the CO2 emissions were caused by the use of natural gas in the heat and electricity gen-erating sector.

Fig. 4-10
CO2 Emissions by Sector (in Mt CO2), Jordan 2005–2019



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

Fig. 4-11
CO_2 Emissions from Electricity and Heat Generation by Energy Source (in Mt CO_2), Jordan 2019



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

Under the terms of its Intended Nationally Determined Contributions (INDCs), Jordan has pledged to reduce GHG emissions by 14% by 2030 compared to the base year of 2006 (UNFCCC, 2015). In the updated NDC submission of October 2021, Jordan intends to reduce the GHG emissions by 31% in 2030 compared to the Business-As-Usual in 2012, 5% of which are unconditional, while 26% will be conditional upon the availability of international financial aid and support. The GHG emissions reduction action plan specifically targets the energy sector by implementing energy efficiency and RE measures.

Despite Jordan's carbon emission reduction plans, as outlined in its NDCs, emissions are actually increasing due to rapid population growth. Emissions reduction efforts in the transportation and industry sectors could be improved through direct electrification as well as hydrogen applications in the future, although these will strongly depend on the price.

Efficiency

Energy efficiency measures are an integral part of the Jordanian energy strategy. The Energy Strategy 2007–2020 aimed for all sectors to enhance energy efficiency by 20% by 2020 (Shahin, 2015). As part of this strategy, the first National Energy Efficiency Action Plan (NEEAP) was developed in 2011 to cover the period 2012–2014. The plan aimed to decrease energy intensity by 180 kgoe/1,000 JD by 2020 compared with 210 kgoe/1,000 JD in 2010. This was supposed to save 502 GWh of electricity in the first two years of the NEEAP's implementation (RCREEE, 2013). Although some efficiency measures were applied successfully, the set targets could not be achieved. They were revised for the updated strategies with more ambition.

In addition, Bylaw (73) of the Renewable Energy and Energy Efficiency Law No. 13 aimed to disseminate solar water heaters (SWHs) and dictated their compulsory installation in new buildings from April 2013 (ibid.). Also, a SWH subsidy programme was launched under JREEEF that planned to install 20,000 SWHs in the residential sector between 2013 and 2019 (IEA, 2019). This target was not achieved and was reconsidered for the next updated efficiency strategy. Further energy efficiency measures were developed, such as the labelling of electrical appliances and the licensing and regulation of the Energy Services Company (ESCO) market. Bylaw (10) of the Renewable Energy and Energy Efficiency Law No. 13 called for tax exemptions from sales and custom duties on all RE and energy efficiency systems and equipment. Other recommendations included in the Energy Strategy Plan 2007–2020 focused on organising public awareness campaigns on energy saving behaviour and the thermal insulation of buildings (Abu-Rumman et al., 2020).

The second NEEAP was developed for the period 2018–2020, and it aimed to save almost 2,000 GWh of electricity by 2020 through 35 measures, including cross-cutting projects that encompass the residential, tertiary, industrial, water pumping, street lighting, and transport sectors (MEMR, 2017). The target for the residential sector was to introduce 15,000 PV systems, 50,000 SWHs, 150,000 LED tubes, and 51,000 LED bulbs, while the objectives for the industrial sector included conducting more energy audits. The second NEEAP was successful and significantly contributed to the realisation of the measures, but it did not manage to reach all the set targets.

An evaluation of the steps taken by Jordan in terms of energy efficiency shows that the government has recognised energy efficiency as an essential part of the energy transition. The plans outlined in the regulatory framework indicate that Jordan is putting energy efficiency measures into practice despite some drawbacks. New updates on the strategy will include more ambitious targets to be met. Consequently, regarding energy efficiency, Jordan can be classified as having completed the first phase according to the MENA energy transition phase model.

Society

Involvement of society in matters associated with energy is crucial. Jordanian society has a tradition of actively participating in decisions concerning national energy issues (Komendantova et al., 2021). Through the parliamentary council, academic institutions, and the media, Jordanian society communicates directly or indirectly about energy-related issues.

