STUDY

CLIMATE CHANGE, ENERGY AND ENVIRONMENT

SUSTAINABLE TRANSFORMATION OF ALGERIA'S ENERGY SYSTEM

Development of a Phase Model

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

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The energy transition towards renewables presents a long-term opportunity for economic and social development in Algeria.

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Algeria has sufficient potential to export renewable energy in various forms in the future, which offers the opportunity to replace declining revenues from fossil fuels.

FRIEDRICH EBERT STIFTUNG

CLIMATE CHANGE, ENERGY AND ENVIRONMENT

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Wuppertal Institut

Contents

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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 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 renewable energy 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 – renewable energy 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 renewable energy production. The significant potential in the MENA region for renewable energy production, in particular wind and solar power, creates an opportunity both to produce electricity that is almost CO_2 neutral and to boost economic prosperity. However, most countries in the region still use fossil fuels as their dominant energy source, and dependency on fossil fuel imports in some of the highly populated countries poses a risk in terms of energy security and public budget spending.

A transition towards a renewables-based energy system involves large-scale deployment of renewable energy 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 Algeria. The current state of development in Algeria is assessed and analysed against the phase model. Expert interviews were conducted to gain insights to specify the previously defined abstract components of the model. As a result, further steps for the energy transition (based on the steps of the phase model) are proposed. This application is based on findings from previous studies and projects conducted in the MENA region, while case study specific data was collected for this study by local partners and the expert Zineb Mechieche.

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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 renewable energies. The four phases of the models correlate with the main assumptions deduced from the fundamental characteristics of renewable energy sources, labelled as follows: »Take-off Renewable Energies (RE)«, »System Integration«, »Power-to-Fuel/Gas (PtF/G)«, and »Towards 100% Renewables«.

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

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

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

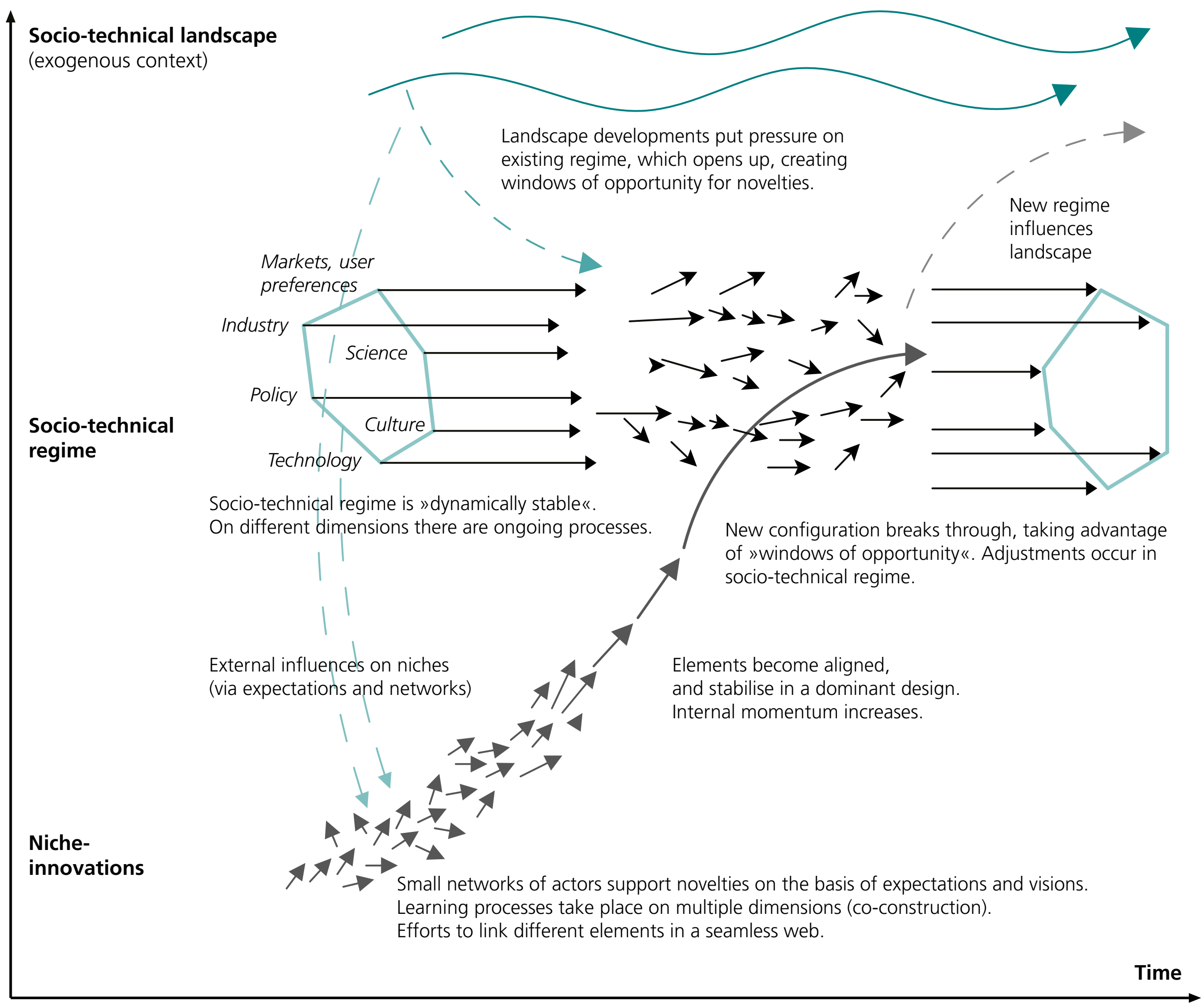
1 Text is based on Holtz et al. (2018).

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

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

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

Figure 2-1
The Multi-Level Perspective



Source: Geels and Schot, 2007

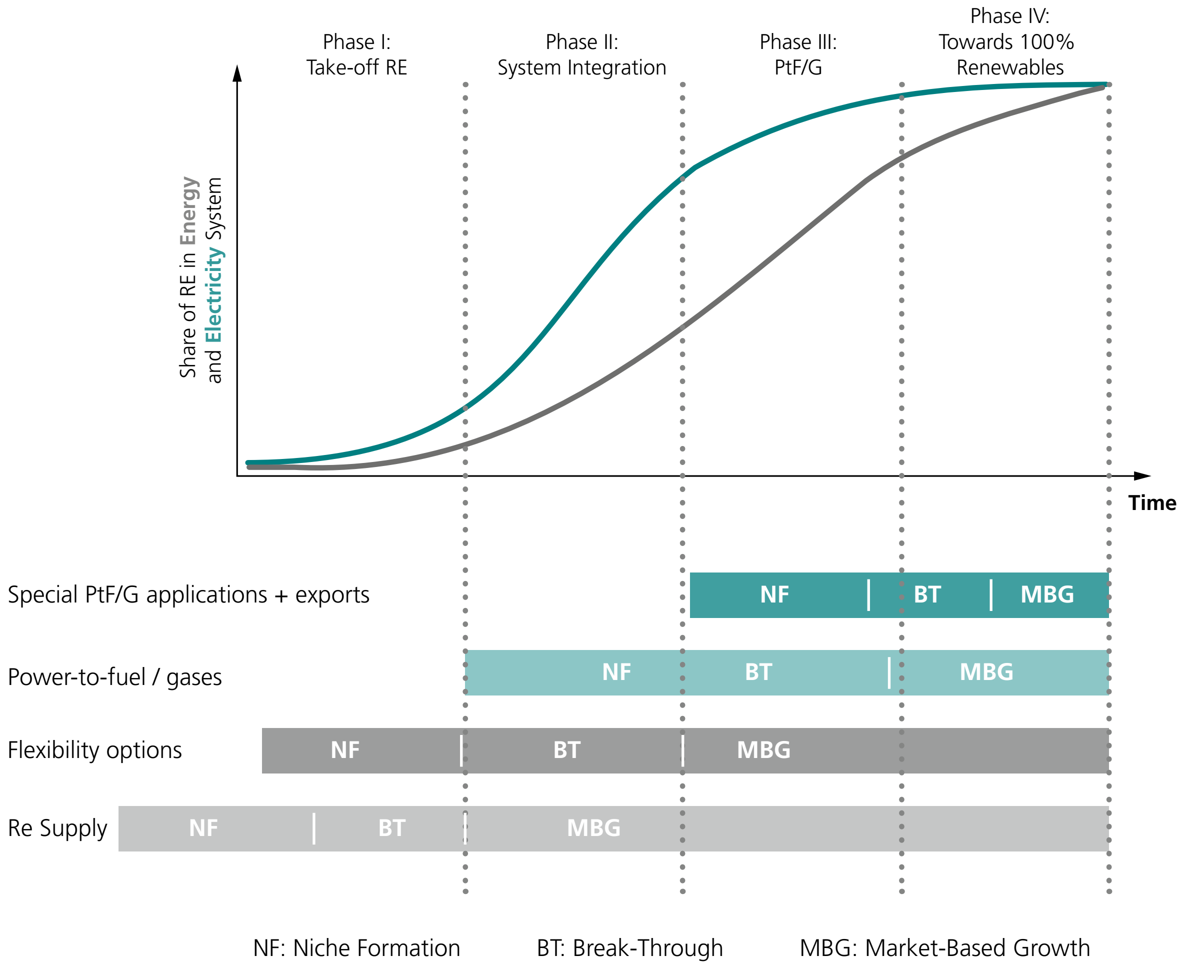
»market-based growth«. In the »niche formation« stage, a niche develops and matures, and it may offer solutions that can be absorbed by the regime. Within this stage, expectations and visions that provide direction to learning processes are essential. In addition, actor involvement and social networks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

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

2.3 ADDITIONS IN THE MENA PHASE MODEL

Assuming that the phase model for the German energy transition by Fischedick et al. (2014) and Henning et al. (2015) is relevant for the MENA countries, the four transition phases remain the same. The »system layer«, which was adopted from the original phase models, provides clear targets for the development of the system by orienting guidelines for decision-makers. Since niche formation processes are required for successfully upscaling niche innovations, a »niche« layer was added into the original phase model by Fischedick et al. (2020). A specific cluster of innovations was identified for each phase: renewable energy 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. Therefore, specific governance measures support the breakthrough and upscaling processes in the current phase. In later phases, the innovation clusters continue to spread through market-based growth (Fischedick et al., 2020). Consequently, the addition of the »niche layer« creates

Figure 2-2
Transition Phase Model for the MENA Regio



Source: Holtz et al., 2018

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

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

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

3

THE MENA PHASE MODEL

3.1 SPECIFIC CHARACTERISTICS OF THE MENA REGION

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

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

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

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

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

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

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

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

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

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

3.3 PHASES OF THE ENERGY TRANSITION IN MENA COUNTRIES

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

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

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

Phase 1 – »Take-Off Renewable Energies (RE)«

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

Developments occurring at the »niche« level pave the way for phase 2. The regional potential of different flexibility options is assessed (e.g. the possibilities for pump storage and 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. Expected flexibility needs and sector coupling lay the ground for information and communication technology (ICT) start-ups and new digital business models.

Phase 2 – »System Integration«

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

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

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

Phase 3 – »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. Actor networks are established, initial learning is gained, and business models are studied.

Phase 4 – »Towards 100% Renewables«

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

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

The MENA phase model was exploratively applied to the Jordan case in Holtz et al. (2018). The model was discussed with high-ranking policymakers, representatives from science, industry, and civil society from Jordan. It proved to be a helpful tool to support discussions about strategies and policymaking in regard to the energy transition that can also be applied to other MENA countries. Therefore, the MENA phase model was applied to the country case of Algeria after necessary adaptations were made to it. The results illustrate a structured overview of the continuous developments in Algeria's energy system. Furthermore, they provide insights into the next steps required to transform Algeria's energy system into a renewables-based system.

In order to reflect the specific challenges and opportunities for the energy transition in Algeria, 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 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 renewable energy 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.

Expert interviews were carried out in Algeria by Zineb Mechieche to investigate the country-specific challenges and barriers that could hinder the unlocking of the renewable energy potential in the country. The main interview partners were Solar Cluster – Algeria and Tewfik Hasni, as well as other relevant stakeholders with several years of experience in Algeria's energy sector from political institutions, academia, and the private sector.

