STUDY

CLIMATE CHANGE, ENERGY AND ENVIRONMENT

SUSTAINABLE TRANSFORMATION OF TUNISIA'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 Middle East and North Africa (MENA) countries to Tunisia, the study provides a guiding vision to support the strategy development and steering of the energy transition process.

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The Tunisian electricity sector faces three main challenges: high dependence on imported fossil fuels, distortive subsidies, and a weak financial performance at utility level.

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The upscaling of renewables in Tunisia offers the opportunity to meet the growing electricity demand, reduce the energy deficit, and foster economic development.

FRIEDRICH EBERT STIFTUNG

CLIMATE CHANGE, ENERGY AND ENVIRONMENT

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Wuppertal Institut

Contents

1

INTRODUCTION

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

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

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

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

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

In this study, the MENA phase model is applied to the case of Tunisia. The current state of development in Tunisia 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.

2

CONCEPTUAL MODEL

2.1 THE ORIGINAL PHASE MODELS[1]

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

The four phases are crucial to achieve a fully renewables-based energy system. In the first phase, RE technologies are developed and introduced into the market. In the second phase, dedicated measures for the integration of renewable electricity into the energy system are introduced. These include flexibility of the residual fossil power production, development and integration of storage, and activation of demand side flexibility. In the third phase, the long-term storage of renewable electricity to balance periods where supply exceeds demand is 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.

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

To describe the long-term changes in energy systems in these four phases, the phase model is supplemented by insights from the field of sustainability transition research. Energy transitions cannot be completely steered, nor are they totally predictable. The involvement of many actors and processes creates a high level of interdependency and uncertainty surrounding technological, economic, and socio-cultural developments. The multi-level perspective (MLP) is a prominent framework that facilitates the conceptualisation of transition dynamics (Fig. 2-1).

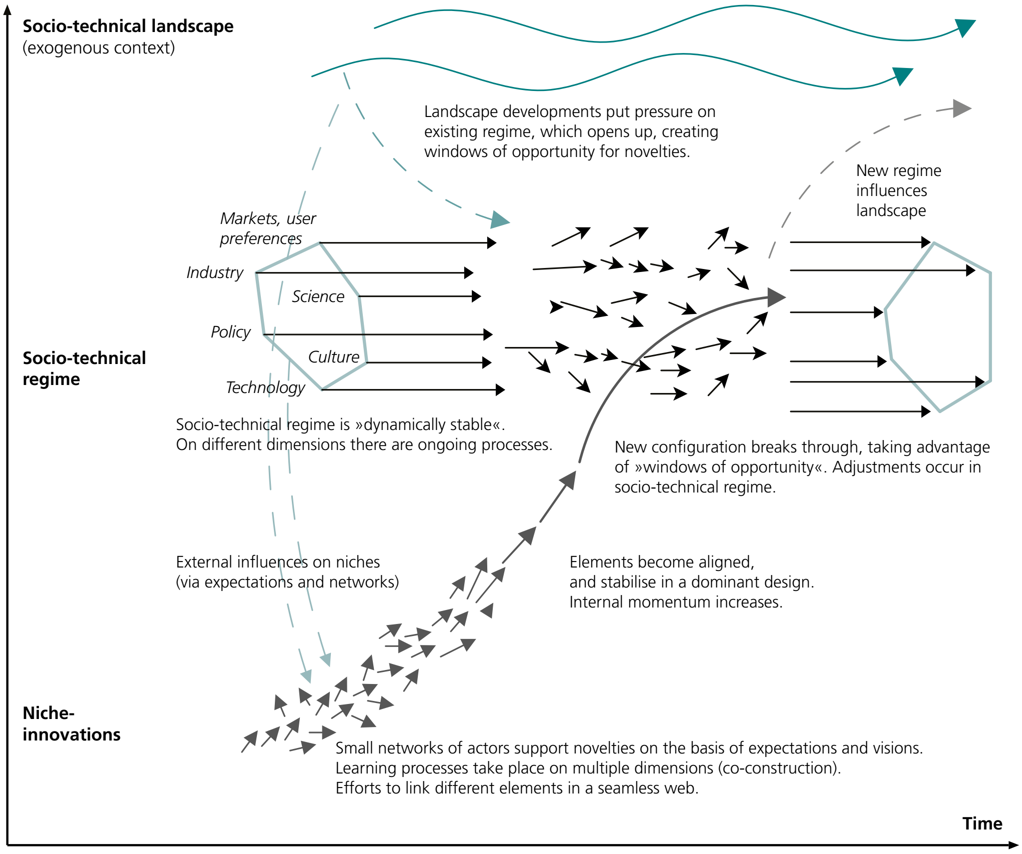
At »landscape« level, pervasive trends such as demographic shifts, climate change, and economic crises affect the »regime« and »niche« level. The »regime« level captures the socio-technical system that dominates the sector of interest. In this study, the regime is the energy sector. It comprises the existing technologies, regulations, user patterns, infrastructure, and cultural discourses that combine to form socio-technical systems. To achieve system changes at the »regime« level, innovations at the »niche« level are incremental because they provide the fundamental base for systemic change (Geels, 2012). Within the transition phases, three stages can be distinguished: »niche formation«, »breakthrough«, and »market-based growth«. In the »niche formation« stage, a niche develops and matures. In the »breakthrough« stage, the niche innovation spreads and when the niche innovation becomes fully price-competitive and specific supportive policy mechanisms are no longer needed, the »market-based growth« stage is achieved. RE technologies are, at this stage, fully integrated into the system.

2.3 ADDITIONS IN THE MENA PHASE MODEL

Assuming that the phase model for the German energy transition by Fischedick et al. (2014) and Henning et al. (2015) is relevant for the MENA countries, the four transition phases remain the same. Since niche formation processes are required for successfully upscaling niche innovations, a »niche« layer was added into the original phase model by Fischedick et al. (2020). A specific cluster of innovations was identified for each phase: RE technologies (phase 1), flexibility options (phase 2), PtF/G technologies (phase 3), and sectors such as heavy industry or aviation that are difficult to decarbonise (phase 4). In its breakthrough stage, each innovation cluster is dependent on the niche-formation process of the previous phase. Consequently, the addition of the »niche layer« creates a stronger emphasis on the processes that must occur to achieve the system targets (Fig. 2-2).

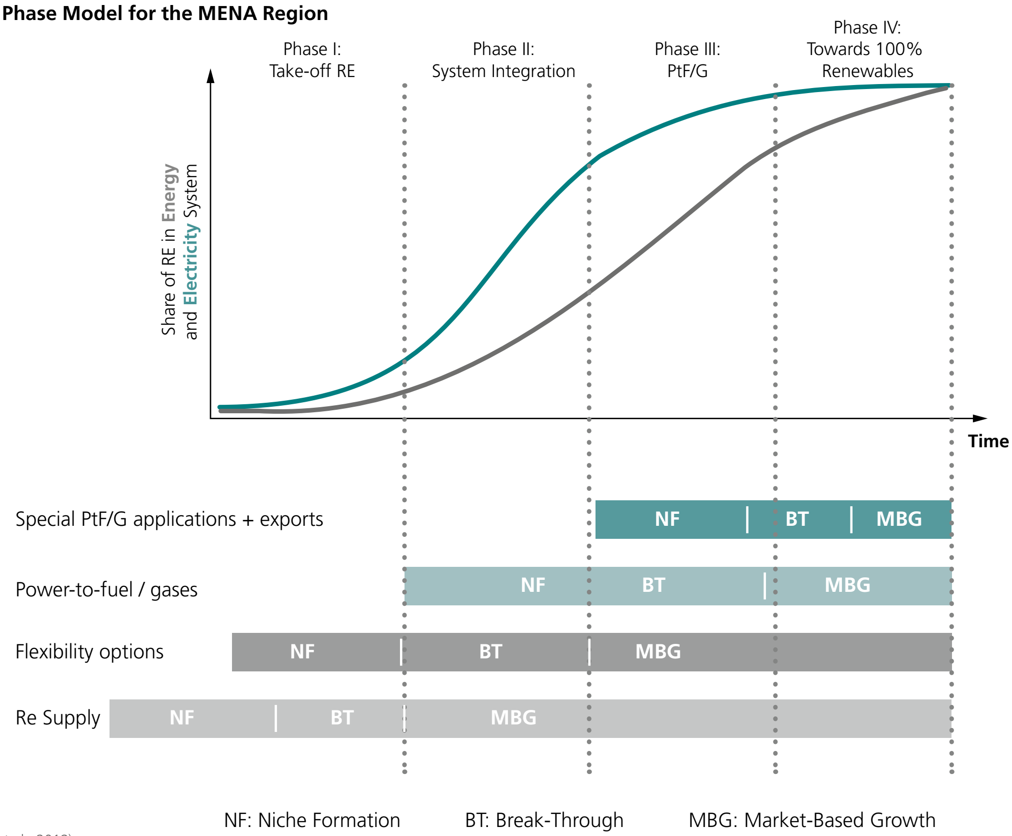
1 Text is based on Holtz et al. (2018).