Moreover, community acceptance of renewables is an important step for the implementation of large-scale projects. For instance, the Tafila PV project in Jordan was ultimately only achieved because the residents approved the project (Shahin, 2015). The gas agreement with Israel is another example; after protests started in Amman against the agreement, the issue was taken to the constitutional court. The court decided that the agreement was valid, as it had been signed between two companies and not between the two countries (Komendantova et al., 2021).

There are a few reasons behind the community's acceptance of energy projects. According to Komendantova et al. (2021), most people are aware of RE projects and are in favour of them. People learn about the projects mainly from social media but also from information campaigns run by non-governmental organisations (NGOs), on TV, from newspapers, or in the broadcast media. Thus, social acceptance of large-scale energy projects in Jordan is clearly related to the general understanding that these projects enhance Jordan's energy security and lessen its dependence on imported energy (ibid.). Low prices for PV systems are also a major reason for their broad social acceptance. However, PV panels are often damaged, seeing as people lack information on how to properly handle the systems (Shahin, 2015).

Today, there are a number of institutions that concentrate on training those in the field of RE. Several universities offer graduate programmes in RE technologies. Moreover, the National Energy Research Centre (NERC) contributes to research & development (R&D) in the field of RE. In addition, the Jordanian Engineers Association operates an Engineers Training Centre (ETC) with a focus on RE technologies. In October 2021, the Energy Academy of Germany and Jordan was also launched. It aims to become a training facility for upskilling technicians in RE technologies.

Overall, Jordan has well-established institutions that contribute to awareness, acceptance, and technical training in the field of RE. However, awareness campaigns remain limited and fail to teach people how to properly use PV panels. This leads to the damaging of solar installations and, in some cases, acts of vandalism.

Summary of the Landscape and System Level Developments

At the landscape level, the COVID-19 pandemic is expected to affect the energy transition at least in the short term but potentially also in the long term. Other barriers to the development of the energy transition at system level reflect technical, financial, and regulatory patterns.

Although Jordan started the liberalisation of its electricity market and guarantees priority access for electricity generated from renewables, the electricity market remains a single buyer market, with NEPCO having a monopoly. Despite a stable and clear policy and regulatory framework, attractive incentives such as the net metering system, and significant interest from international companies to invest in the Jordanian market, Jordan still lacks a broad and long-term vision for its energy sector up to 2050 (Franceschini, 2019).

In summary, at the system level, a number of factors currently limit Jordan's progress in the energy transition: its long-term natural gas agreements, the cap on RE system installations above 1 MW, an overstressed grid, and the high number of refugees entering Jordan and substantially increasing the energy demand. All these aspects together impede the energy transition in Jordan. Challenges, including the pandemic and the recently inaugurated oil shale facility in Attarat that is likely to create technological lock-ins, are hindering the pace of Jordan's energy transition. Nevertheless, Jordan has not only managed to implement the Renewable Energy and Energy Efficiency Law No. 13 and its Bylaws on tax exemptions and energy efficiency, but it is also increasing the share of renewables in its electricity mix. These actions indicate that Jordan has entered the first phase of the energy transition towards a renewables-based system according to the applied MENA energy transition phase model. The country currently lies between the first and second phases.

Table 4-3 summarises the current trends and goals of the energy transition according to relevant indicators.

Table 4-3

Current Trends and Goals of the Energy Transition

Category	Indicator	2005	2010	2015	2018	2020	2030	2050
Carbon Emissions (Compared to 1990)	CO2 emissions per unit of GDP	-7%	-30%	-23%	N/A	N/A	-	-
	CO2 emissions per capita	+23%	0%	0%	-12%	N/A		
RE	Installed and planned capacity (MW)	N/A	17	177	1,142	1,401 (2019)	3,200	-
	Share in final energy use	1.7%	3%	3.2%	6.3	N/A	14%	-
	Share in electricity mix (existing and planned)	0.6%	0.5%	0.9%	10%	14 (2019)	11%	-
Efficiency	Total primary energy supply (TPES) (compared to 1990)	+104.3%	+117.1%	+163.6%	+178.6%	N/A	-	-
	Energy intensity of primary energy (compared to 1990)	-9.3%	-28.7%	-24.2%	N/A	N/A	-	-
	Total energy supply (TES) per capita (compared to 1990)	+33.3%	+11.1%	0%	0%	N/A	-	-
	Electricity consumption per capita (compared to 1990)	+77.8%	+111.1%	+111.1%	+111.1%	N/A	-	-
	Fossil fuel subsidies (share of GDP)	N/A	10.5% (2013)	3.6%	N/A	N/A		
Buildings	Residential final electricity consumption (compared to 1990)	+265.3%	+498.7%	+728%	+805.3%	N/A	-	-