Table 3-1
Developments During the Transition Phases

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

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

			Development before phase I	Phase I: "Take-Off RE'	Phase II: "System Integration RE'	Phase III: "Power-to-Fuel/Gas (PtF/G)'	Phase IV: "Towards 100% RE'
			* Niche formation RE	* Breakthrough RE * Niche formation flexibility option	* Market-based growth RE * Breakthrough flexibility option * Niche formation PtF/G	* Market-based growth flexibility option * Breakthrough PtF/G * Niche formation special PtF/G application and exports	* Market-based growth PtF/G * Breakthrough special PtF/G application and exports
Power Sector	Niche level	Techno-economic layer	* Assessment of RE potential	* Assessment of regional potential for different flexibility options	* Assessment of potential for different PtF/G conversion routes	* Experiment with PtF/G applications in sectors such as industry (e.g. steel, cement and chemical sectors) and special transport (e.g. aviation, shipping)	
Power Sector	Niche level	Techno-economic layer	* 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	
Power Sector	Niche level	Techno-economic layer		* 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	
Power Sector	Niche level	Techno-economic layer			• 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)		
Power Sector	Niche level	Techno-economic layer			* Tap into global experiences of PtF/G		
Power Sector	Niche level	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)	
Power Sector	Niche level	Governance layer	* 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)	
Power Sector	Niche level	Governance layer	* 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)	
Power Sector	Niche level	Governance layer	• 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 ALGERIA

Factsheet

Paris Agreement ratified	✔
Green growth strategy	✗
Renewable energy targets set	✔
Regulatory policies for renewable energy implementation established	✔
Energy efficiency strategy existing	✔
Power-to-X strategy	✗

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

Algeria's energy system is highly dependent on fossil fuels, as the country has abundant oil and gas reserves. As a member of the Organisation of the Petroleum Exporting Countries (OPEC), Algeria is one of the world's largest hydrocarbon producers, deriving over 90% of its hydrocarbon revenues from export. However, Algeria also has significant solar potential, as it benefits from over 3,000 hours of sunshine per year and has the largest land area on the continent. Thus, Algeria possesses the potential to become a major player in the renewable energy sector. Yet, presently, the country is barely exploiting this potential and is at a crossroads for the development of a future energy system with competing visions in the political landscape (Hochberg, 2020).

Under the framework of the Paris Agreement, Algeria has committed to reducing its GHG emissions by 7% by 2030 compared to the business-as-usual scenario (INDC-Algeria, 2015). With international support, Algeria could even reduce its GHG emissions by 22% by 2030 (Darby, 2015). However, despite Algeria formulating ambitious renewable energy targets and establishing a regulatory framework for the deployment of renewable energy technologies, the current share of renewables in the overall energy mix remains insignificant. The COVID-19 pandemic has highlighted Algeria's high vulnerability to global oil and gas market prices. The pandemic has also slowed the pace of Algeria's energy transition plans. Nevertheless, the crisis could be the impetus needed to introduce fundamental change and ultimately prioritise clean energy investments in Algeria, although this will depend on the efforts and willingness of key decision-makers in the country.

This study aims to support the discussion about Algeria's future energy system by providing an overarching guiding vision for the transition to a renewables-based system. In order to assist the development of appropriate policy strategies, the current status of Algeria's energy transition and potential developments are assessed in detail along 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 Algeria's energy system in terms of supply, demand, the oil and gas sector, renewable energy, infrastructure, actor network, and market development.

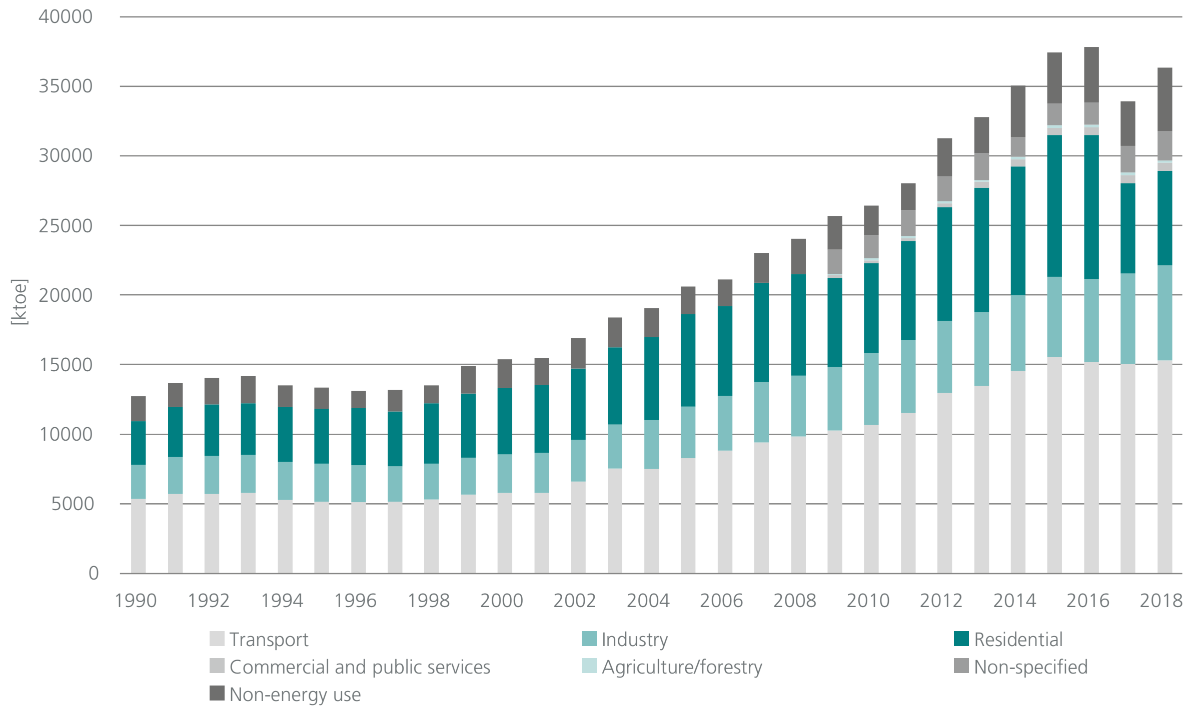
Energy Supply and Demand

Demographic change, industrial development, and urbanisation all drive Algeria's rising energy demand. In 2018, Algeria's total final energy consumption was 36,360 ktoe (IEA, 2020a). Broken down by sector, transport dominated energy consumption (42%), followed by households and industry (19% each), and others (21%) (IEA, 2020a) (Fig. 4-1).

In 2018, the energy mix was dominated by fossil fuels (Fig. 4-2), with natural gas accounting for 63.8%, oil for 35.4%, and coal for 0.6%, while renewable energies had in total a negligible share of 0.1% (IEA, 2020a).

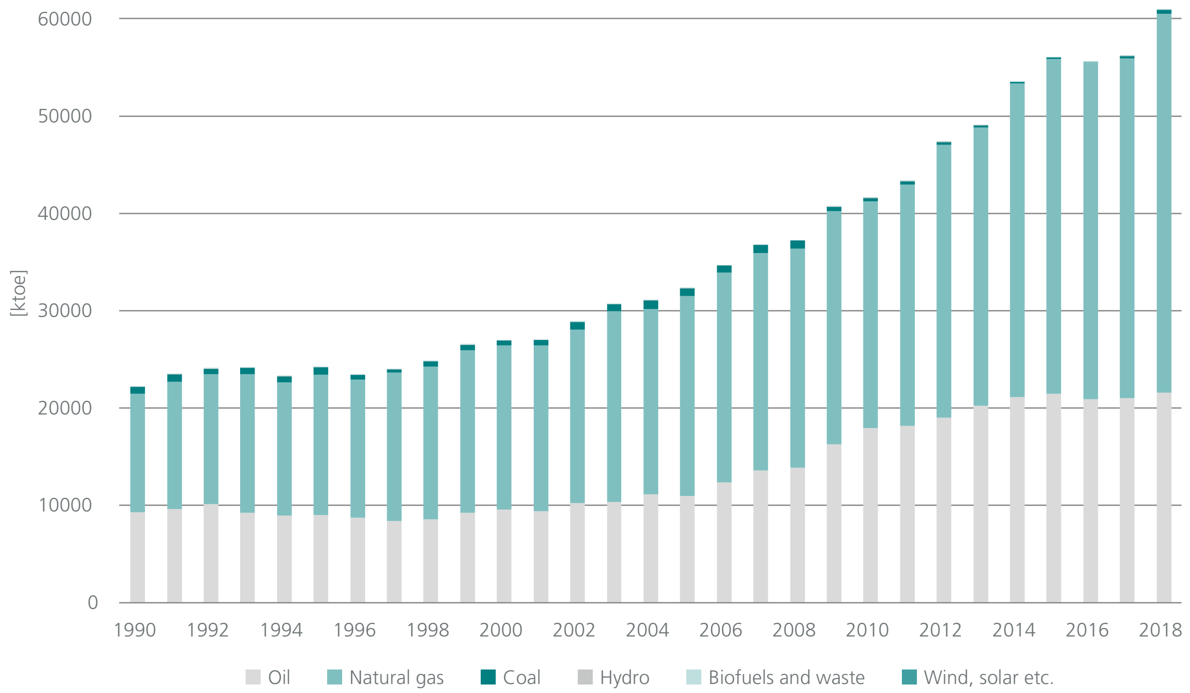
The average growth of energy consumption in Algeria between 2000 and 2017 was around 5%. According to the Commission for Renewable Energy and Energy Efficiency (CEREFE), Algeria had in 2019 a total installed capacity of 20,963 MW (CEREFE, 2020), of which 96% was from natural gas power plants. According to the Commission for Energy and Gas Regulation (CREG), Algeria plans to increase its total installed capacity to 36,000 MW by 2028. In addition to natural gas, the expansion will include solar power plants, which are expected to occupy a 15% share of the installed generation capacity by 2028 (Hochberg, 2020). A plan may also be pending for the development of a nuclear