Figure 2-1
The Multi-Level Perspective



(Source: Geels and Schot, 2007)

Figure 2-2
Transition Phase Model for the MENA Region



(Source: Holtz et al., 2018)

3

THE MENA PHASE MODEL

3.1 SPECIFIC CHARACTERISTICS OF THE MENA REGION

One of the fundamental 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. Furthermore, the energy intensity in many MENA countries is high, due to low insulation quality in buildings, technical inefficiencies of cooling and heating technologies, and distribution infrastructure. The electricity losses in distribution are between 11% and 15% in stable MENA countries compared to 4% in Germany (The World Bank, 2019). Although the MENA region does benefit from significant RE resources, much of the economic RE potential remains untapped. By exploiting this potential, most of the countries could become self-sufficient in terms of energy, and they could eventually become net exporters of renewables-based energy.

Another difference is that the electricity grid in Germany is fully developed, whereas most of the MENA countries have grid systems that need to be expanded, developed nationally, and connected cross-border. Physical interconnections exist, but these are mainly in regional clusters (The World Bank, 2013). Therefore, the region lacks the necessary framework for electricity trade.

The MENA countries could benefit considerably from global advances in RE technologies. While the phase model for the German context assumed that RE technologies need time to mature, the phase model for the MENA context can include cost reductions. However, the conditions for developing RE industries are weak due to a lack of supporting frameworks for entrepreneurship and technological innovation. While in Germany private actors play a major role in small-scale photovoltaic (PV) and wind power plants, state-owned companies and large-scale projects take centre stage in most countries in the MENA region. The mobilisation of capital is an additional significant factor that would require dedicated strategies.

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

The phases of the original phase model were adapted to correspond to the characteristics of the MENA region.

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

3.3 PHASES OF THE ENERGY TRANSITION IN MENA COUNTRIES

Phase 1 – »Take-Off REs«

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

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

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

Phase 2 – »System Integration«

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

PtF/G applications are developed at the »niche« level to prepare the system for a breakthrough in phase 3. Pilot projects test the application of synthetic fuels and gases under local conditions. Green hydrogen is expected to replace fossil fuels in sectors such as chemical production. Actor networks create and share knowledge and skills in the field of PtF/G. Based on an assessment of the potentials for different PtF/G conversion routes, strategies and plans for infrastructure development are elaborated, and business models are explored.

Phase 3 – »PtF/G«

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

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

Phase 4 – »Towards 100% Renewables«

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

Table 31 summarises the main developments in the »techno-economic« and »governance« layers, as well as on the »landscape«, »system«, and »niche« levels during the four phases.

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

The MENA phase model, originally applied to the Jordan case in Holtz et al. (2018), was partly adapted and applied to nine countries in the MENA region, one of which is Tunisia. The aspects associated with the different phases of the model were discussed with policymakers, representatives from science, industry, and civil society in the respective countries. Based on the experience in Jordan, the model proved to be a helpful tool to support discussions about strategies and policymaking in regard to the energy transition in MENA countries. The results of the model's application to Tunisia illustrate a structured overview of the continuous developments in Tunisia's energy system. Furthermore, they provide insights into the necessary steps to be taken to transform Tunisia's energy system into a renewables-based system.

In order to reflect the specific challenges and opportunities for the energy transition in Tunisia, some adaptations to the criteria set of the MENA phase model were made on the landscape level. These include factors such as the COVID-19 pandemic as well as 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 to unlocking the RE potential in the country. The expert interviews were carried out in Tunisia by the Research and Technologies Centre of Energy (CRTEn), and they were conducted in the form of structured interviews. The interviewees included relevant stakeholders with experience in the energy sector or related sectors such as policy institutions, academia, and the private sector. 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). Otherwise, it was calculated using available information. The subsequent results identify the current status and future trends.

Table 3-1
Developments During the Transition Phases

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

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

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

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

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

After the Jasmine Revolution in 2010/2011, Tunisia made great strides in its transition towards democracy. However, recent events have shown that democracy is still noticeably fragile. The main challenges stem from a persistent economic crisis that has resulted in high unemployment rates (particularly among young people), regional disparities, and mounting government debt. This has been exacerbated by the COVID-19 pandemic, the consequences of which caused the economy to sharply shrink in 2020. Moreover, Tunisia is highly vulnerable to environmental risks. The country's slow economic development and the negative impacts of climate change challenge the country's energy system transformation. Tunisia is highly dependent on energy imports, and the energy demand has been progressively growing, mainly due to population growth, urbanization, economic development, and subsidies that foster overconsumption. Despite the country's high solar and wind energy potential, the Tunisian electricity mix is dominated by gas generation that is largely imported from Algeria.

Overall, the Tunisian energy situation can be divided into three aspects: a large fuel import dependency, high fossil fuels use, and a vast fiscal deficit resulting from high subsidies (Döring et al., 2018). Yet, the Tunisian government already took steps towards developing the RE sector through the implementation of the Tunisian Solar Plan (TSP) in 2010. The TSP aims to initialise the energy transition by developing RE on a large scale and increasing the share of renewables in electricity generation to 30% in 2030. So far, however, the share of renewables in the electricity mix remains low at about 3% in 2020. Tunisia still faces an array of legal and administrative challenges, such as complicated processes to sell electricity from REs or unclear, complex, and long-lasting permitting procedures. Furthermore, the limited participation from the private sector poses a problem. These issues hinder plans to increase the RE share and move towards an energy system based on renewables. Nevertheless, discussions about the opportunities of PtX strategies have started to take place in Tunisia. This is reflected, for example, by the Tunisian-German green hydrogen alliance, which was established in December 2020.

Against this background, the following study analyses Tunisia's energy sector along the transition phase model. The analysis provides valuable insights at the country level and contains recommendations for the development of strategies to support the sustainable energy transition in Tunisia.

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

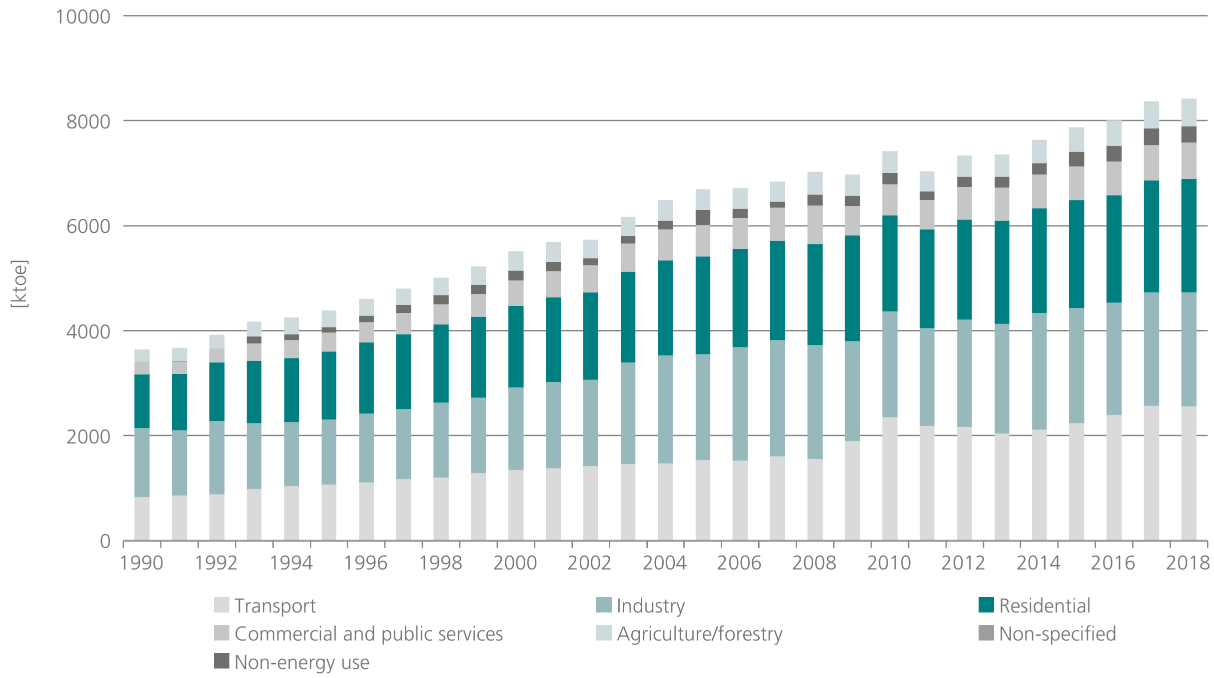
This section discusses the current state and trends of Tunisia's energy system in terms of supply, demand, the fossil fuel sector, RE, infrastructure, actor network, and market development.