Category	Indicator	2005	2010	2015	2018	2020	2030	2050
Transport	Total final energy consumption (compared to 1990)	+77.7%	+93.3%	+188.1%	+231.8%	N/A	-	-
	CO_2 emissions in the transport sector (compared to 1990)	+66.7%	+66.7%	+166.7%	+200%	N/A	-	-
	Number of electric vehicles (EVs)	N/A	N/A	N/A	18,000	20,000	-	-
Industry	Carbon intensity of industry consumption (compared to 1995)	-0.3%	-10.9%	-11.7%	-15.2%	N/A	-	-
	Value added (share of GDP)	25.5%	26.2%	25.2%	24.5%	23.9%	-	-
Supply Security	Natural gas imports (compared to 2009)	N/A	+78.6%	+52.9%	+199.4%	N/A	-	-
	Oil products imports (compared to 1990)	+37.8%	+104.5%	+310.8%	N/A	N/A	-	-
	Electricity imports (compared to 2005)	N/A	N/A	-20%	+60%	N/A	-	-
	Electricity exports (compared to 2005)	56%	73.7%	71%	62%	N/A	-	-
	Coal imports (compared to 2008)	N/A	N/A	N/A	+17.1%	+50%	-	-
	Electricity access by population proportion	99.2%	100%	99.9%	99.9%	N/A	-	-
Investment	Decarbonisation investments (USD million)	N/A	6.9	252.2	89	N/A	-	-
Socio-economy	Population				10,203,140	-	-	
	Population growth	3.2%	5.2%	3.8%	1.8%	0.9%	-	-
	Urbanisation rate	N/A	86%	90.2%	90.9%	91.4%	-	-
	GDP growth	8.1%	2.3%	2.4%	1.9%	-1.5%	-	-
Water	Level of water stress	95.9%	98.9%	96.1%	100%	N/A	-	-

(Source: Based on data from FES (2019); BP (2020); FAO (2020); IEA (2020a); IRENA (2020); Statista (2020); The World Bank (2020a); Abu Dayyeh (2021))

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). Along with the aforementioned advances towards RE at the system level in Jordan, previous and parallel developments have been made at the niche level. Jordan displays clear progress in terms of potential flexibility options, which is represented by pumped storage projects, battery storage projects, e-mobility, and hydrogen.

• Pumped Hydroelectric Energy Storage Dam (PHES)

A feasibility study is being carried out to evaluate the viability of a pumped hydro storage project at the Al-Mujib dam in Jordan (Hydropower & Dams, 2020). A pre-evaluation has shown that the Al-Mujib dam has the lowest projected specific cost of energy storage compared to other dams (such as the Wadi Al-Arab and King Talal dams). The Al-Mujib dam is, therefore, considered to have the greatest potential of all sites studied so far (IRENA, 2021). In the same region, a new dam, Wadi Nukheila, is being developed. It could be used as an upper reservoir for the intended pumped-storage project (Hydropower & Dams, 2020). The 200 MW pumped-storage dam in Al-Mujib could function as an option for energy storage in Jordan, as energy storage is considered critical for progressing towards the next phase of the energy transition. However, water shortages at the Al-Mujib dam could limit the storage potential (Farah, 2021).

- **Battery Storage**

In response to the increasing share of renewables in the grid network, MEMR has initiated a study to examine "the potential for battery energy storage" (Fichtner, 2021) and will aid the execution of a pilot project. "This project involves developing a novel BOO model, which enables the grid operator to flexibly dispatch the electrical storage facility" (Fichtner, 2021). Philadelphia Solar's subsidiary, Al Badiya, has signed a 20-year PPA with IDECO to operate the large-scale lithium-ion battery with an electrical storage capacity of 12 MWh coupled to a 23 MW PV farm (EDAMA, 2020). This project is considered to be the largest solar-battery-storage project in the MENA region to date. The project shows the relevance of energy storage in the transition to renewables to ensure grid stability, optimise the use of conventional generation, and provide load shifting services.