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



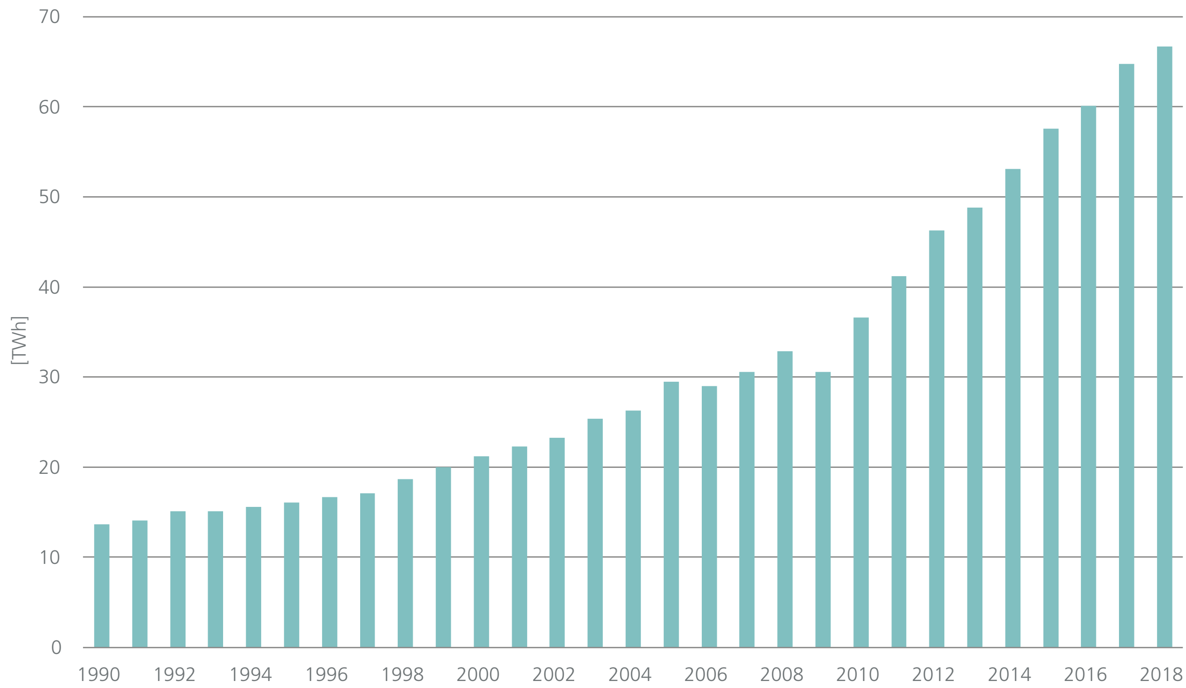
Source: data based on IEA, 2020a

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



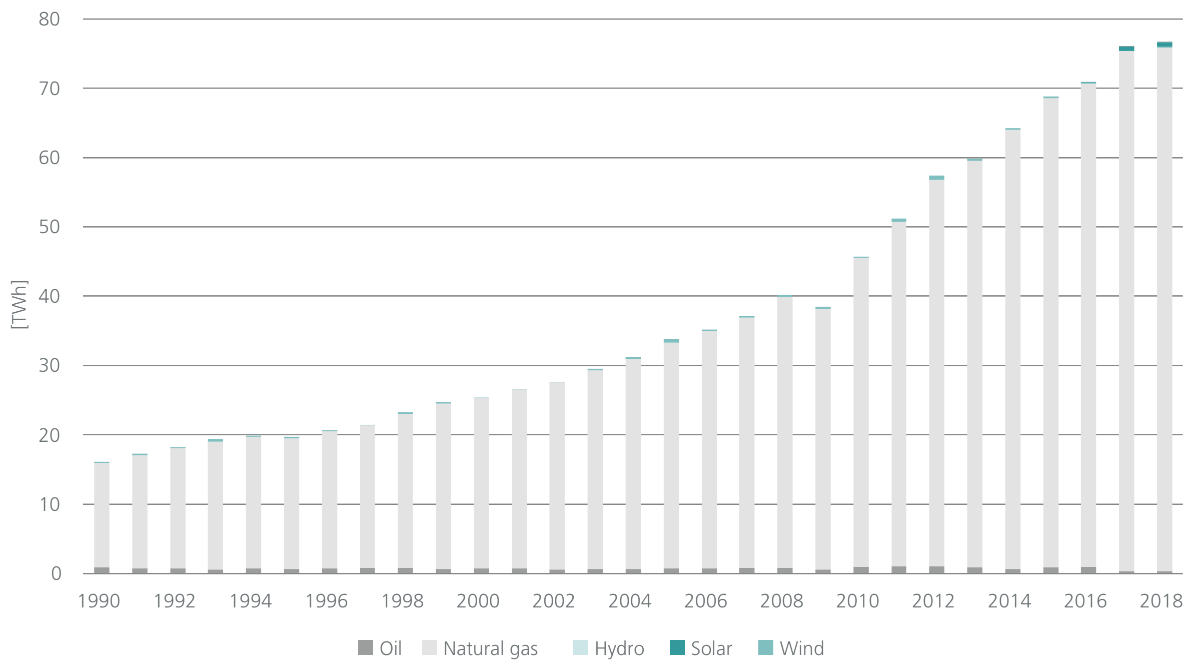
Source: data based on IEA, 2020a

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



Source: data based on IEA, 2020a

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



Source: data based on IEA, 2020a

power plant using the country's large uranium reserves to meet the growing demand for electricity (Xinhua, 2019).

Electricity consumption in 2018 amounted to around 66.7 TWh, which is almost five times the electricity demand in 1990 (Fig. 4-3). In the summer months, the use of cooling technologies is high; thus, demand peaks between 1pm and 3pm. In August 2019, the highest peak for Algeria was registered at 15,656 MW at 2:30pm. According to CREG, it is estimated that Algeria's electricity demand will rise to 150 TWh by 2030 and reach 250 TWh by 2050. This increasing demand is driven by changes in consumer behaviour and in the production processes of industrial goods (Bouznit et al., 2020). Although the capacity reserve margin for 2013 was 47% (The World Bank, 2013), demand for electricity in earlier years exceeded supply (e.g. in 2003 and 2012), leading to regular civil protests. The industry is also highly vulnerable to power outages (Deutsch-Algerische Industrie- und Handelskammer, 2018).

To tackle the increasing levels of consumption, Algeria is planning to integrate a substantial volume of renewable energy into its power network. However, this may be a long road, for by 2018 more than 98% of electricity supply had been generated from natural gas, while the share of renewables had been around only 1% (Fig. 4-4).

The figures show that renewables play only a marginal role in the energy mix and are not yet able to replace fossil fuels to meet Algeria's growing energy needs. This is consistent with the initial phase described in the MENA phase model.

The Oil and Gas Sector

Algeria's substantial hydrocarbon reserves are its economic backbone. As the fourth largest global exporter of liquefied natural gas (LNG), the third largest global exporter of liquefied petroleum gas, and the fifth largest global exporter of natural gas, Algeria is a net exporting country (Fig. 4-5). The hydrocarbon sector contributes 45.9% to Algeria's Gross Domestic Product (GDP). Its most important export regions are Europe (49%) and North America (36%) (Dena, 2014). Due to its natural resources, Algeria plays a crucial role in the European Neighbourhood and Partnership policies. Hence, it has signed several bilateral agreements to integrate free trade zones (Deutsch-Algerische Industrie- und Handelskammer, 2011)

Furthermore, recent discoveries have shown that Algeria has the third largest volume of shale gas resources worldwide (19,800 bn m^3) and 5.7 bn barrels of shale oil (Boersma et al., 2015). Algeria has considered shale gas fracking, but public protests against shale gas exploration have halted its development for the time being. The current pandemic has further impeded any development in this direction due to the global market price drop in oil and gas.

Assessments have also shown that Algeria's resources could far exceed its proven conventional gas reserves. More than half of these reserves are located at Hassi R'Mel in central Algeria. Despite recent discoveries, the exploitation of hydrocarbons has decreased in recent years due to fields drying up and delays to new exploitation. The latter is caused by a lack of national approval, insufficient infrastructure, and technical challenges (Dena, 2014). While the country still produced about 1.5 million barrels of gas per day in 2005, its current daily production has fallen to about 1 million barrels (Germany Trade and Invest, 2020).

Reforms intended to facilitate foreign investment and halt this decline in development were established, notably in 2005. However, they were later reversed by the military and security institutions that had a vested financial and power interest in maintaining the status quo (Boersma et al., 2015). In January 2020, a new energy law aiming to improve investment conditions for foreign companies (through mechanisms including low taxation) entered into force in Algeria (Henle and Schmitz, 2020).

Recent political debate has come out in favour of exporting natural gas, whereas the goal is to replace its domestic consumption with renewable energy. By exporting all the natural gas that it currently uses, Algeria could generate around 200 million USD per year. However, decision-makers in Algeria are cautious, adhering to the narrative of securing energy supplies at all costs (including maintaining existing subsidy structures), owing to the negative impact of the civil war in the 1990s. As a result, it is likely that the current structure of the energy supply regime will remain in place for some years to come.

Renewable Energy

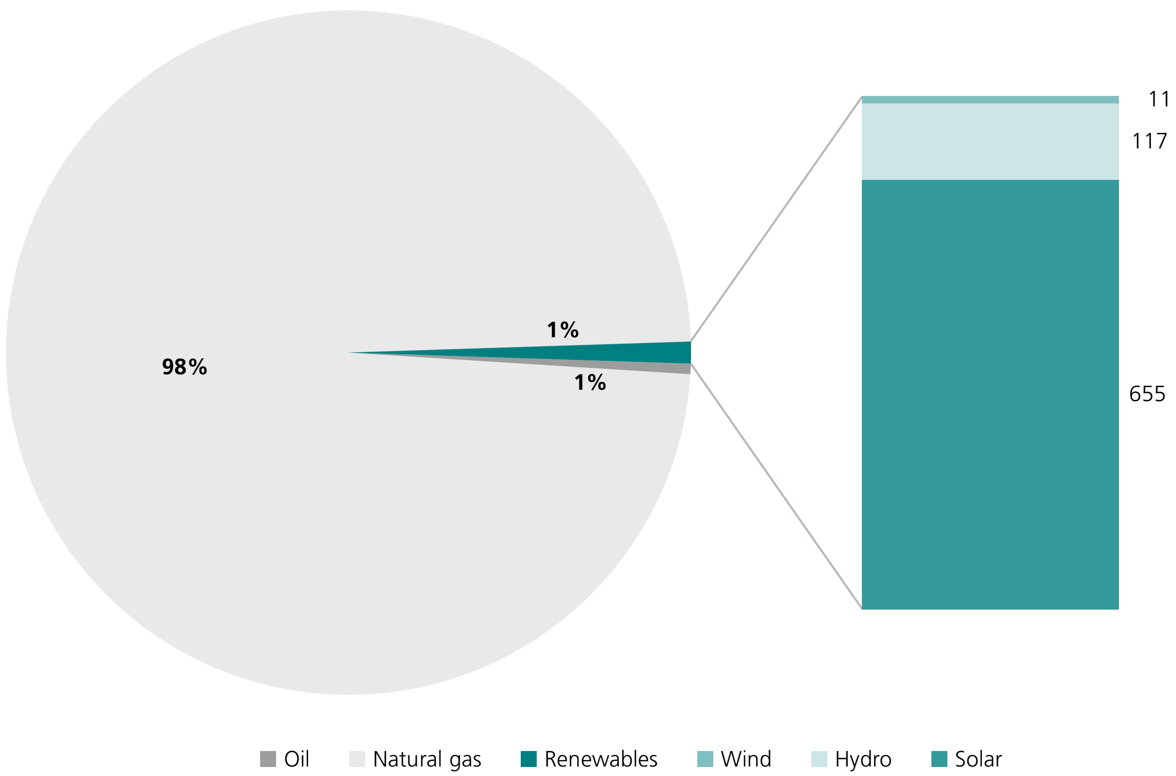
As noted above, renewable sources by 2018 had accounted for 1% of the country's electricity generation mix. In 2018, solar power accounted for 84% of the total electricity generated from renewable sources, while hydropower accounted for 15% and wind power for 1% (Fig. 4-6).

Despite its slow expansion of renewables, Algeria's solar energy potential is among the highest worldwide with daily average irradiation of 6.57 kWh/m^2, making an annual total of between 2,000 kWh per m^2 and 2,650 kWh per m^2. As 86% of Algeria is covered by the Sahara Desert, there is good potential for the implementation of large-scale solar projects. The solar thermal potential is around 170,000 TWh per year, while the PV potential amounts to around 13.9 TWh per year (Dena, 2014). Most of the potential is in the south of the country, while most of the demand comes from the urban centres in the north. Algeria's flagship concentrated solar power (CSP) project – a hybrid CSP-gas power plant – is located in Hassi R'Mel. The plant has a capacity of 25 MWp CSP and 125 MW gas. The investment for this plant was around 313 million Euros, and it started operating in 2011. In 2014, the PV power plant in Ghardaia with a 1.1 MWp capacity started operating, and, in 2018, a further PV power plant with a 10 MWp capacity was commissioned in Bir Rebaa. The renewable energy arm of Sonelgaz, SKTM, has built 22 PV power plants with a total capacity of 343 MWp (see Table 4-1). As well as the larger-scale implemen-

Figure 4-5
Net Energy Imports (in Mtoe), Algeria 1990–2018

Source: data based on IEA, 2020a

Figure 4-6
Electricity Generation Mix (in GWh), Algeria 2018



Source: data based on IEA, 2020a

tations, island micro-grids supplied by solar power have been constructed to meet local demand in the remote and sparsely populated regions in the south. These supply 16 villages with 1.5 GWh per year (Dena, 2014).

Central and Western Algeria are prominent locations for wind energy, with an average wind speed of 7.5 m/s. From the few existing studies available, it can be deduced that the Algerian potential for wind power amounts to 35 TWh per year. A limiting factor is the high share of sand and dust in the air, which could affect the functionality of the turbines. Moreover, transporting heavy wind equipment to remote desert areas (where the potential for wind power generation is the highest) could be a further challenge, as Algeria's desert road networks are not suitable for this kind of traffic (Dena, 2014). In 2014, the first large-scale wind power project, Kabertène, started operating with an installed capacity of 10.2 MWp (see Table 4-1).