Energy Supply and Demand

Tunisia's total primary energy supply in 2018 was 11,366 ktoe (IEA, 2020a). Broken down by sector, transport dominated energy consumption (30%), followed by households and industry (25% each), and others (20%) (IEA, 2020a) (Fig. 4-1).

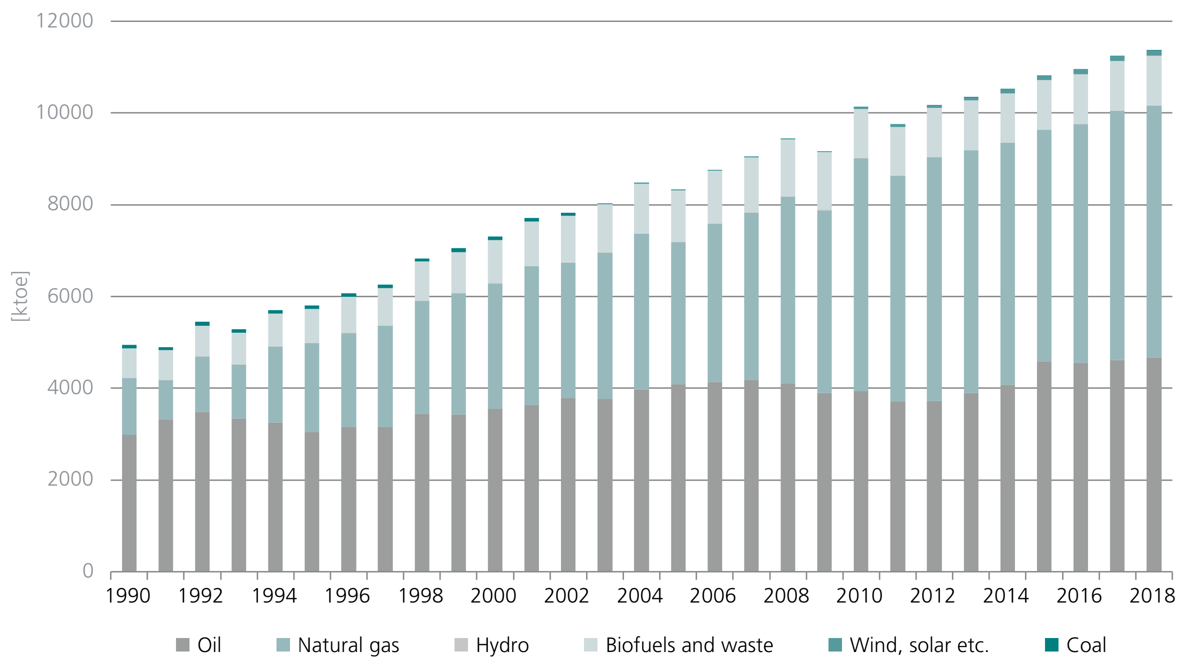
In terms of the energy mix, fossil fuels dominated (Fig. 4-2), with natural gas accounting for 48%, oil for 41%, while biofuels and waste had in total a share of 10%, and wind and solar held a negligible 0.1% share (IEA, 2020a). The annual average growth rate of energy consumption in Tunisia between 1990 and 2018 was approximately 3%. The generation fleet in Tunisia is composed of a significant number of gas turbines that operate in open cycle to meet the peak demand (Benedetti et al., 2013). Tunisia's installed capacity

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



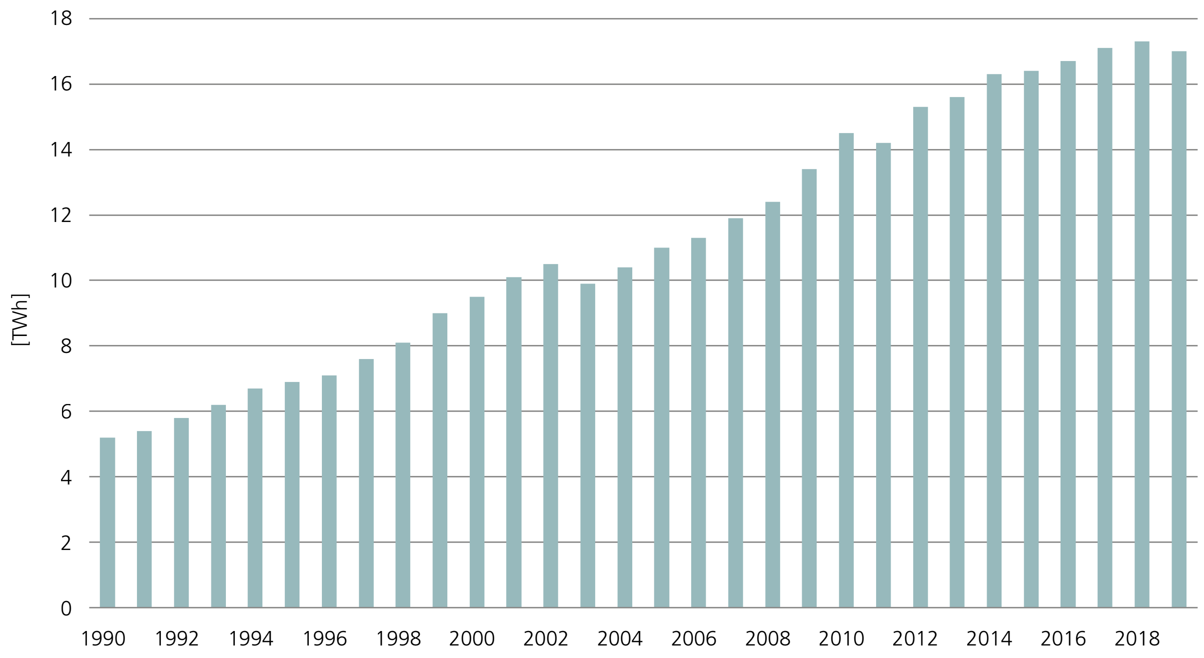
(Source: data based on IEA (2020a))