- **E-mobility**

Jordan is one of the first countries in the MENA region to develop electrical transportation (Shalalfeh et al., 2021). Progress towards e-mobility is incentivised by a favourable tax system that exempts EVs from registration fees, tax, and import tariffs (Holtz et al., 2018). In 2015, Jordan began to sell hybrid vehicles, and by 2018 EVs became largely available (Bsisu and Bahlawan, 2019). Moreover, the Jordan National Vision 2025, which was initiated by the government, aims to expand the EV infrastructure (Shalalfeh et al., 2021), and the German company "eCharge" has signed an agreement for the installation of 10,000 charging stations (ibid.). The political support for e-mobility has further enabled Jordan to take essential steps towards direct electrification of the transportation sector, thereby starting sector coupling activities.

- **Desalination Plant**

In 2020, the Ministry of Water and Irrigation launched the first phase of the Aqaba-Amman desalination and water transport project, "National Water Carrier Project". Through a build, operate, and transfer (BOT) scheme, the seawater desalination facility will provide fresh water to other parts of the country. The maximum capacity will be around 300 million m3, and the project will require a power plant with a generation capacity of 400 MW. According to the Ministry of Environment, 50% of the required power should be delivered by renewable sources. The operation will start by 2027 (Jordan Times, 2021c).

- **Hydrogen**

MEMR has expressed interest to venture into hydrogen technology (FuelCellsWorks, 2021; Jordan Times, 2021b). In December 2021, a stakeholder discussion on green hydrogen was organised in frame of the research project MENA Fuels, implemented by the Wuppertal Institute with the support of the Jordanian-German Energy Partnership and the National University College of Technology. During the workshop, the energy state secretary stressed Jordan's potentially important role in green hydrogen production and exports. He confirmed that green hydrogen will be added to Jordan's new energy strategy as part of a critical step towards a green economy (Jordan Times, 2021b). The development of hydrogen and PtF conversion routes, which have increasingly become a subject of political debate in Jordan, illustrates the political will to move towards the next step of system integration and PtF/G via the development of shared visions and strategic plans.

4.1.3 Necessary Steps for Achieving the Next Phase

Jordan has already taken considerable steps towards a RE transition and can be categorised as being in a transition phase between the first phase, 'Take-Off Renewables', and the second phase, 'System Integration RE', according to the applied MENA energy transition phase model. In order to proceed with its energy transition and reach the second phase 'System Integration RE', Jordan must strengthen its efforts in the field of integration and flexibility. This includes developing storage options and exploring sector coupling and electrification of industrial processes as flexibility options.

RE has an important role to play in improving energy security, reducing costs, protecting the environment, and supporting Jordan›s recovery from the COVID-19 crisis (IRENA, 2021). To fulfil this role, actions to improve transmission, distribution infrastructure, storage, DSM, flexible generation, and sector coupling must be designed and implemented (ibid.). Furthermore, synergies and integration between digitalisation, storage, and mobility need to be harvested.

The grid infrastructure must be expanded and strengthened to align with the RE development plans. It will be necessary to integrate an increasing share of renewables into the grid while ensuring stable and reliable infrastructure. Jordan needs to invest in upgrading its equipment, such as transformers, and it has to improve the system management (IRENA, 2021). This will be even more crucial when the broad adoption of EVs creates additional demand for electricity. Therefore, investments must be made in smart grid and metering systems, and the associated digitalisation must be undertaken. It will be important to create a good network infrastructure for cloud computing services. This will also increase energy efficiency and reduce down-stream losses. New regulations for DC-Coupling, AC-Coupling, and Hybrid-Coupling for solar energy plants with batteries will be required as well.

Wheeling and net metering projects are essential for Jordan's energy transition (IRENA, 2021). Rooftop solar has enormous potential but has not yet been fully exploited. Thus, additional programmes to further upscale this technology are needed. Moreover, in order to expand renewables, it will be crucial to lift the cap on projects above 1 MW. This action will positively impact the dynamic of private investments within the RE sector, and it can reduce the energy-related production of companies and increase their competitiveness. The cost allocation of electricity also needs to be revised and distributed amongst end users to alleviate the costs borne by distribution companies (ibid.).