The potential to use biomass for energy production is limited and is not included in Algeria's renewable energy deployment plan. Likewise, geothermal potential is not considered for large-scale deployment, although some geothermal potential in areas with limestone and sandstone formations exists (Dena, 2014).

Hydropower potential is also severely limited in Algeria, as the country suffers from water scarcity. Low rates of precipitation, fast discharge, and an extremely high evaporation rate limit the potential for hydropower generation. In addition, most of the river wadis are seasonal. Although Algeria has an installed hydropower capacity of 313 MW and could produce up to 500 GWh electricity per year, only 117 GWh was generated in 2018. There is no record of the installed capacity of small-scale hydropower stations (Dena, 2014). Table 4-1 summarises the operational grid-connected renewable energy projects in Algeria, which have a combined total installed capacity of 389.3 MWp.

Despite the current low levels of renewables, the government has the will to combat climate change and secure Algeria's energy supply by implementing renewable energy projects. Therefore, in 2011 the Ministry of Energy launched its renewable energy and energy efficiency programme, »Programme national d'énergies renouvelables et d'efficacité énergétique« (PNEREE). This plan foresees the installation of 22 GW capacity of renewable energies by 2030, of which 10 GW are intended for export. By 2030, electricity generation from renewables is expected to increase by around 40%, which will equate to a 27% share in the energy mix (REN21, 2019). Achieving this plan will cost Algeria around 86.55 bn Euros (Dena, 2014). Table 4-2 summarises the different phases of the renewable energy programme and refers to the specific energy technology.

The programme was updated in 2015, setting ambitious targets to raise the solar capacity to 13.5 GW by 2030. The share of PV capacity was increased and CSP was withdrawn from the first implementation phase. The main argument for withdrawing CSP technology was its higher costs. However, as energy scenarios show that Algeria's overall energy use splits into 20% for electricity and 80% for heat, the government's decision on CSP might prove to be illogical.

Table 4-2
Renewable Energy Programme 2030 in Algeria (in MWp)

	Phase 2015–2020	Phase 2021–2030	Total
PV	3,000	10,575	13,575
Wind	1,010	4,000	5,010
CSP	–	2,000	2,000
Cogeneration	150	250	400
Biomass	360	640	1,000
Geothermal	5	10	15
Total	4,525	17,475	22,000

Source: data based on CEREFE, 2020

The repercussions of the COVID-19 pandemic, which has led to a global drop in the oil price, are expected to further accelerate the Algerian government's ambition and political will to invest in solar energy (Stahl, 2020). Against this backdrop, Algeria's government has recently shown a keen interest in the possibility of replacing gas-fired power plants with solar power plants. The gas could be exported instead of burnt in Algeria's gas power plants, which could generate foreign currency savings (Henle and Schmitz, 2020).

Table 4-1
Operational Renewable Energy Projects in Algeria

Operational wind power plants				
Site	Kabertène (Adrar)			
Operational Year	2014			
Installed Capacity (MWp)	10.2			
Operational solar power plants (CSP and PV)				
Site	Hassi-R'Mel	Ghardaia	Bir Rebaa Nord (Ouargla)	Programme de SKTM
Type	Solar thermal and steam (natural gas)	PV	PV	PV
Operational Year	2011	2014	2018	2018
Installed Capacity (MWp)	25 (CSP)	1.1	10	343

Source: data based on CEREFE, 2020

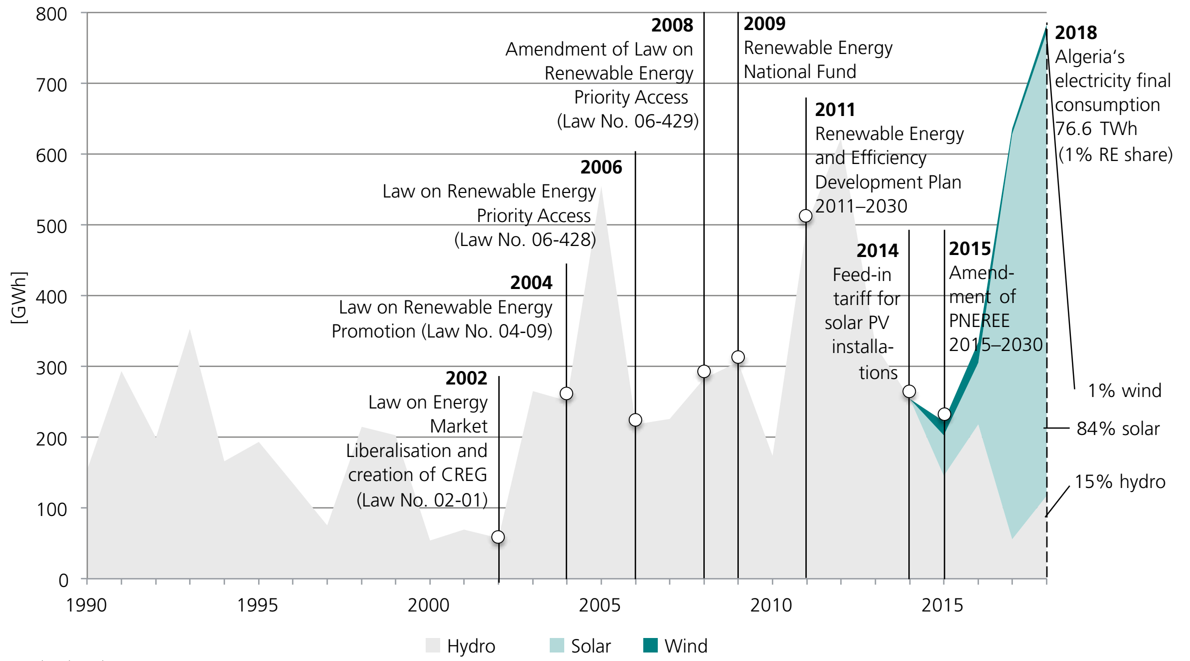
To meet its targets, Algeria is also planning a solar project, Tafouk 1, which consists of five 800 MW tenders. The 4,000 MW project has the potential to increase Algeria's solar manufacturing capacity for modules, racks, and cables. It also provides momentum for meeting Algeria's renewable energy targets (Hochberg, 2020). A substantial element of the tender is the requirement for parts to be locally manufactured; this could cause initial barriers because Algeria's solar market is not yet fully developed. Nevertheless, such policies have the potential to encourage knowledge transfer to the local economy. Located at the crossroads of Europe and MENA, Algeria could, in an optimistic scenario, become a manufacturing supply hub for the renewables industry (ibid.).

Within Algeria, the agricultural sector is a pioneer in using renewable energies. Most of the agricultural sites are in the remote south, far from the transmission network. Some agricultural facilities have, therefore, invested in solar or wind power plants to guarantee uninterrupted business operation for cooling, drying, and processing – as well as for irrigation. However, this has not yet become the industry standard, and the majority of agriculture producers continue to use diesel generators (Deutsch-Algerische Industrie- und Handelskammer, 2018). Several small-scale off-grid projects have also been implemented; these include solar kits and solar and wind pumped irrigation systems (CEREFE, 2020).

To incentivise the deployment of renewable energies, the Algerian government has set up several financing mechanisms. These include power purchase agreements (PPAs), regulated by the Executive Decree No.13-218, and feed-in-tariffs (FiT) for solar energy, wind energy, and cogeneration, which are regulated by the *Arrêtés* of 2014. The feed-in-tariffs vary according to the capacity of the power plant. Wind power plants with a capacity of more than 5 MW receive 9.5 eurocents per kWh, and smaller wind power plants (under 5 MW) receive 11.9 eurocents per kWh. Solar power plants with a capacity of more than 5 MW receive 11.6 eurocents per kWh, and smaller solar power plants (under 5 MW) receive 14.5 eurocents per kWh. CSP projects are not included in the FiT scheme (energypedia, 2020). The National Fund for Renewable Energy and Cogeneration (FNER, *Fond National pour les Energies Renouvelables et la Cogénération*) was also established by the Executive Decree No. 11-423 in 2011, which is financed by a 1% levy on oil tax revenues (RCREEE, 2019). Like Jordan, Algeria provides a statutory guarantee of priority access to the grid for renewables; this is currently a rare mechanism in the MENA region. The Executive Decrees Nos. 06-428 and 06-429 of 2006 and 2008 guarantee this priority access (RCREEE, 2012). Fig. 4-7 depicts the introduction of energy policy measures and their impact on renewable electricity generation by year.

The growth in renewable energy generated since 2014 coincides with the introduction of the feed-in-tariff. The largest growth was achieved the following year after changes were made to the PNEREE. Solar energy accounted for the highest share of renewables, which could be a result of its higher feed-in-tariff. While Fig. 4-7 shows the development of renewable electricity generation and energy policy measures up to 2018, the first tender was only issued in 2019. Perhaps surprisingly, this first tender attracted a low number of bids (Bouznit et al., 2020).

Figure 4-7
Development of Renewable Electricity Generation by Source (in GWh) and Introduction of Energy Policy Measures, Algeria 1990–2018



Source: data based on IEA, 2020a

In summary, when it comes to renewable energy, the Algerian government seems to be taking a gradual approach rather than making rapid large-scale changes. As long as the government continues to subsidise energy prices and the well-developed electricity infrastructure near coastal demand centres remain in place, the pace of the transition to renewable energy is likely to remain moderate. Despite Algeria's potential for large-scale solar projects, several renewable energy projects planned for the period 2006–2014 and 2016–2020 exist only on paper, and renewable energy projects attract negative publicity due to the powerful oil and gas lobby. Algeria has, therefore, not yet met the requirements to be classified as having completed the first phase according to the phase model.

Infrastructure

In Algeria, 99% of the population is connected to the national electricity transmission grid. The grid is 30,515 km in length, 4,497 km of which is a 400 kV high voltage network. The grid is connected to Morocco and Tunisia via the Maghreb Interconnection. Libya is also part of this connection (The World Bank, 2013). Towards Morocco, the transmission lines are 225 kV and 400 kV, with an overall capacity of 1,400 MW. The Tunisian interconnector lines have a total capacity of 900 MW, with voltages of 90 kV, 150 kV and 220 kV. A 400 kV line has also been ready since 2008 on the Algerian side (IRENA, 2014). The Maghreb states have agreed to reform the transmission grid and to work together to improve and harmonise a joint electricity trade market. Furthermore, in the Algiers Declaration of 2010 the nations declared their aim to create a viable market for electricity within the Maghreb states and to integrate this market with the EU, in particular with the Iberian Peninsula (The World Bank, 2013). Work necessary to integrate with the EU is complete on Morocco's side, while Algeria's part is still under development. Moreover, Algeria has plans to establish a Pan-Arab Electricity Market; this intent was marked by the mutual signing of Memorandums of Understanding with other Arab countries in 2017 (Matar, 2020).

The transmission grid assets are owned by *Societé Algérienne de Gestion du Réseau de Transport de l'Electricité* (GRTE – the transmission company owned and operated by Sonelgaz), which acts as a single buyer in the Algerian energy market model. Security of supply is the responsibility of another Sonelgaz entity, *Opérateur système électrique.* GRTE has developed plans to extend the transmission grid in the period 2020 to 2029, creating a total length of 50,280 km (Mansour, 2020a). The distribution sector is monitored by four distribution companies, who supervise their own system. The Algerian grid presently faces several challenges. These include one-way communication, high carbon emission levels, long transmission lines to deliver power, high electricity costs, and fluctuation in the future if increasing levels of renewable energy are fed into the grid (Harrouz et al., 2017). Currently, 389.3 MWp of renewable energy is fed into the Algerian grid, which provides preferential grid-access conditions for renewables, as it guarantees priority of dispatch (RCREEE, 2019). Having a high share of renewables in the electricity structure will create substantial economic advantages in the long term. However, the grid must be able to integrate a high percentage of fluctuating generation, and the grid extensions will depend on suitable sites for renewables (Platzer, 2016). Necessary adaptations must also be made to control distribution systems, such as the net-metering of grid-connected self-producers of renewables (RCREEE, 2019). Therefore, the need for a complete overview is essential for all further planning measures.