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



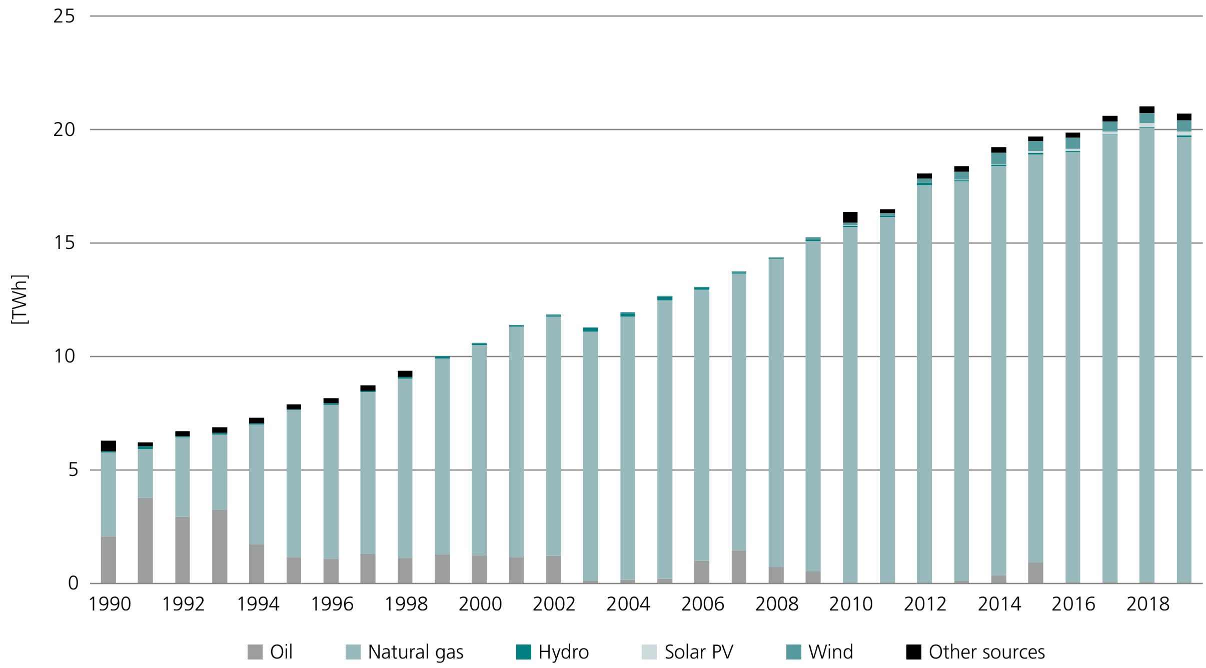
(Source: data based on IEA (2020a))

Figure 4-3
Electricity Consumption (in TWh), Tunisia 1990–2019



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

Figure 4-4
Electricity Generation by Source (in TWh), Tunisia 1990–2019



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

in 2019 reached 5,653 MW. Up to 94% of this amount was derived from natural gas power plants, while the remaining stemmed from wind, hydropower, and residential PV systems (Detoc, 2016; GIZ, 2019). In 2019, combustion turbines represented the largest share of installed capacity (46%), compared to 37% for the combined cycle (STEG, 2020).

Electricity consumption in 2018 amounted to around 17 TWh, which is triple the electricity demand in 1990, with an annual average growth rate of 4% (Fig. 4-3). The annual power demand is projected to continue growing between 2-5% (UNDP, 2018b). The rise in power demand reflects the increasing need for it, mainly by the industrial and residential sectors. Electricity generation rose from 5,811 GWh in 1990 to 20,690 GWh in 2019, recording an average annual growth rate of 4.5% (Fig. 4-4). In 2018, nearly 97% of electricity generation was from natural gas, while electricity out of renewables alone reached a share of 3% only. Regarding generation technology, the share of combined cycle power plants increased from 41% in 2010 to more than 60% in 2016. The Tunisian Company of Electricity and Gas (STEG) was responsible for 92% of the generation, while 8% stemmed from independent power producers (IPPs).

The Tunisian load curve structure has changed significantly in the past 20 years, mainly driven by the increasing use of air conditioning during the summer. The annual peak in demand, which is recorded during the day in the summer months, reached 4,247 MW in 2019, whereas it reached 3,010 MW in 2010. The peak load increased at a higher pace than the power demand, resulting in declining load factors of the power plants by more than 13% between 1996 and 2019 (STEG, 2020).

To summarise, the main means for the electricity production are combined cycle power plants and steam power plants, and peak power is provided by gas turbines that operate in an open cycle (ibid.). Summer is usually the peak period due to high temperatures and the resulting excessive use of air conditioning, and the highest consumption levels are recorded between 11 am and 3 pm. A second peak has appeared recently, although of lesser amplitude, during summer nights.

Moreover, the production of fossil energy resources in Tunisia is declining. This is mainly due to missing investments caused by political uncertainty as well as frequent strikes and protests. Simultaneously, the primary energy demand is increasing as a result of population growth, urbanization, and subsidies that foster overconsumption. This led to an energy deficit of 5.9 Mtoe in 2019 (ONE, 2020). Consequently, Tunisia must import energy carriers, for a rising energy deficit in the country may also affect the supply security in the long term. Moreover, the figures and current energy situation in Tunisia show that the energy system is expanding. Also, the COVID-19 crisis has led to the closure of factories, which, in turn, resulted in the decrease of energy consumption. Yet, renewables currently play only a marginal role in the energy mix and have not replaced fossil fuels. This is consistent with the first phase described in the MENA energy transition phase model.

Renewable Energy

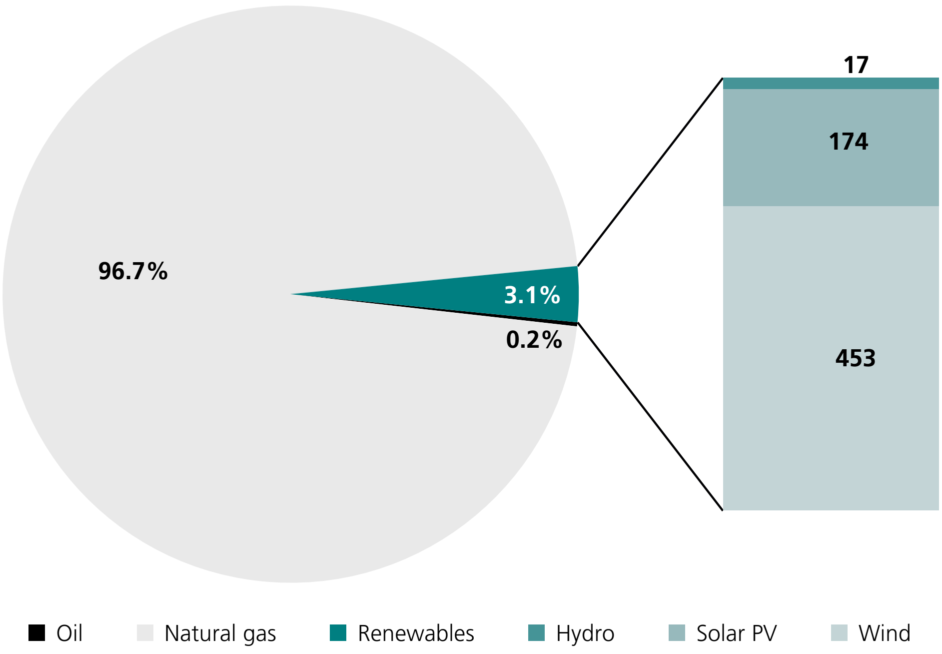
Tunisia has prominent locations for wind and solar energy. The northeast, central west, and southwest regions, in particular, have favourable conditions for the development of wind power, with average wind speeds of 5.9-7.5 m/s at 80 m height (Benedetti et al., 2013; Terrapon-Pfaff et al., 2021). The exploitable onshore wind potential is estimated at around 10 GW, which is in addition to the 250 GW of offshore wind potential (ANME, 2020). Wind energy currently represents the main source of RE generation, and two flagship wind farms in Sidi Daoud and Bizerte are used for this purpose. Sidi Daoud, which began its operation in 2000, is located at the Gulf of Tunis and has a capacity of 54 MW, while the Bizerte farm is composed of two stations (Kchabta and Metline) that have a combined production capacity of around 190 MW. Kchabta station, which has a capacity of 94 MW, and Metline station, with a capacity of 95 MW, both began their operation in 2016. The wind speed at these stations oscillates between 11-17 m/s. The two stations at Bizerte have been partially financed through a loan from the Spanish Fund for Assistance to Development (Detoc, 2016).

In terms of generating solar energy, the southern areas possess the most suitable qualities, for in these areas, the solar irradiation exceeds 2,000 kWh/m^2 per year. The appropriate solar conditions allow for the establishment of PV as well as concentrated solar power (CSP) plants. The gross potential of solar PV is estimated to be approximately 840 GWp, while the CSP potential using cylindro-parabolic sensors is estimated at around 600 GW, and the potential of solar tower plants at 400 GW. While solar power is currently not exploited at large-scale, several small-scale applications are in operation, especially in the residential sector. Different schemes for auto production exist with the support of the National Agency for Energy Management (ANME) and STEG. Most of the small-scale private installations have a capacity between 1 and 10 kW, while the low voltage capacity in the residential sector can reach up to 17 kW. The commercial sector's low voltage capacities range between 10 and 30 kW, whereas the medium voltage capacities are between 25 and 100 kW (Energypedia, 2020).