To match future demand and supply, it is vital to actively implement storage measures (IRENA, 2021). Jordan is already investigating and piloting several new storage options, such as battery storage and additional pumped storage systems. Battery storage can increase flexibility on the demand side, while pumped hydro storage dams, which are dispatchable sources at the operational and transmission levels, offer grid stability. These flexibility services can replace expensive peak pow-er plants and, simultaneously, reduce the overall system costs (ibid.). In parallel to exploring these storage options, Jordan needs to form a detailed peak and storage strategy. More projects focusing on effective grid integration through hybrid solu-tions (for example, solar-storage, solar-wind, concentrated solar power (CSP)-PV) need to be studied and implemented as well. Other measures such as a vehicle-to-grid strategy could also be explored to provide grid services including storage and demand shifting (Abu Hamed and Bressler, 2019; IRENA, 2021).

A smooth energy transition requires a sector coupling strategy along with load shap-ing measures (IRENA, 2021), and the electrification of end use sectors will drive the demand for power. Therefore, it is crucial to develop DSM and load shaping strate-gies, as peak demand may not coincide with peak renewable generation.

The current tariff structure must be revised to better fit the RE generation patterns. For example, time-of-use tariffs could support load shifting and load shaping (ibid.). As well as the introduction of carbon-taxing regulations for all RE applications will support the deployment.

To support the electrification of transport, the charging infrastructure needs to be expanded. Currently, EMRC provides the licences for public and private charging stations. Yet, the ministries involved—such as MEMR and the Ministry of Transport—need to develop coordinated strategies and long-term roadmaps with clear targets. The potential of green hydrogen for industrial uses or heavy transport, where direct electrification is not feasible, needs further exploration, seeing as it could add to the sector coupling strategy. This development will, however, strongly depend on the costs of green hydrogen as well as environmental aspects such as water demand.

At the regulatory level, the development of long-term targets for end use sectors (power, heating, cooling, and transport) is crucial to increase the share of renewa-bles in the overall energy mix. The development of flexibility options, such as the pumped hydro storage dam, and the electrification of the transport sector require strong coordination between ministries, stakeholders, municipalities, and other rel-evant actors. MEMR and other stakeholders, such as NEPCO and the distribution companies, need to create exchange formats and regularly communicate and col-laborate in projects to advance the energy transition in Jordan. Not only must the stakeholders from the energy sector collaborate with another, but actors from other institutions must also work together for a successful energy transition. For example, it is necessary to cooperate with the Ministry of Water and Irrigation to ensure pro-gress is made on pumped storage projects. Similarly, to develop a charging infra-structure for EVs, MEMR must cooperate closely with the Ministry of Transport. These examples show the need for considering and creating integrated plans and policies between ministries (IRENA, 2021).

At the governance level, the simplification of regulations needs to be improved to reduce the permit procedures for RE applications. Furthermore, the private sector needs to be encouraged to invest in the electrification of the transport sector. This can be achieved with adequate governance mechanisms and transparent processes.

The energy transition must occur at all levels to maximise economic, environmental, and societal benefits. For emerging markets, such as Jordan, the energy transition offers the opportunity to create jobs, foster local value chains, and develop new in-dustries. The requirement for a local content, which is currently 35% for RE projects, is an important factor in promoting positive economic impacts and should be main-tained, but it should be carefully weighed so as not to hinder the development of projects (IRENA, 2021). Constant and close assessment in this area is, therefore, necessary.

At the societal level, education about REs must be further expanded. Outreach in the media about accessible financing systems as well as information campaigns should be strengthened (IRENA, 2021). One step could be the establishment of energy in-formation centres that offer concrete technical and financial advice as well as gen-eral information on transformation strategies in a transparent and appropriate manner. This can help to further increase social acceptance.

4.2 Outlook for the Next Phases of the Transition Process

The case of Jordan shows that the political context and the need for energy security are significant drivers in the uptake of REs. Jordan's robust policy and regulatory frameworks have enabled the solid development of the domestic RE sector. For ex-ample, by adopting Law No. 13 on Renewable Energy and Energy Efficiency, the RE sector received a clear legal and political mandate. Bylaws that have been added or amended over time have contributed to raising the sector's performance.