The time taken to complete the expansion and retrofitting will depend on the power resource construction and the motivation of the relevant institutions (Shen et al., 2018). Fig. 4-8 depicts Algeria's electricity transmission network with its major load centres located in the urban coastal zones of the country.

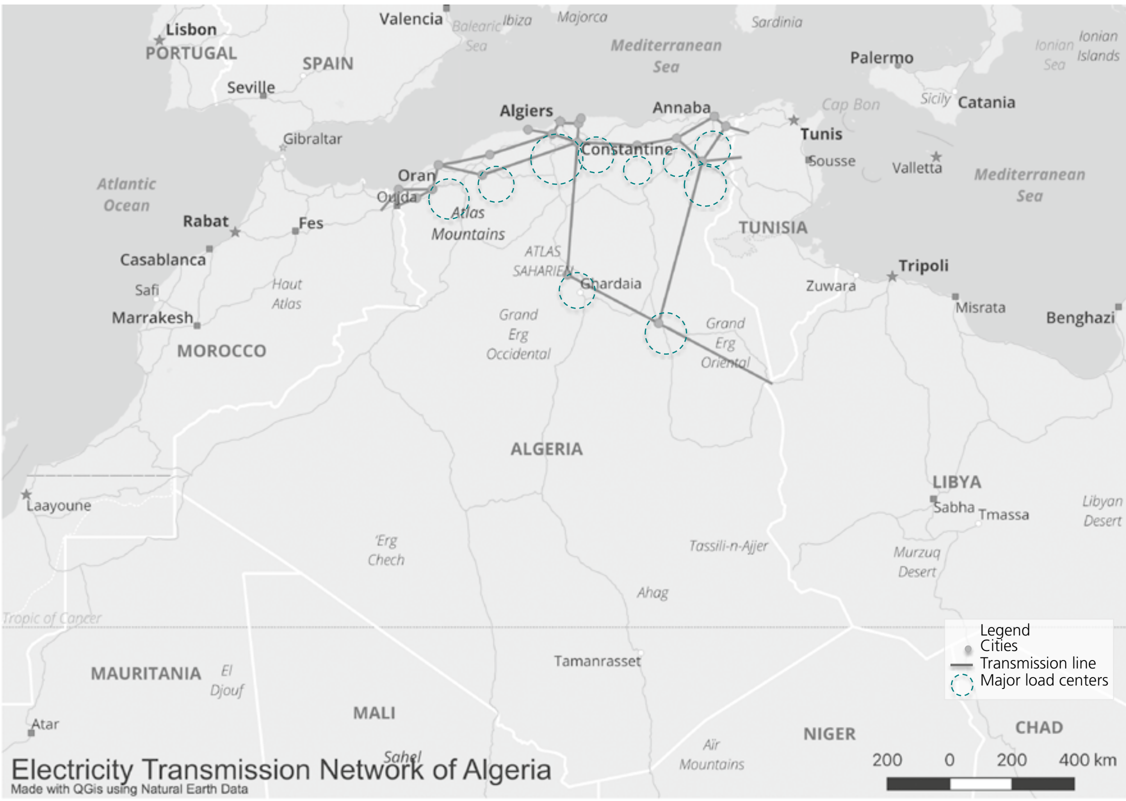
In its current state, Algeria's transmission infrastructure is unable to integrate large volumes of renewables. Although a regulatory framework is in place and liberalisation of the market has started (Law No. 02-01 in 2002 dictates the unbundling of the former vertically integrated utility Sonelgaz (Ministère De L'Énergie, 2020)), the grid still faces technical and regulatory challenges. The Algerian grid is still in the expansion phase. Consequently, the development of the electricity infrastructure for the integration of renewables according to phase one of the phase model has been initiated but is not yet complete.

Institutions and Governance

The Ministry of Energy is the key actor in Algeria's electricity and energy sector. It supervises the whole energy sector and is responsible for the development and implementation of energy policies and strategies. Due to increasing awareness of the importance of renewable energy in Algeria, the Ministry of Energy Transition and Renewable Energy was created to promote the deployment of renewables in the country. Following measures to unbundle the electricity market in 2002, the market was divided into several institutions. However, these are mostly state-owned. Created in 2002, CREG oversees the electricity and national gas markets to protect the interests of both consumers and operators. CREG also manages and controls public energy services and acts as a consultant to the government (energypedia, 2020). In addition, it publishes tenders for the deployment of renewable energy technologies.

On the extraction and generation side, several national companies dominate the Algerian energy sector: Sonatrach Group is responsible for hydrocarbons, while Sonelgaz Group produces and commercialises electricity and is responsible for the national distribution of natural gas. *Societé Algérienne de l'Electricité* – Algerian company for electricity (SPE) also produces electricity, while GRTE (the Algerian company for electricity transmission) is in charge of the transmission of electricity. Electricity distribution is the responsibility of *Societé Algérienne de Distribution de l'Electricité et du Gaz* (SADEG), which was created by the merger of the four former Sonelgaz distribution companies: the *Societé de Distribution du centre* – distribution company for the centre (SDC), *Societé de Distribution de*

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



Source: own creation data based on Energydata, 2017

l'ouest – distribution company for the west (SDO), *Societé de Distribution de l'est* – distribution company for the east (SDE), and *Societé de Distribution d'Alger* – distribution company for Alger (SDA) (Mansour, 2020b). In 1985, the Ministry of Energy created the Agency for the Promotion of the Rationalisation of the Use of Energy (APRUE) to promote energy efficiency measures. APRUE is responsible for educational and awareness-raising campaigns regarding energy efficiency.

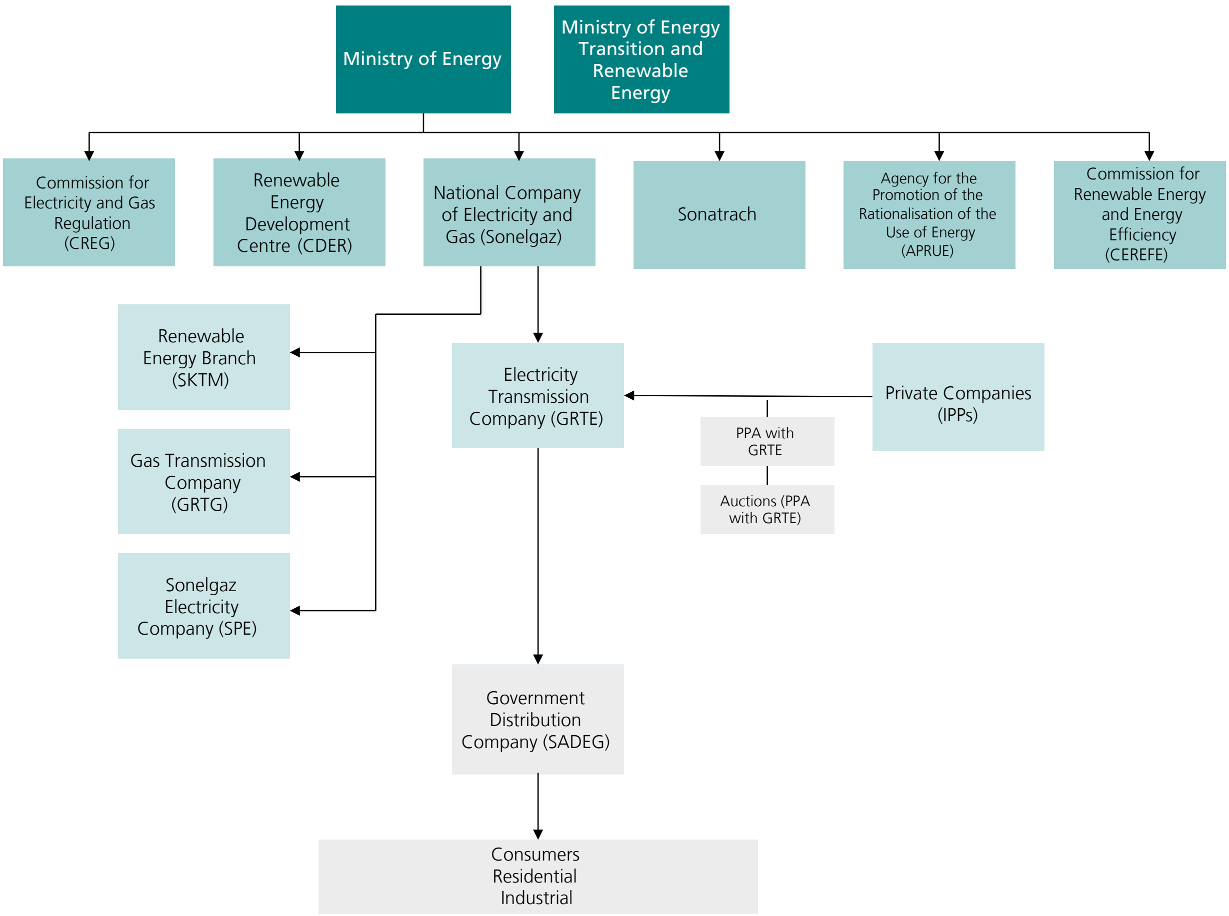
IPPs have been permitted to produce and sell electricity under the framework of the single buyer market since 2002. A PPA must be signed with GRTE, which buys the electricity from the IPPs. Currently, 13% of electricity produced in Algeria comes from IPPs, which are mostly active in the fossil fuel sector (Dena, 2014). A tender scheme is in place to drive investment in renewables in Algeria. Contracts, in form of a PPA, are awarded to companies that bid to produce the power at the lowest cost. The first tender was issued in 2019, seeking a total of 150 MW. However, as the tender rules required substantial local manufacture of solar modules and other equipment – despite the limited number of local solar manufacturers – offers were only made for 90 MW, even though the agreement included a mandatory 51% stake for the Algerian entity and finance from Algerian banks (Bellini, 2019; Hochberg, 2020; Bouznit et al., 2020). The selected projects from the 2019 tender round will be developed under a build-own-operate (BOO) scheme with a PPA over 20 years. The government has issued a further tender for 50 MW for the development of off-grid hybrid gas/diesel and solar energy projects. The tenders and FiT scheme are part of the Algerian plan to install 22 GW of renewable energy power generation capacity by 2030. Fig. 4-9 depicts the Algerian institutional framework of the electricity and energy market.

Since Sonelgaz was restructured as a holding company in 2002 (Law No. 02-01), experts have argued that Algeria's efforts to liberalise the market are minimal and still represent a considerable barrier for the private sector. The legal framework is already mature, but the regulatory framework and financial mechanisms have proven to be insufficient (Hochberg, 2020). According to Boersma et al. (2015), companies operating in the energy sector face bureaucratic and lengthy processes because all communications have to go through Sonatrach or Sonelgaz. This delays the fulfillment of projects and can lead to problems in communication. Therefore, the current state of development and effectiveness of the institutional framework places Algeria at the beginning of the first phase towards a renewable-based energy system according to the MENA phase model.

Energy Market and Economy

The electricity tariff structure in Algeria varies according to the time of the day: there are six tariffs – peak, off-peak, main consumption hours, day, night, and one fixed tariff. Furthermore, the tariffs are differentiated based on the type of customer (e.g. households and industry), with the latter usually paying more per kWh. The tariffs, therefore, vary

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



Source: own creation data based on Energydata, 2017

between 0.007 and 0.05[2] eurocents per kWh. The tariff structure is controlled by CREG.

Algeria is a typical rentier state. As well as exporting natural gas and oil, it relies on hydrocarbons for domestic consumption. Both resources are heavily subsidised. In 2019, around 7.6% of Algeria's GDP went into subsidies: oil was subsidised by 8.8 bn USD, gas by 2.3 bn USD, and electricity by 2 bn USD (IEA, 2020b). The electricity price is linked to the subsidised power generation cost of gas power plants. One of the main barriers for renewable energy development in Algeria is the low electricity market price resulting from these subsidies. Furthermore, the low price results in negative externalities; not only would the energy usage be high, but the cost of energy will also not be reflected in the prices of energy-intensive commodities. Subsidy reforms would alleviate fiscal pressures and allow for the reallocation of the budget to other priorities, such as renewables (RCREEE, 2019). However, as the Algerian government has not yet initiated or announced any subsidy reforms, it is anticipated that this situation will not change in the near future (Dena, 2014).