Furthermore, Tunisia benefits from hydropower potential that is estimated to be around 250 GWh per year (Benedetti et al., 2013), while the installed capacity can harness a variable production between 40 and 160 GWh (Detoc, 2016).

Biomass energy is applied in rural households using traditional wood and charcoal fuels. Projects that aim at disseminating more efficient biomass stoves have been implemented, and the potential for biomass gasification is also being tested in pilot projects. In addition, Tunisia has some geothermal potential, which is specifically used for the heating of greenhouses, spas, resorts, and other heat-dependent activities. The geothermal resources are mainly lo-

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



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

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

Operational wind power plants							
Site	Sidi Daoud	Metline Station (Bizerte)	Kchabta Station (Bizerte)				
Installed Capacity (MW)	54	95	94				
Planned wind power plants							
Site	Mornag (Governorate of Ben Arous)	Jebel Sidi Bchir	Jebel Kchbata	Batiha (Governorate of Bizerte)	Kebili	Nabeul	Pending developer proposals
Installed Capacity (MW)	30	30	30	30	100	200	200
Status	Under development	Under development	Under development	Under development	Under development	Under development	Under development
Operational solar power plants							
Site	Global capacity	Tozeur	PRO-SOL Elec	Om Somaa			
Type	PV	PV	Solar roof PV	CPV			
Installed Capacity (MW)	100 (90 MW for self-generation, 10 MW STEG)	10	4	0.02			
Planned solar power plants							
Site	Kairrouan	Sidi Bouz-id	Gafsa	Tozeur	Tataouine		
Installed Capacity (MW)	100	50	100	50	200		
Status	Under development	Under development	Under development	Under development	Under development		
Operational hydropower plants							
Site	Arroussia	Nebeur	Fernana	Kesseb	Sidi Salem	Bouhertma-Sejnene	
Installed Capacity (MW)	4,8	13,2	9,5	0,66	36	1,82	

(Source: data based on Albrecht-Heider (2020); Detoc (2016); IRENA (2021); IRENA & EIB (2018)) cated in the southern regions of Kebili, Tozeur, and Gabes, extending to Algeria and Libya (Benedetti et al., 2013).

Despite the large RE potential, the share of renewables in the electricity generation remains extremely low and was at around 3% in 2018 (Fig. 4-5). Fig. 4--5 illustrates the electricity generation mix in 2018, where electricity from wind amounted to 453 GWh, solar energy to 174 GWh, and hydropower to 17 GWh.

In relation to installed renewable capacity, the total capacity in 2020 amounted to around 400 MW, with wind power installations accounting for 245 MW, solar PV power plants totalling 100 MW (including around 90 MW for self-generation and 10 MW of STEG), and hydropower amounting to 62 MW (Terrapon-Pfaff et al., 2021). The installed capacity of renewables represents around 5% of the total electricity production capacity (ibid.). Table 4-1 lists all operational and planned RE projects in Tunisia.

The promotion of REs and energy conservation in Tunisia started more than 20 years ago. The main step that was taken for the purpose of developing the RE sector in Tunisia was the establishment of the TSP. The TSP aims to reduce energy import dependence and lower emissions by promoting large-scale renewables. The TSP was originally formulated in 2009 and was launched in 2010, following the shift from surplus to deficit in the energy balance sheet in the early 2000s. It was then updated in 2012 and 2015. The TSP provides a roadmap for implementing the Tunisian energy strategy that intends to diversify the energy mix (Detoc, 2016; Moisseron et al., 2018). Energy efficiency and REs are essential pillars of the TSP that should achieve a 30% share in the energy mix by 2030. This equals a RE capacity of 3,800 MW by 2030. In order to achieve this objective, the Ministry of Energy and Mines published the following planned capacities to be installed by 2022 under regimes that are defined by Law No. 2015-12: self-generation, authorisation, and concessions (Table 4-2). In addition to the principal guide and action plan until 2030, the Tunisian strategy aims to create dialogues and partnerships (Detoc, 2016).

Table 4-2
Renewable Energy Programme Targets, 2017–2022

Regime	Wind (MW)	Solar PV (MWp)
Concessions (tender)	500	500
Authorisations (call for projects)	130	140
Self-generation (requests)	80	130
STEG projects (tender)	80	300
Total	**790**	**1,070**

(Source: data based on IRENA (2021))

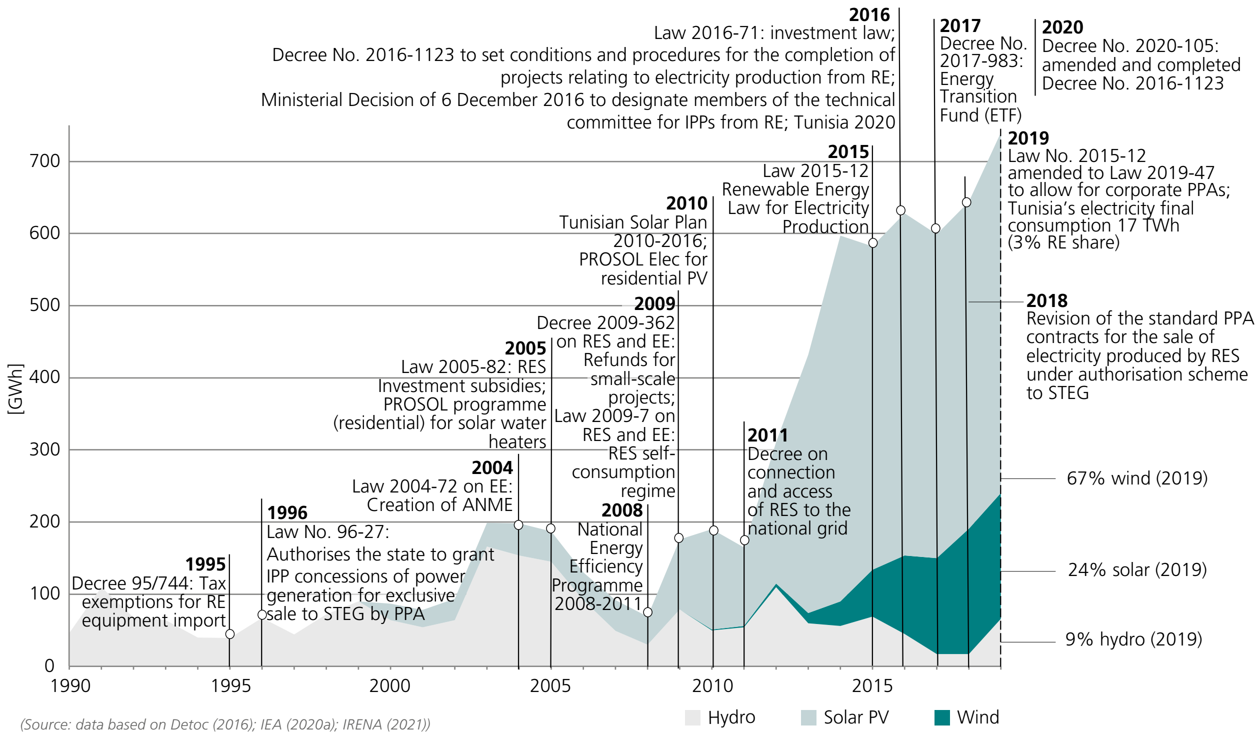
Tunisia currently lacks utility-scale solar projects. Since May 2017, four rounds of calls for PV projects have been launched under the authorisation regime, and a fifth tender call was issued in early 2021 (Bellini, 2021). The first three rounds comprised 18 solar PV projects with a capacity of 10 MW each and 24 projects with a capacity of 1 MW each. So far, only a few of these projects are either operating or will start operating. In addition, in May 2018, a prequalification call for tenders to implement five solar PV plants, with a total capacity of 500 MW under the concession regime, was launched (IRENA & EIB, 2018). The concessions are currently at an advanced stage of negotiations with the authorities (Terrapon-Pfaff et al., 2021). For wind power, only one round has been completed under the authorisation regime. In this round, four projects with a capacity of 30 MW each were selected. Under the concession scheme, a tender was launched for a total capacity of 500 MW, resulting in three projects to be selected. These large-scale projects will be developed under the build, own, and operate (BOO) model (Baba-Aissa et al. 2018).