However, Jordan lacks a long-term vision beyond 2030. Long-term planning is neces-sary, especially in a capital-intensive sector like the RE sector, in order to guarantee stability and increase planning security. Such plans include binding RE targets for 2040 and 2050 as well as a decarbonisation strategy for all energy consuming sec-tors in line with the Paris Agreement. The renewed NDCs represent a first step in this direction.

Also, the construction of the new oil shale power plant and the plans to build several conventional power plants, which are likely to create new path dependencies in the energy system, are clear obstacles to the progress of the sustainable energy transition, as shown by the phase model. While fossil fuels (particularly gas) can be used in the short term during the transitional stage, the long-term aim must be for renewables to become the primary energy source. Whether Jordan will make further progress towards a more sustainable electricity system is, therefore, still unclear, although many signs point in the right direction.

To continue on this path, it is crucial to increase cooperation between different sec-tors and levels of governance. MEMR and NEPCO, in particular, will play a key role in the transition to a renewables-based energy system. In addition, the liberalisation of the power sector should be further pursued to include transmission and distribu-tion. Initial ideas to separate NEPCO's activities into independent entities for renew-ables and fossil energy could be a step forward to remove restrictions and bottle-necks and to strengthen renewables.

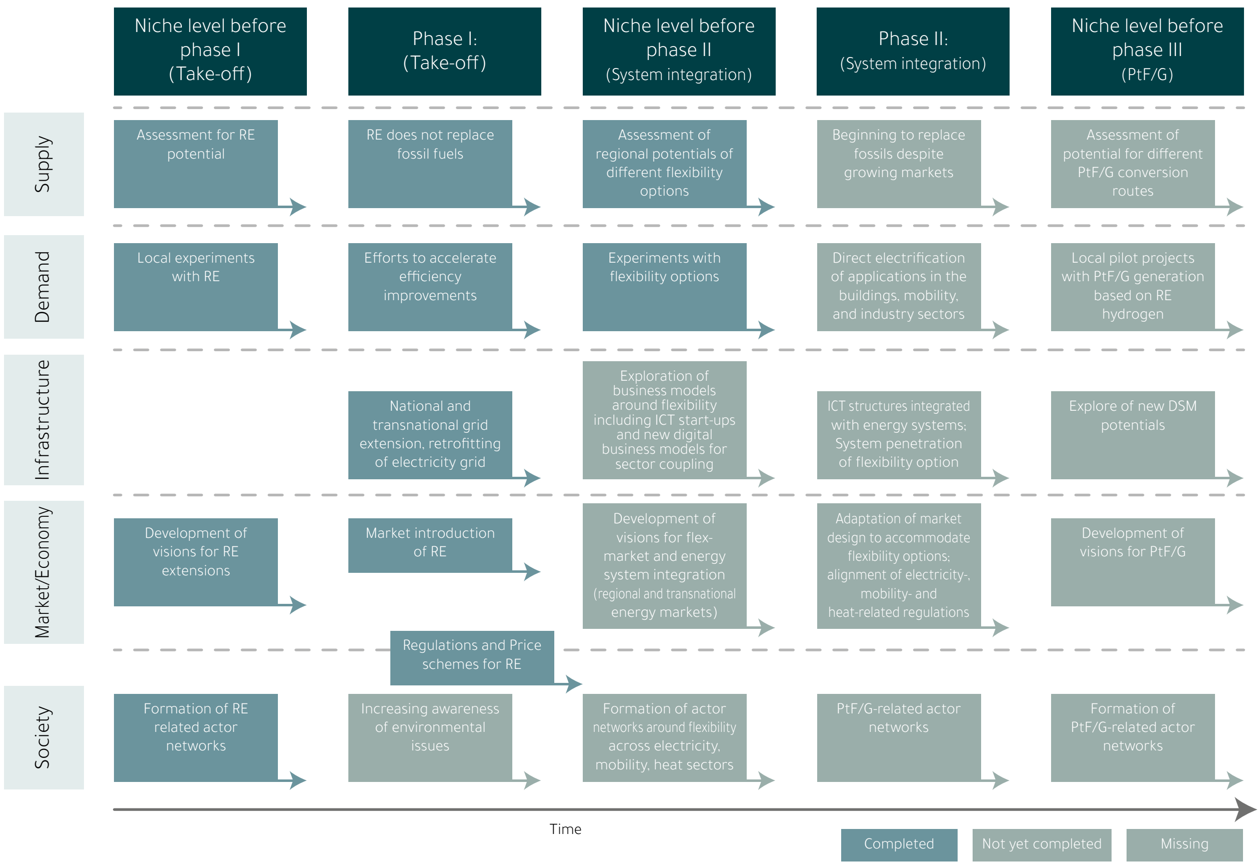
It is also necessary to expand the transmission grid structure, as outlined in the Green Corridor project, seeing as demand centres are localised in the middle of Jor-dan, whereas the greatest potential for RE is in the south. This step would lay the groundwork for the large-scale transport of renewable electricity within the country. Furthermore, there is currently a lack of smart grids and grid management technologies to transport significant amounts of renewable electricity to demand centres. The planning of infrastructure capacity must, therefore, be approached and developed holistically to accommodate the increasing share of RE.