In support of renewables, Algeria has established the National Energy Efficiency Fund, *Fond National de la Maîtrise de l'Energie* (FNME), a renewables and cogeneration fund financed by taxes and fines. The taxes necessary to finance the fund are recalculated annually on the basis of annual budget requirements for the renewable energy and energy efficiency programmes. They are also included in the budget law (Deutsch-Algerische Industrie- und Handelskammer, 2018).

In terms of private sector finance, it is generally difficult to obtain a bank loan for renewable energy or energy efficiency projects (Deutsch-Algerische Industrie- und Handelskammer, 2018) because the sector is still at an early stage in Algeria, which makes the risks unpredictable for banks. The option to finance projects through private equity in the form of investment funds is possible. However, only a small number of Algerian private firms specialise in this sector. Other options include project finance schemes, where repayments are linked to future cashflow. However, a disadvantage of these schemes is that foreign utilities are only permitted to own 49% of the holding (ibid.).

In summary, the state-subsidised energy prices are a major barrier for the wider deployment of renewable energy, and they constrain the Algerian government's support for

2 The tariffs of 120.5 cDA and 811.47 cDA have been converted by using the currency converter www1.oanda.com

renewables. The subsidies distort the market at the expense of the energy transition. Until Algeria reforms its fossil fuel subsidies and actively invests instead in energy diversification, its development towards a renewables-based energy system is unlikely to progress. Thus, Algeria is classified to remain in the first phase of the transition phase model.

Efficiency

In 2011, the Algerian government launched a national programme for energy efficiency that was amended in 2015. The energy efficiency programme aims to implement efficiency targets in the building, transport, and industrial sectors. For the building sector, the target is to save more than 30 million toe by 2030 through the use of thermal insulation in construction, LED lamps, and solar water heaters. The transport sector's target is to save 15 million toe, largely by replacing conventional fuels with liquefied petroleum gas (LPG) and compressed natural gas (CNG). The industrial sector is expected to contribute by saving up to 34 million toe by 2030. In total, the government plans to spend 900 bn DA[3] on the energy efficiency programme. To achieve the measures set out in the plan, the following actions will have to be taken every year until 2030: 100,000 residential buildings will have to adopt thermal insulation measures, 10 million energy-efficient lamps will have to be distributed, and 1.3 million vehicles will have to be adapted to use liquid petroleum gas. It is expected that these measures will create up to 180,000 jobs (energypedia, 2020; Sahnoune and Imessad, 2017). Furthermore, the government plans to reduce gas flaring in power plants by 1% by 2030.

For new technological devices using electricity, gas, or other fuel, energy certification and labelling exists. For instance, typical residential equipment, such as air conditioning units, fridges, heaters, lamps, and televisions, are labelled with energy classifications according to the efficiency Law No. 05-16, introduced in 2015. Measures for energy efficiency in the building sector have not yet been regulated by law; however, technical documents guide the retrofitting work for thermal insulation and lighting (Deutsch-Algerische Industrie- und Handelskammer, 2018). Another plan is to focus on the circular economy by introducing the composting of organic waste and the valorisation of methane gas in water treatment plants. Clearly, the energy efficiency plan does include first steps towards resource efficiency.

An evaluation of the steps taken by Algeria regarding energy efficiency shows that the government has recognised it as an essential part of the energy transition. The plans in the regulatory framework indicate that Algeria has put energy efficiency measures into practice at political level. However, the targets have not yet been reached, meaning that Algeria is in the first phase of the energy transition according to the MENA phase model. In other words, Algeria has not yet fully completed the first phase of its energy efficiency measures.

Greenhouse Gas Emissions

Algeria ranks third in Africa for CO_2 emissions generation (Hochberg, 2020). In 2014, energy use per capita amounted to 1,327 kg of oil equivalent (The World Bank, 2014), which is relatively high compared to the other Maghreb states. In 2018, the transport sector was responsible for 32% of the CO_2 emissions, electricity and heat producers for 28%, followed by the residential sector at 19%. Industry accounted for 9% of CO_2 emissions in the same year. Since 2005, CO_2 emissions had increased by 77% due to increasing demographic dynamics, industrial development, and impacts resulting from climate change (Fig. 4-10). Fig. 4-10 depicts the Algerian CO_2 profile, while Fig. 4-11 illustrates the resulting emissions from heat and electricity generation by source for 2018.

Algeria is highly vulnerable to climate change, as it already experiences significant levels of water stress. Water resources remain a major challenge. Out of all the Mediterranean countries, Algeria is ranked second only to Spain in terms of desalination. Desalination in Algeria is largely based on fossil fuels (Sahnoune and Imessad, 2017). With an installed capacity of 2.4 million m^3 per day in 2015 for desalination, this sector generates high levels of CO_2 emissions because of its energy-intensive process.

Although Algeria's Nationally Determined Contributions (NDC) target is to reduce CO_2 emissions by 7% by 2030, emissions are, in fact, increasing due to industrialisation. In order to decarbonise the transportation sector, which is responsible for the major share of GHG emissions, programmes targeting electrification need to be implemented. However, direct electrification will only succeed in reducing GHG emissions if the electricity is generated from renewable sources.

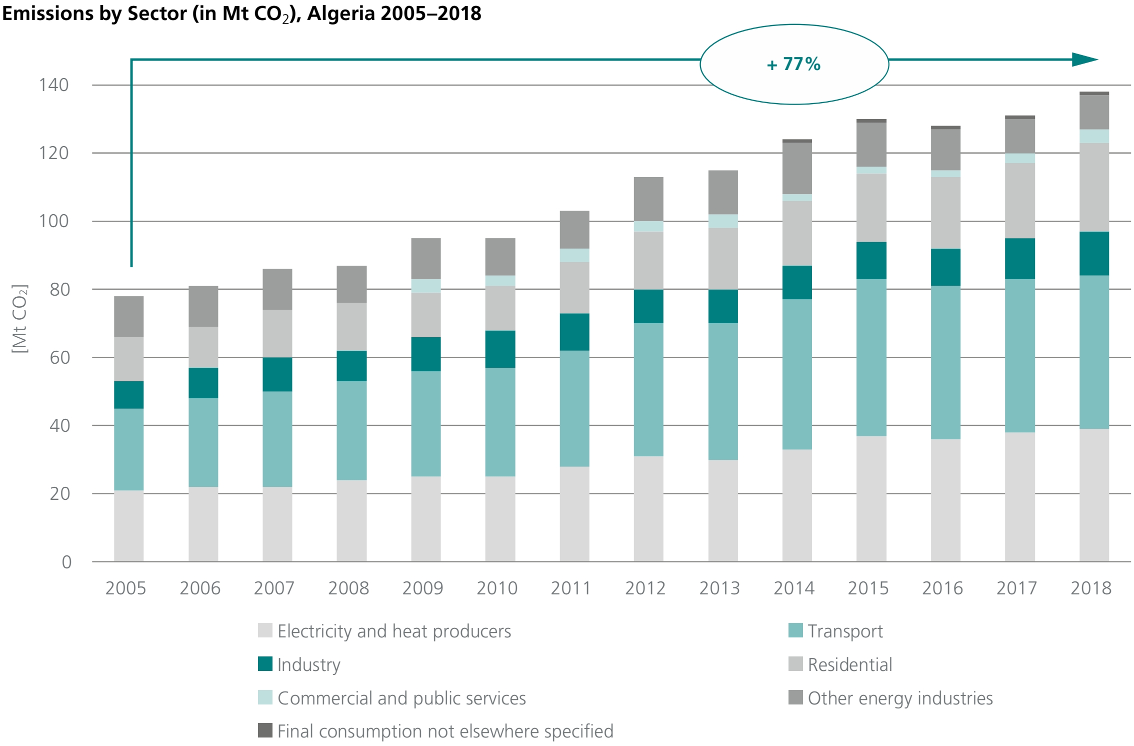
Society

The number of social, cultural, and environmental organisations is increasing in Algeria, and environmental awareness among citizens seems to be slowly rising (BTI, 2020). There has also been considerable opposition to certain energy projects, particularly a project in southwestern Algeria to explore the country's shale gas resources. Unexpected protests by local communities led to countrywide resistance and have succeeded in halting shale gas exploration in Algeria for the time being. Notwithstanding the environmental and socio-economic benefits associated with the development of renewable energies, social acceptance of renewable energy projects should not be taken for granted.

Various renewable energy research and training agencies and institutions have been created. These include the Institute for Renewable Energy and Energy Efficiency (IAER), APRUE, and the Renewable Energy Development Centre (CDER) (Tuerk et al., 2015). APRUE organises awareness-raising campaigns for energy conservation, and CDER disseminates relevant information about renewables and regularly publishes news on this topic on its website. The Solar Energy Cluster was

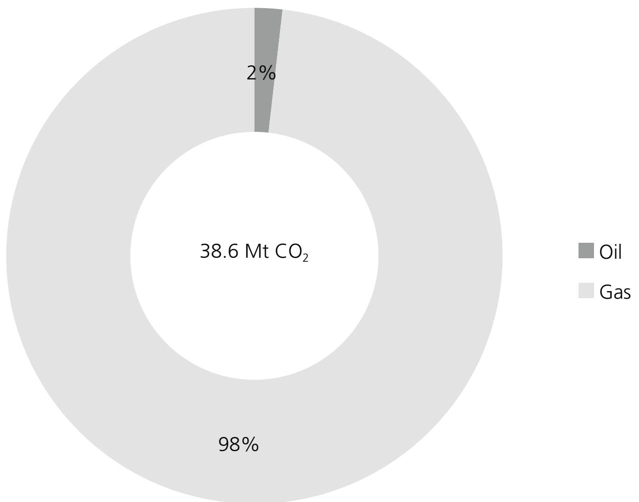
3 around 8 bn Euro

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



Source: data based on IEA, 2020a

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



Source: data based on IEA, 2020a

created in 2017 by 12 energy companies to strengthen the network of national companies and actors operating in the value chain. These include raw material suppliers, developers, installers, professional trainers, academics, and designers. At present, 34 companies are members of this network. The cluster aims to raise awareness and encourage the use of renewable energies, in particular solar energy, by providing in-depth information and good practice guidelines to support the country's energy transition (Haouari, 2017). The creation of the Solar Energy Cluster has led to a new vision of an Algeria powered solely by renewables; however, the government still includes fossil fuels in its future vision of the energy system.

A limited number of institutions offer master's degrees or PhDs in this field. The IAER offers specific training and workshops for capacity-building, including courses on engineering, safety and security, energy auditing, and project management for installers and technicians (Tuerk et al., 2015). According to CEREFE (2020), between 2017 and 2018, 40 people obtained a professional certification in energy efficiency, 46 in PV module installation and maintenance, and 268 in the installation of PV and solar thermal systems.

As the financial sector has a limited understanding of the renewable energy sector, the large-scale deployment of renewable energy projects is difficult in Algeria. Specific training for the financial sector is crucial, but this has not yet become a reality.

Overall, Algeria has recently established a number of institutions to raise awareness about renewable energies. However, the Algerian society does not yet consider environmental topics as being of consequence. Awareness-raising campaigns will contribute to this dimension; however, it will take considerable efforts to embed these aspects in people's daily habits and mindsets.

Summary of the Landscape and System Level Developments

On 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 impacting the development of the energy transition at system level reflect technical, financial, and regulatory patterns.

Algeria has officially unbundled its electricity market and guarantees priority access for electricity generated from renewables, but the electricity market remains a single buyer market, with Sonelgaz having a monopoly. The tenders recently issued in Algeria have hitherto failed to balance the interests of the public sector with those of the private sector (IPPs) and foreign investment. Contributing factors to the limited number of projects are most likely the strict local content requirements for renewable energy projects.