On a small-scale level, the government started programmes to develop solar power generation in the residential sector. For instance, after receiving financial aid from STEG and other organisations, ANME managed to initiate the two projects PROSOL and PROSOL Elec. (Detoc, 2016). These projects assist the development of the usage of solar water heaters and PV panels (ibid.). The project PROSOL implemented 750,000 m^2 of solar installations between 2005 and 2016 and provided capacity building for the local workforce. The project PROSOL Elec. started in 2010 and has been focusing on the deployment of roof PV panels for residential auto consumption. Funding for PROSOL Elec. is provided by the Energy Transition Fund (ETF) and public-private agreements between STEG and partner banks. By the end of September 2016, the installed capacity reached 32 MW.

Overall, several international organisations support RE development in Tunisia. These include the European Bank for Reconstruction and Development (EBRD) that aids the STEG network, the European Union (EU), and the French Development Agency (AFD) (UNDP, 2018b).

Regarding electricity production from renewables, Decree No. 2009-362 governs the sector and regulates electricity transport and the sale of surpluses to STEG. The main legislation concerning RE production is Law 2015-12 that was enacted in 2015, and it establishes a legal framework governing the development of renewable projects. The law describes the National Plan for the generation of electricity through RE sources, the project development framework, and the role of the Technical Commission and Authority for private power generation (GIZ, 2019). It entails three regulatory schemes, which are self-consumption, authorisations through calls for projects, and concessions through calls for tenders. Accordingly, any public or private entity that is connected to the national electricity grid in medium voltage or high voltage and operates in the industrial, agricultural, or tertiary sector is able to produce its own electricity through RE sources with the possibility of power wheeling (GIZ, 2019). Under the Law 2016-71, the Tunisian Investment Fund (FTI) was established, and it is supported by state resources, loans, and grants from within Tunisia and from abroad. Moreover, Decree 2017-983 governs the ETF, which is the principal financing tool for RE in Tunisia.

Figure 4-6
Development of Renewable Electricity Generation by Source (in GWh) and Introduction of Energy Policy Measures, Tunisia 1990–2018



(Source: data based on Detoc (2016); IEA (2020a); IRENA (2021))

The ETF governs around TND 100 million[2] and can lend up to 50% of the total costs for a RE system that is intended for self-consumption. Furthermore, there are other subsidy models that can be financed by the ETF. However, these financing schemes are currently not operational.

In 2018, standard power purchase agreements (PPAs) for the sale of electricity (produced by renewables under authorisation scheme) to the STEG were approved. In 2019, Law No. 2015-12 was amended to Law 2019-47, allowing for incorporate PPAs. Also, Decree No. 2020-105 that completes Decree No. 2016-1123 sets the conditions and procedures for RE projects. Fig. 4-6 depicts the introduction of energy policy measures and their impact on renewable electricity generation by year.

The increase in RE generation since 2010 coincides with the introduction of the TSP and its financial schemes. So far, wind energy holds the highest share of renewables. However, successful implementation of solar energy has still not been achieved, and the overall share of RE remains low. The slow development of renewables in Tunisia can be attributed to a number of barriers. These include long-lasting administrative procedures that cause large delays in the project implementation, difficulties with land access, the lack of regulatory body for IPPs, or the absence of sovereign guarantees, which results in a high off-taker risk. Also, PPAs under the authorisation regime are considered as non-bankable by financiers and local banks. The financial difficulty that STEG (as the buyer of electricity) is facing further increases the uncertainty among project developers to invest in large-scale projects. Yet, COVID-19 has already affected the 2020 state budget and shifted priorities towards health care. Funds that were allocated to other activities and investments have shrunk, and this could also have an impact on the power system planning.

In summary, the steps taken by the Tunisian government in the RE sector fall under the first phase of the energy transition according to the applied phase model. One such step is the creation of a coherent legal framework. Despite the large RE potential in Tunisia, the country has still not implemented any significant large-scale solar energy projects, as envisioned under the TSP. Thus, the TSP remains a vision that is only slowly being translated into reality.

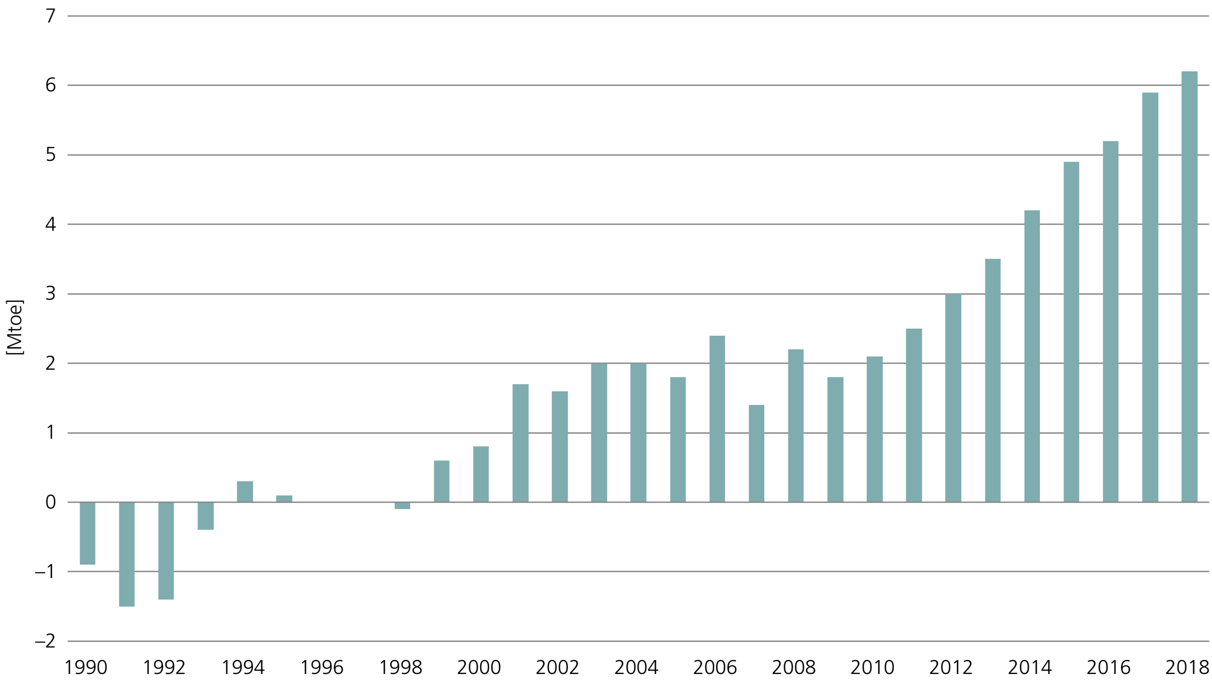
The Fossil Fuel Sector

Until the year 2000, Tunisia was considered to be an energy exporting country, seeing as it was able to cover its energy needs largely from its own resources and the »gas fees« from the Algerian-Italian pipeline (Moisseron et al., 2018). However, since 2000, Tunisia has become an energy importing country with a growing deficit throughout the years (Fig. 4-7). Due to the decrease of oil and gas resources, coupled with the population growth, Tunisia's energy import demand has increased substantially (Detoc, 2016).

The current Tunisian energy supply is almost entirely imported, mainly from neighbouring Algeria. This poses increasing risks for the energy security in Tunisia, especially with the continuing depreciation of the currency, the Tunisian Dinar.

2 This amount equals around 305,100 Euro. https://www1.oanda.com/lang/de/currency/converter/

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



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

As a result, the energy subsidies have already reached 7% of Gross Domestic Product (GDP) in 2018, while smuggling and illegal trade with Libya have grown (Moisseron et al., 2018).

When oil prices started to rise in 2013, the Tunisian policy makers discussed the future energy path the country should pursue. Relevant stakeholders and experts in the energy field gathered to partake in a national debate that took place between the end of 2013 and April 2014. The debate was under the responsibility of ANME, and it aimed to address Tunisia's energy strategy for 2030 and define the strategic objectives of the new policy through extensive consultations with key energy stakeholders. The results of this debate concluded that Tunisia should engage in an energy transition.

Based on the results of the debate, ANME and the Tunisian government have developed the national energy strategy that focuses on four axes (Moisseron et al., 2018):

1. The need for an energy transition,
2. The principle of energy efficiency,
3. Policy measures in the Action Plan 2014–2020, and
4. Recommendations in terms of institutional, financial, and socio-cultural measures.