The expansion of REs can contribute to employment and local value creation, which is a great opportunity, especially for a developing economy like Jordan. In order to take full advantage of this opportunity, Jordan must continue to invest in training not only in the form of higher education but also in the form of vocational training. In addition, knowledge transfer will be particularly important for new technologies. This can be done by involving local research institutes in international research pro-jects or pilot projects in Jordan or the MENA region. Study exchanges can also be done to achieve this step. Considering the energy transition not only from an eco-nomic point of view but also from a socio-economic perspective can help to address broader issues such as energy and climate justice. Involvement of different stake-holders, the private sector, and representatives from civil society can increase transparency and participation.

In summary, fossil fuels (particularly gas due to Jordan's long-term purchase agreements) will remain key components of the energy system in Jordan in the short to mid-term. Nevertheless, RE should be integrated into long-term strategic planning at an early stage to seize economic opportunities and enable a smooth transition. The current energy strategy does not provide an integrated approach to effectively incorporate the entire energy system and align it with long-term goals. Therefore, Jordan needs to develop a long-term strategy and would be well advised to embark on a sustainable path sooner rather than later to avoid technological lock-in effects and stranded investments in the fossil fuel sector.

Fig. 4-12 summarises Jordan's current status in the energy system transition and gives an outlook on the following steps.

Fig. 4-12
Overview of Jordan's Status in the Energy System Transition Model



(Source: Special preparation based on the Friedrich-Ebert-Stiftung (2011))

5

Conclusions and Outlook

A clear understanding and a structured vision are prerequisites for fostering and steering the transition towards a fully renewables-based energy system. The MENA phase model was adapted to the country case of Jordan in 2018 in order to provide information to support the energy system's transition towards sustainability. The analysis has been updated in response to rapid change in the sector in the past years. The model, which built on the German context and was complemented by insights into transition governance, captures differences between general underlying assumptions, characteristics of the MENA region, and the specific Jordanian context.

The model, which includes four phases ('Take-off RE', 'System Integration', 'PtF/G', and 'Towards 100% Renewables'), was applied to update and determine Jordan's position in 2021 regarding its energy transition towards renewables. The analysis shows that Jordan has taken essential steps towards a RE transition. According to the MENA phase model, Jordan can be classified as being in a transitional stage between the first phase, 'Take-Off Renewables', and the second phase, 'System Integration'. Nevertheless, fossil fuels still play a dominant role in the Jordanian energy sector, and high energy imports make the Jordanian economy vulnerable to fluctuations in world oil and gas prices. To reach a sustainable energy system, Jordan must increase the system integration of REs and introduce comprehensive flexibility measures. These include the development of storage solutions, improved load management, the upgrade of the existing grid infrastructure, enhanced energy efficiency, the electrification of end use sectors, and strong cooperation between stakeholders.