In summary, at the system level a number of factors currently limit Algeria's progress in the energy transition: the abundance of natural gas resources, subsidised electricity prices, energy market structures, hesitant support from institutional actors, and a lack of social readiness to pay for renewables. All these aspects are preventing Algeria from achieving its ambitious transition goals. By implementing the PNEREE and Law No. 02-01 on market liberalisation, Algeria has entered the first phase of the energy transition towards a renewables-based system according to the MENA phase model. However, current challenges, such as the pandemic, could negatively impact progress or hamper further development. In addition, renewables are not currently replacing oil and gas due to the growth in energy demand. In fact, the opposite is true: the consumption of fossil fuels is increasing, GHG emissions are rising, and fossil fuel capacities are being expanded, which is likely to create technological lock-ins.

Table 43 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)	CO_2 emissions per unit of GDP	–10%	–12%	–3%	N/A	N/A	–7% to 20% (compared to BAU)	
	CO_2 emissions per capita	+15%	+35%	+65%	+65%	N/A	–	–
Renewable Energy	Capacity Growth (MW)	N/A	253	312	solar water heating targets: 490,000 m2 of collector area (solar CSP) (2020)	1 GW bio-power from Waste-to-Energy, 15 MW geothermal, 13.5 GW solar PV, 2 GW CSP, 5 GW wind (2030)		
	Share in final energy use	0.6%	0.3%	0.1%	0.1% (2017)	N/A	40%	–
	Share in electricity mix	1.6%	0.38%	0.23%	1.02%	6%	27%	–
Efficiency (Compared to 1990)	Total primary energy supply (TPES)	+46.1%	+87.7%	+152.5%	+174.7%	N/A	–	–
	Energy intensity of primary energy	–5.4%	+3.2%	+18.1%	N/A	N/A	–	–
	Total energy supply (TES) per capita	+11.1%	+33.3%	+55.6%	+55.6%	N/A	–	–
	Electricity consumption per capita	+80%	+100%	+200%	+220%	N/A	–	–
	Fossil fuel subsidies (% of GDP 2019)	N/A	N/A	N/A	7.6% of GDP: 8.8 bn USD (oil), 2.3 bn USD (gas), 2 bn USD (electricity)	–	–	

Category	Indicator	2005	2010	2015	2018	2020	2030	2050
Buildings	Residential final electricity consumption (compared to 2005)	+186%	+94%	+224.6%	+308.1%	N/A	–	–
Transport (Compared to 1990)	Total final energy consumption	+55.2%	+99.5%	+190.9%	+186.4%	N/A	–	–
	CO_2 emissions in transport sector	+50%	+100%	+187.5%	+181.3%	N/A	–	–
	Number of e-vehicles	N/A	N/A	N/A	N/A	N/A	100,000	
Industry	Carbon intensity of industry consumption (compared to 1990)	–4.3%	–10.9 %	–19.2%	–19.2%	N/A	–	–
	Value added (% of GDP)	57.33%	50.5%	35.7%	39.6%	37.4% (2019)	–	–
Supply Security	Natural gas exports (compared to 1990)	+106.5%	+82.3%	+38.7%	+63.9%	N/A	–	–
	Oil products imports (compared to 1990)	+243%	+597%	+2,696%	+491%	N/A	–	–
	Global crude oil exports (compared to 2012)	N/A	N/A	–21.76 (2017)	–29.42 (2018)	–27.81% (2019)	–	–
	Electricity imports (compared to 1990)	+72.2%	+103.2%	+67.7%	+41.9%	N/A	–	–
	Electricity exports (compared to 1990)	–7.7%	+165.4%	+111.5%	+96.2 %	N/A	–	–
	Electricity access by population proportion	N/A	98.8 %	99.93%	100%	N/A	–	–
	Oil reserves (compared to 1999)	N/A	+7.87%	N/A	+7.9%	+7.87%	–	–
	Gas reserves (compared to 1999)	N/A	–1.15%	N/A	–0.2%	–1.15%	–	–
Investment (Compared to 2007)	Decarbonisation investments (millions USD)	0.1499 USD	0.3892 USD	0.8838 USD	N/A	N/A	–	–
Socio-economy	Population (2019)				43,053,054	–	–	
	Population growth	1.39%	1.80%	2.04%	2%	N/A	–	
	Urbanisation rate	63.83%	67.54%	70.85%	72.05% (2017)	N/A	–	–
	GDP growth	5.9%	3.6%	3.7%	1.4%	N/A	–	–
	Oil rents (% of GDP)	29%	23.3%	12.8%	15.7%	N/A	–	–
	Natural gas rents (% of GDP)	3.9%	3.2%	3.2%	3.1%	N/A	–	–
	Jobs in low-carbon industries	N/A	N/A	N/A	N/A	13,776 (2019)	–	–
Water	Level of water stress	92.5%	104.9%	126%	137.9 (2017)	N/A	–	–

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

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 31). With the aforementioned advances made at the system level in Algeria towards renewable energy, previous and parallel developments have taken place at the niche level. While some aspects, such as solar energy and energy efficiency, are being integrated at the energy system level, other aspects are still at the niche level. Initial developments are evident in areas such as the electrification of the transport sector or PtX, which are important for moving forward to the next phases. Algeria shows some progress in almost all the relevant dimensions of supply, demand, infrastructure, markets/economy, and society. However, important steps towards renewable energy still need to be implemented by the government to achieve the full introduction of renewable energy in Algerian markets.

Off-Grid PV

Off-grid PV is a clear niche in Algeria. Remote regions in the south, as well as highly congested areas in the north face serious challenges in terms of stable energy supply. Power shortages in the summer threaten reliable production. The energy demand for industrial activities, such as cement, ceramics, chemistry, and food production, as well as the construction of new buildings that consume large amounts of energy, cannot be met solely by the state (Deutsch-Algerische Industrie- und Handelskammer, 2018). To counter this issue, decentralised solutions are required. However, due to the lack of alternatives, diesel generators are mainly used to meet this demand (ibid.). The exception is in the agricultural sector that possesses solar-powered irrigation systems. The increasing number of these systems is proving their feasibility and leading to rising demand.

Energy Efficiency

As part of the 2015 Energy Efficiency Plan, Algeria is targeting the building sector. Refurbishment measures include the use of thermal insulation materials; however, this is currently an immature market in Algeria. Against this background, local industrial production must focus on insulation materials and expand these production capacities. Energy auditing is also part of the efficiency plan, but Algeria has few qualified specialist companies in this sector (Deutsch-Algerische Industrie- und Handelskammer, 2018).

E-mobility

Concrete e-mobility measures are still under development, but some targets do exist. For instance, the Minister of Energy Transition has set a target of 100,000 electric vehicles (EV) on the streets by 2030. However, the main aim for the public transport sector is to switch to electric locomotives to replace the many diesel trains still in use. Algeria has plans to electrify railway lines, and the planned railway connection to the south – to Tamanghasset – is also to be electrified. The electrification in the railway sector could be powered by solar technology built along the line (Oxford Business Group, 2016). Some discussions are taking place about electrification of the road transport sector, but there have been no significant developments yet.

Biofuels

The production of biofuels is currently not under consideration in Algeria. However, a pilot project took place to produce bioethanol from the residues of date processing. Blending gasoline with the biofuel produced from the dates is being tested, and a feasibility study has been conducted (Dena, 2014).

Hydrogen and PtX

Two pilot research projects for the development of hydrogen were initiated in 2006. Both the "Solar Hydrogen Pilot Project" (implemented by the CDER's Technological Studies and Innovation Department) and the HYDROSOL project (in cooperation with the Institute of Technical Thermodynamics and Solar Research at the German Aerospace Center (DLR)) aim to exploit Algeria's solar potential to produce hydrogen (Deutsch-Algerische Industrie- und Handelskammer, 2011). Synthetic fuels are discussed to a limited extent on the political level, although Algeria was expected to sign a Memorandum of Understanding (MoU) with Dii Desert Energy on hydrogen in 2020 (Hochberg, 2020). An existing hydrogen study from 2003 analysed the potential estimated production in the south of the country (Boudries-Khellaf and Khellaf, 2003).

The current global momentum for hydrogen should not be ignored by Algeria and its industrial actors (Kefaifi, 2020). Algeria has a reforming sector that consists of a number of ammonia, methanol, and refining plants that have been operating for over 60 years and use synthetic gas to produce methanol and ammonia. It could, therefore, be pivotal to convert the standard process and use hydrogen produced from renewables. However, there are currently no incentives to support such a step.

4.1.3 Necessary Steps for Achieving the Next Phase

Algeria has already taken first steps towards a renewable energy transition and can be categorised as entering the »Take-Off Renewables« phase according to the MENA phase model. In order to integrate renewables into the energy system (described by the phase model as second phase) and to proceed with the energy transition, efforts in the field of renewable energy implementation must be increased, and the political willingness to act in this regard must be translated into concrete action.

Algeria is a market with high potential for renewables due to its size and resource potential, but challenges remain. The dominance of the oil and gas sector in both the energy mix and the overall economy hinder the widespread deployment of renewables in multiple ways. Due to the COVID-19 pandemic, renewables have become more favourable in terms of costs and available financing. Thus, the government should focus on adopting the increasingly competitive renewable energy technologies, as they have been heralded to be the winner of the crisis (IEA, 2020c). Gas can act in the short term as a bridging technology for the energy transition in Algeria, as it is efficient and flexible and, therefore, compatible with renewable energies. In the long term, however, gas technology should also be phased out.

To support renewables to take-off, strong governmental support is required, especially in a country like Algeria with large fossil fuel resources. For example, the legal and investment framework conditions for implementing renewables projects must be revised to make them attractive. While Algeria has a clear regulatory framework in place for renewables, it is not effective. Tenders for the private sector have had only limited success, and the limitations imposed on foreign investments in Algeria is a definite major barrier. Companies in Algeria should also be incentivised to switch to renewables; for example, through guaranteed revenue from renewable energy generation. This could be in the form of tax allowances or exemptions for renewables, CO_2 certifications, or energy auditing. Furthermore, by providing an adequate framework and regulations to support businesses to adopt energy efficiency and GHG emissions reduction measures, companies could be encouraged to participate in efforts towards the energy transition (Al-Shamali et al., 2019).

Furthermore, Algeria must create incentives for the introduction and integration of renewable energies and flexibility options. One important step would be to phase out energy subsidies for fossil fuels, which currently hinder the energy transition. This would give the state fiscal leverage and help to reduce excessive energy consumption (Al-Shamali et al., 2019).

Strengthening cooperation with neighbouring countries and the EU on technology transfer and capacity-building could also help to achieve the goal of a higher share of renewables in the electricity mix. Promoting energy partnerships and alliances, such as the German-Moroccan Hydrogen Alliance concluded in June 2020, could be an important step in this direction. Specifically, the introduction of dedicated vocational training, as well as certified courses for stakeholders, such as banks, could help to increase domestic capacity levels in the renewable energy sector.

To further advance the renewable energy transition towards system integration, Algeria must start to consider flexibility options. Some incentives in the e-mobility and hydrogen sector do exist, but the government has not yet focused on these (Hochberg, 2020). The discussion on e-mobility could be advanced by imposing a carbon tax on gasoline vehicles or by introducing electric buses in the public transport sector. Establishing a differentiated and dynamic tariff structure could further provide an opportunity to exploit existing flexibility potentials. Moreover, the transmission and distribution networks must be expanded and improved.

Another important factor for the system integration of renewable energies is the digitalisation of the energy sector. This is at a very early stage in Algeria. To make progress in digitalisation, the necessary know-how needs to be transferred and adapted to the local Algerian context.

Overall, progress will largely depend on political motivation to actively support the energy transition. This not only entails state investment but also includes designing the necessary framework conditions to encourage participation and to attract investment from the private sector.

4.2 OUTLOOK FOR THE NEXT PHASES OF THE TRANSITION PROCESS

As shown in this analysis, Algeria has made some progress in the field of renewable energies. With the PNEREE, Algeria has a useful short to mid-term concept that helps to address the challenges faced by the energy sector. However, for Algeria to achieve its renewable energy targets, it must increase its efforts. Although there is a strong legal framework for renewables, practical implementation lags behind. This is due to lobbying by the oil and gas sector, which has led to the construction of more conventional power plants. New fossil fuel generation capacities have long operating lifetimes, which could create new path dependencies in the energy system. This is an obstacle to a sustainable energy transition, as shown by the phase model. While gas can be a bridging technology in the short term during the transitional stage, the aim in the long term must be for renewables to become the primary energy source.