The exploitation of shale gas was highlighted as an option within this strategy. This idea, however, led to protests from the civil society. Despite the opposition, the government still launched an environmental impact study on shale gas to be considered as a new approach to the energy transition (Moisseron et al., 2018).

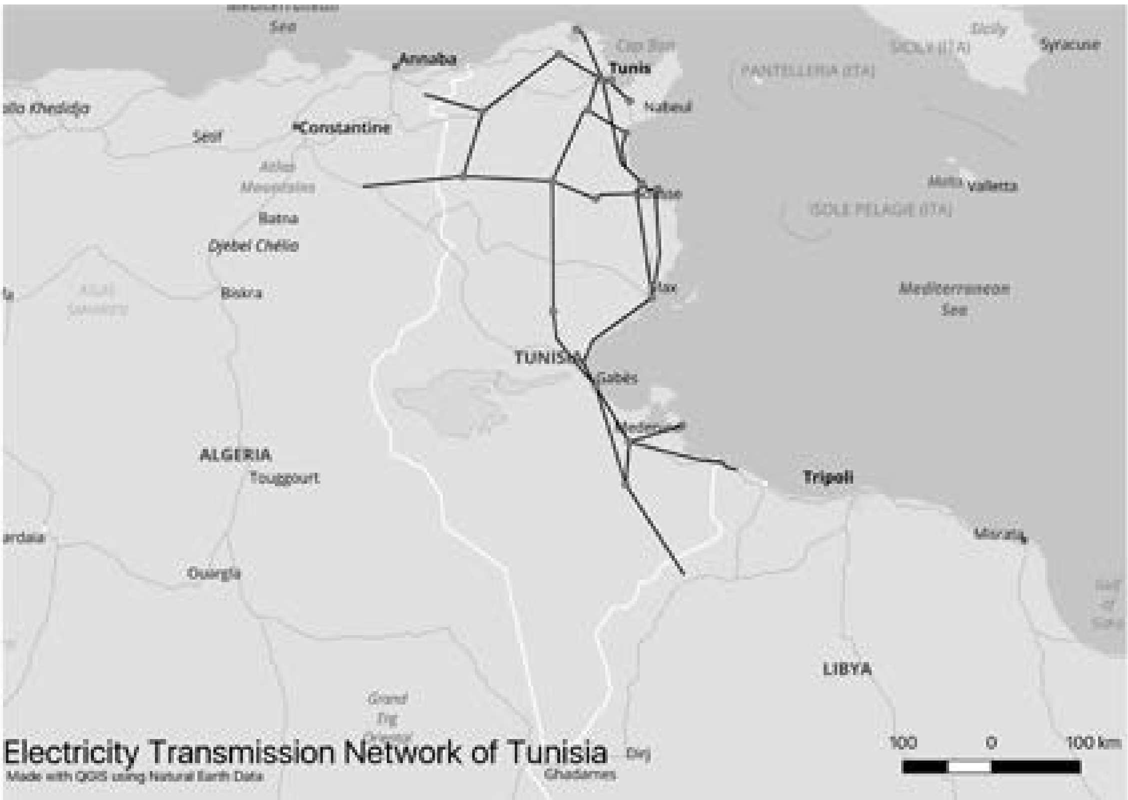
A second national debate on the energy and mining sector was conducted on May 30, 2019, in Tunis under the responsibility of the Presidency of the Government. The debate focused on themes of energy security, energy management and its rationalisation, as well as the mining sector and ways to improve its performance. Being aware of the need to revitalise the energy management policy in Tunisia, the Tunisian government also carried out a set of energy prospective studies. The objective of these studies was to map out strategic directions and set ambitious goals for reducing energy demand and developing REs. These studies were the subject of a broad consultation and focused on rational energy use, the development of REs, the energy mix for production of electricity, and the updating of the TSP.

To summarise, Tunisia's energy situation is characterised by high dependencies on fossil fuels imports that negatively impact the state's financial sustainability. The negative trade balance regarding energy commodities raises the state's deficit, which, in turn, delays the energy transition. In order to address this deficit in the Tunisian energy balance, structural reforms and a stronger focus on exploiting the domestic RE resources are needed. Based on the current situation, Tunisia can be classified as being in the early stages of the first phase of the energy transition according to the applied phase model.

Infrastructure

Tunisia's power sector is well developed, and nearly the entire population enjoys access to the national electricity grid. Tunisia's electricity transmission grid is operated by STEG.

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



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

The Tunisian high-voltage network connects all power plants to the consumption centres (Detoc, 2016). The voltage levels in Tunisia are 400 kV, 225 kV, 150 kV, and 90 kV. By 2019, the grid lines extended over a total of 6,990 km. In the north and the coastal zones, the grid connections are more developed. The north is connected to the south via a main line of 225 kV. The overall electrification for Tunisia is around 99.8%, while the urban areas are fully electrified (100%) (Detoc, 2016). Fig. 4-8 depicts Tunisia's electricity transmission network with its major load centres located in the urban coastal zones of the country.

The grid, which has been extended constantly in the recent years, is connected to the European grid via Algeria and Morocco. The Tunisian power grid is connected to Alegria via two 90 kV lines, one 150 kV line, one 225 kV line, and one 400 kV line. Also, two 225 kV lines connect the Tunisian grid with the Libyan grid (Terrapon-Pfaff et al., 2021). Moreover, there are plans to establish a North African interconnection between Libya, Egypt, Jordan, and Syria. The aim of this transmission corridor is to create a joint electricity market that will help to accommodate increasing shares of electricity from RE in the MENA region.

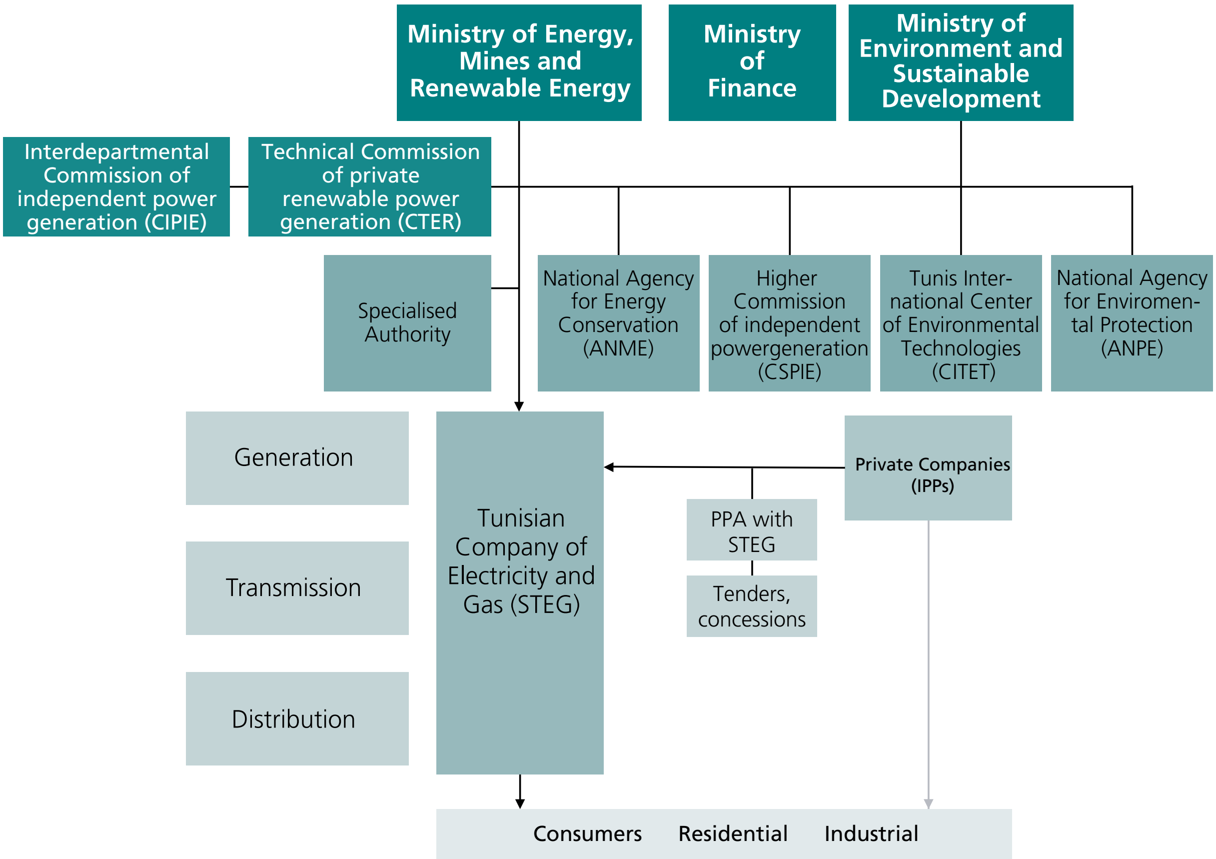
In its current state, Tunisia's transmission infrastructure is not well suited to integrate large volumes of renewables. To be able to accommodate large amounts of electricity from intermittent renewable sources, the transmission network must be expanded, and substantial investments are needed to increase the flexibility of the Tunisian electricity grid. Presently, only limited storage options exist. Consequently, the development of the electricity infrastructure for the integration of renewables is only in its initiation stage, which corresponds to the first stage of the applied phase model.