The expansion of domestic REs would significantly contribute to reducing imports of fossil fuels that have caused a major financial burden for Jordan. Thus, REs can help strengthen energy security in the country. In addition to large-scale deployment, decentralised application should be further promoted to advance the energy transition at all levels. The results of the analysis along the MENA energy transition phase model towards 100% RE are intended to stimulate and support the discussion on Jordan›s future energy system by providing an overarching guiding vision for the energy transition and the development of appropriate policies.

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List of Abbreviations

BOO	Build, own, and operate
BOT	Build, operate, and transfer
CCS	Carbon capture and storage
CCU	Carbon capture and use
CEGCO	Central Electricity Generation Company
COVID-19	Coronavirus disease 2019
CSP	Concentrated solar power
dena	German Energy Agency
EDCO	Electricity Distribution Company
EMRC	Energy and Minerals Regulatory Commission
EPC	Engineering, procurement, and construction
ESCO	Energy Services Company
ESCWA	United Nations Economic and Social Commission for Western Asia
ETC	Engineers Training Centre
EU	European Union
EV	Electric vehicle
FAO	Food and Agriculture Organization
FES	Friedrich-Ebert-Stiftung
FiT	Feed-in tariff
GCC	Gulf Cooperation Council
GDP	Gross Domestic Product
GG-NAP	Energy Sector Green Growth Action National Action Plan 2021–2025
GHG	Greenhouse gas
ICT	Information and communication technologies
IDECO	Irbid District Electricity Company
IEA	International Energy Agency
INDC	Intended Nationally Determined Contribution
IRENA	International Renewable Energy Agency
JD	Jordanian Dinar
JEPCO	Jordan Electric Power Company
JREEEF	Jordan Renewable Energy & Energy Efficiency Fund
LNG	Liquefied natural gas
LSE	London School of Economics and Political Science
MEMR	Ministry of Energy and Mineral Resources
MENA	Middle East and North Africa
MLP	Multi-level perspective
MoU	Memorandum of Understanding
NDC	Nationally Determined Contribution
NEEAP	National Energy Efficiency Action Plan
NEPCO	National Electric Power Company
NERC	National Energy Research Centre
NGO	Non-governmental organisation
PPA	Power Purchase Agreement
PtF	Power-to-fuel
PtG	Power-to-gas
PtX	Power-to-X
PV	Photovoltaic
R&D	Research & Development
RCREEE	Regional Center for Renewable Energy and Energy Efficiency
RE	Renewable Energy
SEPCO	Samra Electric Power Company
SHAMCI	Solar Heating Arab Mark and Certification Initiative
SWH	Solar Water Heaters
UNFCCC	United Nations Framework Convention on Climate Change
USD	US-Dollar

List of Units and Symbols

%	Percent
AC	Alternating current
CO2	Carbon dioxide
DC	Direct current
GW	Gigawatt
GWh	Gigawatt hour
kgoe	Kilogramme of oil equivalent
ktoe	Kilotonne of oil equivalent
kV	Kilo Volt
kW	Kilowatt
kWh	Kilowatt hour
m3	Cubic Metre
m/s	Metre per second
Mt	Megatonne
Mtoe	Millions of tonnes of oil equivalent
MVA	Megavolt-ampere
MWh	Megawatt hour

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About this study

This study has been conducted as part of a regional project applying the MENA 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 the current state of the energy transition processes in the respective countries. It also offers key learning points for the whole region based on findings across the analysed countries. This aligns with FES's strategy of bringing together government representatives and 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.

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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 Jordan. It is designed to support the strategy development and to serve as a guide for decision-makers.

The analysis shows that Jordan has taken essential steps towards a RE transition. According to the MENA energy transition phase model, Jordan can be classified as being in a transitional stage between the first phase, 'Take-Off Renewables', and the second phase, 'System Integration'. However, fossil fuels continue to play a dominant role in the Jordanian energy sector, and the fluctuating world market prices for fossil fuels impact the economy.

The expansion of domestically produced RE could significantly contribute to reducing Jordan›s high imports of fossil fuels. This simultaneously increases energy security and reduces the trade deficit.

To move towards a sustainable energy system, Jordan needs to embrace comprehensive flexibility measures. These include developing storage options, improving load management, upgrading the existing grid infrastructure, enhancing energy efficiency, exploring the electrification of end use sectors, and creating strong cooperation between stakeholders.

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