To reach this target, it is crucial to increase cooperation between different sectors and levels of governance. On the vertical level, communication between governance entities must be enhanced. On the horizontal level, platforms for cross-sectoral and interdisciplinary dialogue must be created to develop a robust, coherent, and comprehensive policy framework that will facilitate the transformation of the energy system towards renewables. The overall objective should be providing recommendations to strengthen 100% renewable energy development in Algeria for the benefit of the population. The energy transition must be considered within the socio-economic system in which it is deployed. Bidirectional interactions between the energy transition and the socio-economic system can foster synergies (IRENA, 2018). Therefore, policy should consider the energy transition not only from an economic point of view but also from a socio-economic perspective and address broader issues, such as energy and climate justice. The involvement of different stakeholders and representatives of the population can increase transparency and participation. For example, assembling different actors for the development of energy scenarios can also increase motivation to engage in the energy transition.

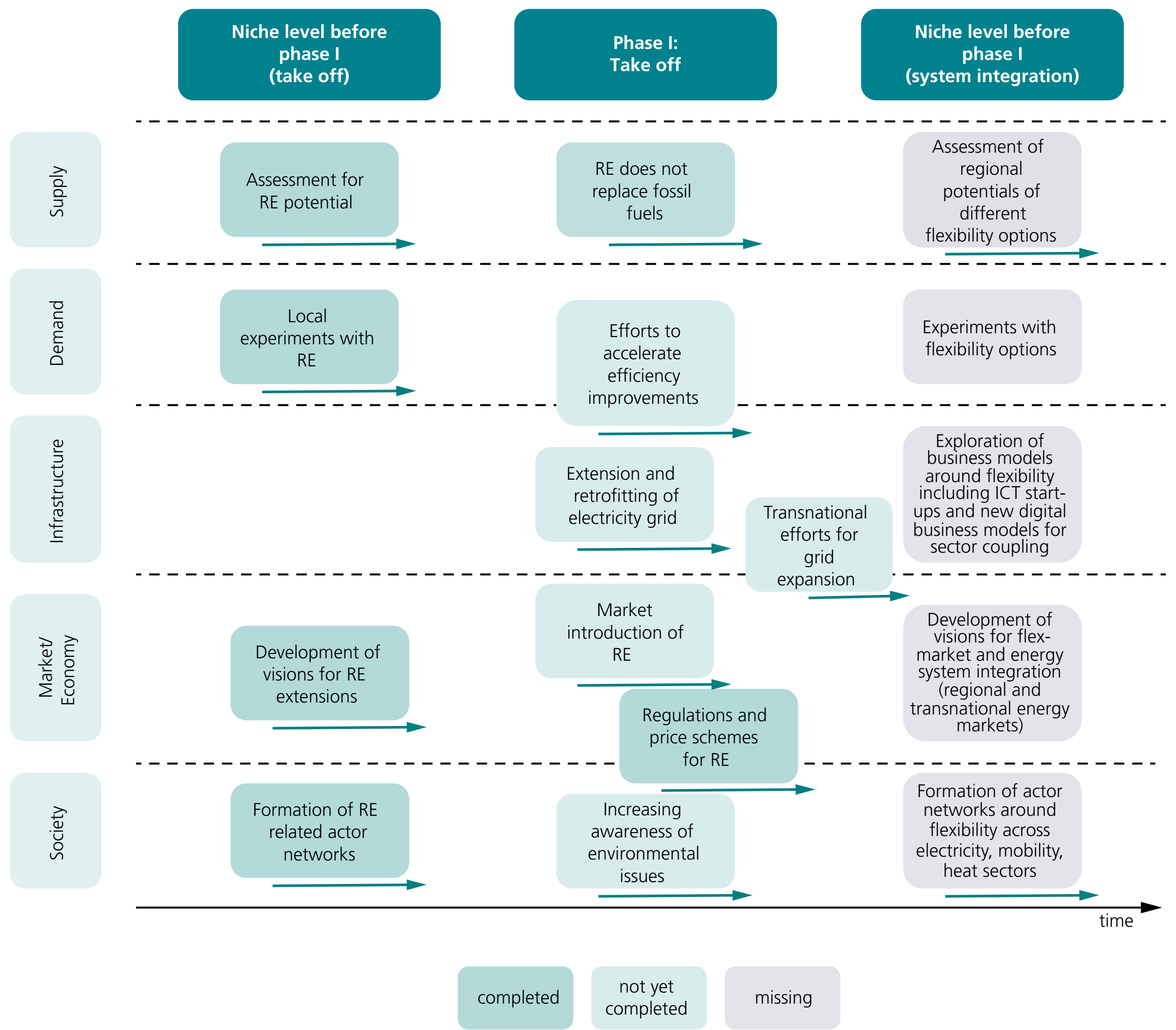
In its energy policy, Algeria still displays the typical attitude of a rentier state with a strong focus on fossil fuels, while ambitions around renewable energies remain mainly on paper. Moreover, the liberalisation of the energy market is delayed. An example is Law. No. 02-01, which foresees market liberalisation but groups the energy companies into a holding company that owns more than 50% of the market. The creation of an independent regulatory authority could be a first step towards better monitoring of the electricity market.

Given that the centres of demand are in the north on the coast, while all the current energy production around Hassi R'Mel is in the south and the renewable energy potential is also in the Sahara, appropriate infrastructure for transporting energy is a critical component. Whereas transportation infrastructure for oil and gas is already in place, there is a lack of smart grid and grid management technology to bring large amounts of renewable electricity to the coast (Hasni et al., 2021). Therefore, infrastructure capacity planning needs to be approached holistically and developed in favour of renewable energy.

In summary, gas will remain an important component of the energy system in Algeria in the short to mid-term. Nevertheless, renewable energy should be integrated into strategic planning at an early stage to seize economic opportunities and enable a smooth transition. The current PNEREE energy plan does not provide an integrated approach to effectively incorporate the entire energy system and align it with long-term goals. It is, therefore, recommended that Algeria starts developing a long-term strategy that takes into account its renewable energy potential to enable the efficient transformation of its energy supply. With the on-going global decarbonisation efforts and the expected changing demand from consumers worldwide in the favour of sustainable fuels, Algeria would be well advised to embark on this path sooner rather than later to avoid technological lock-in effects and stranded investments in the fossil fuel sector.

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

Figure 4-12
Overview of Algeria's Status in the Energy System Transition Model



Source: data based on IEA, 2020a

5

CONCLUSIONS AND OUTLOOK

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

The model, which includes four phases (»Take-off RE«, »System Integration«, »Power-to-Fuel/Gas«, and »Towards 100% Renewables«), was applied to analyse and determine where Algeria stands in terms of its energy transition towards renewables. The application of the model also provides a roadmap detailing the steps needed to proceed on this path. The analysis has shown that interest in renewable energies is growing in Algeria, and the Algerian government has set itself ambitious renewable energies targets. Although the legal framework and expansion planning for renewable energies is well developed, regulatory support for renewable energies and financial incentives have so far been somewhat limited. Given that fossil fuels play a major role in Algeria's energy sector, as well as in the economy as a whole, the pathway to a renewable energy-based energy system needs strong government support at all levels to succeed. In order to gain broader political support, the energy transition must be recognised by decision-makers as a long-term opportunity for economic and social development.

Algeria can benefit from its resources by using natural gas as a bridging technology along the development pathway. In the long term, however, achieving an energy system based on 100% renewables should be a realistic objective for the country. Furthermore, Algeria has sufficient potential to export renewable energy in various forms in the future, which offers the opportunity of replacing declining revenues from fossil fuels. In this regard, the structural changes related to global decarbonisation efforts, which are expected to result in decreasing demand for fossil fuels, are likely to become an important driver for the transition towards renewable energy. Therefore, the Algerian government would be well advised to take measures to promote investment in low-carbon energy technologies. This requires holistic planning to facilitate system and infrastructure integration, taking socio-economic structures into account. Building trust among decision-makers and other stakeholders is fundamental to realising Algeria's renewable energy goals, and changes in policy, investment, and behaviour will all be required.

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LIST OF ABBREVIATIONS

APRUE	Agency for the Promotion of the Rationalisation of the Use of Energy
bn	billion
BOO	Build, own and operate scheme
CCS	Carbon capture and storage
CCU	Carbon capture and use
CDER	Renewable Energy Development Centre
CEREFE	Commission for Renewable Energy and Energy Efficiency
CNG	Compressed natural gas
COVID-19	Coronavirus disease 2019
CREG	Commission for Electricity and Gas Regulation
CSP	Concentrated solar power
DA	Algerian Dinar
EU	European Union
EV	Electrical vehicle
FiT	Feed-in tariff
FNER	National Renewable Energy and Cogeneration Fund
FNME	National Energy Efficiency Fund
GDP	Gross Domestic Product
GHG	Greenhouse gas
GRTE	Electricity Transmission Company at Sonelgaz
GRTG	Gas Transmission Company at Sonelgaz
IAER	Institute for Renewable Energy and Energy Efficiency
ICT	Information and communication technologies
IPP	Independent Power Producer
LNG	Liquefied natural gas
LPG	Liquefied petroleum gas
MENA	Middle East and North Africa
MLP	Multi-level perspective
MoU	Memorandum of Understanding
NDC	Nationally Determined Contributions
OPEC	Organisation of the Petroleum Exporting Countries
PNEREE	National programme for renewable energy and energy efficiency
PPA	Power Purchase Agreement
PtF	Power-to-fuel
PtG	Power-to-gas
PtX	Power-to-X
PV	Photovoltaic
R&D	Research & Development
RE	Renewable Energy
SADEG	Algerian Electricity and Gas Distribution Company
SDA	Government Distribution Company – Algiers
SDC	Government Distribution Company – Centre
SDE	Government Distribution Company – East
SDO	Government Distribution Company – West
SKTM	Renewable Energy Branch at Sonelgaz
SPE	Sonelgaz Electricity Company
USD	US-Dollar

LIST OF UNITS AND SYMBOLS

%	Percent
CO_2	Carbon dioxide
GWh	Gigawatt hour
ktoe	Kilo tonnes of oil equivalent
kV	Kilo Volt
kW	Kilowatt
kWh	Kilowatt hour
m/s	Metre per second
Mt	Megatonne
Mtoe	Million tonnes of oil equivalent
MW	Megawatt
MWp	Megawatt peak
TWh	Terawatt hour
W/m^2	Watts per square metre

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ABOUT THIS STUDY

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

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SUSTAINABLE TRANSFORMATION OF ALGERIA'S ENERGY SYSTEM

Development of a Phase Model

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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 transition in MENA countries has been developed and applied to the country case of Algeria. It is designed to support the strategy development and governance of the energy transition and to serve as a guide for decision makers.

→

The analysis shows that Algeria has already taken first steps towards a renewable energy transition. According to the MENA phase model, Algeria can be classified as entering the »Take-Off Renewables« phase. Nevertheless, fossil fuels still play a dominant role in the Algerian energy sector and in the economy as a whole. To support the renewables take-off, strong support is therefore needed at all levels. Only then can the necessary framework conditions be created to encourage participation and to attract investment from the private sector. To this end, a long-term energy strategy should to be developed that takes into account the renewable energy potential to support an efficient transformation of the Algerian energy supply and enables a smooth transition.

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Especially, with the ongoing global decarbonisation efforts and the expected changing demand from consumers worldwide in the favour of sustainable fuels, Algeria would be well advised to embark on a sustainable path sooner rather than later to seize economic opportunities and avoid technological lock-in effects and stranded investments in the fossil fuel sector. The results of the analysis along the transition phase model towards 100% renewable energy are intended to stimulate and support the discussion on Algeria's future energy system by providing an overarching guiding vision for the energy transition and the development of appropriate policies.

For further information on this topic:
https://algeria.fes.de
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