Institutions and Governance

The Ministry of Energy, Mines and Renewable Energy is one of the key actors in Tunisia's electricity and energy sector. It supervises the energy sector and oversees the implementation of energy policies and strategies. The main tasks of the Ministry are to promote the research and the exploitation of energy resources, to assure the energy security of the country, to develop and implement policies and juridical texts regarding energy efficiency and energy transition, to negotiate with companies and attribute permits, to elaborate energy projects, to assure the optimisation of hydrocarbon production, to optimise market conditions, and to promote RE technologies (Detoc, 2016). Within the Ministry, the Interdepartmental Commission of independent power generation (CIPIE) and the Technical Commission of private renewable power generation (CTER) are located. While CTER's responsibilities include undertaking projects under the authorisation scheme and studying issues related to RE development, CIPIE is in charge of monitoring the negotiations with the selected IPP (Benedetti et al., 2013; GIZ, 2019).

Moreover, the STEG is the state-owned utility that operates under the supervision of the Ministry of Energy and

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



(Source: own creation data based on Detoc (2016); GIZ (2019))

is considered to be the leading actor in the Tunisian electricity market. STEG is the main producer, transmitter, and distributor of electricity. Historically, STEG had a vertically integrated monopoly status. However, since the opening of the electricity market in 1996, STEG's monopoly has been reduced to the transmission, commercialization, and distribution of electricity in Tunisia (Döring et al., 2018; GIZ, 2019). According to Law No. 7-2009, self-production of electricity from RE sources is allowed, with the right to sell to STEG a maximum of 30% of electricity generated at the same price of STEG's high voltage sale price (Benedetti et al., 2013). In this framework, STEG operates as a single buyer under a PPA that is partially defined by the tender call for concession and the final negotiations between STEG and the concessionaire (ibid.). The Higher Commission of independent power generation (CSPIE) is responsible for choosing the concessionaire.

Furthermore, ANME is an agency that promotes energy efficiency and RE development programmes. ANME oversees the implementation of energy management policies to promote energy efficiency, RE, and energy substitution. It is also in charge of the ETF, ensuring that it grants subsidies for self-consumption projects (GIZ, 2019). Another relevant actor in the Tunisian electricity sector is the Specialised Authority that is responsible for the issues and claims regarding projects developed under Law No. 2015-12. Led by a judge and representatives of the government presidency, as well as ministries and electricity and RE experts, the Specialised Authority manages the approval, authorisation, and disputes between the project company and STEG (GIZ, 2019). Other actors in the environmental and energy field include the Tunis International Centre of Environmental Technologies (CITET), which is a governmental institution under the authority of the Ministry of Environment and Sustainable Development that builds capacity and skills, and the National Agency for Environmental Protection (ANPE), which conducts environmental impact assessments that are required for the approval of power plant projects (Döring et al., 2018). Fig. 4-9 depicts the Tunisian institutional framework of the electricity and energy market.

Institutions that promote investment in the field of renewables in Tunisia are the Tunisia Investment Authority (TIA), the Agency for the Promotion of Industry and Innovation (APII), the Agency for the Promotion of Agricultural Investments (APIA), and the Foreign Investment Promotion Agency (FIPA Tunisia) (GIZ, 2019).

Although Law No. 7-2009 authorises the participation of private power producers in the market, the electricity market is still dominated by STEG and its extremely vertically integrated structure. The successful implementation of RE projects is dependent on a significant number of private participators that enhance the energy transition, which is still lacking in Tunisia. Therefore, the current state of development and effectiveness of the institutional framework places Tunisia at the beginning of the first phase towards a renewable-based energy system according to the MENA phase model.

Energy Market and Economy

Tunisia has established an energy price system that takes into account international oil and gas prices, on the one hand, but is built on extensive energy subsidies, on the other hand (Detoc, 2016; Eibl, 2017). The Ministry of Industry together with the Ministry of Finance, the General Direction for Energy (DGE), Tunisian Enterprise of Petroleum Activities (ETAP), Tunisian Company of Refining Industries (STIR), and Ministry of Commerce are all responsible for the price setting (Benedetti et al., 2013). At the end of each financial year, the price rates are set, reflecting the international oil and gas prices as well as the financial balance of the businesses of STEG, ETAP, and STIR. This is dependent on the subsidy level that the government can spend. The set prices for gas and electricity, therefore, do not reflect the real production costs and are below the level of the world market. As a consequence, the two main energy providers, STIR and STEG, account annual deficits that are largely covered by transfers from the state budget (Eibl, 2017). Over the past 10 years, the subsidisation of energy has increased significantly and currently accounts for up to 13% of the total expenditures.

To reduce the fiscal burden, several mechanisms have been introduced. In 2009, the introduction of an automatic indexation mechanism for local petrol prices was implemented, which was then repealed. Moreover, for an International Monetary Fund (IMF) programme, the government increased fuel prices by 7% in 2012 and 2013, and electricity and gas prices for medium-voltage consumers have risen by 20% in 2014. Additionally, a gradual subsidy phase-out took place for selected energy-intensive industries, such as cement, textiles, ceramics, and food processing. However, the measures have had only limited success and lack a systematic review (Eibl, 2017).

The prices of gas and electricity differ between time periods for high voltage consumers, medium voltage consumers, and water pumping for agricultural irrigation. Consumers pay different tariffs for day, peak, evening, and night electricity use (Benedetti et al., 2013). Medium voltage consumers can also pay a flat tariff. For low-voltage consumers, the tariffs are divided into three sub-tariffs: a base tariff up to 300 kWh per month, a normal tariff above 300 kWh per month, and a social tariff for consumers that use less than 50 kWh per month (ibid.). Therefore, the tariff can vary between TND 75-186 million[3] per consumed kWh. Due to the described measures, these tariffs have increased several times in recent years, on average 10% per year for high and medium voltage users and 8% for low voltage customers. However, subsidies favouring the use of fossil fuels remain high and distort the market to the detriment of the energy transition towards RE in Tunisia. In summary, the state-subsidised energy prices are a major barrier to the wider deployment of RE, as they distort markets and support the continuous use of fossil fuels. Thus, Tunisia can be classified as being in the first phase of the applied transition phase model, as support and price schemes still favour fossil fuels.

Greenhouse Gas Emissions

In the context of the Paris Climate Agreement, Tunisia has committed itself, in form of its Nationally Determined Contribution (NDC), to reduce its greenhouse gas emissions in all sectors, including the energy sector, by 41% in 2030, relative to the base year 2010. In terms of carbon emission reductions, the NDCs entail the suppression of 207 million tCO_2eq from 2015 to 2030 (Detoc, 2016; MESD, 2015). In the energy sector, Tunisia aims to reduce its energy consumption by 46% until 2030, compared to the base year 2010 (GIZ, 2019).

In 2018, Tunisia emitted 26 Mt CO_2. While the electricity and heat producers were responsible for 38% of the CO_2 emissions, the transport sector held a share of 33%, followed by the industrial sector with 21%. The agricultural, commercial, and public services sectors each had a share of 4% of CO_2 emissions in the same year. Since 2005, CO_2 emissions have risen by 33% due to increasing demographic dynamics and industrial development (Fig. 4-10). Fig. 4-10 depicts the Tunisian CO_2 profile, while Fig. 4-11 illustrates the resulting emissions from heat and electricity generation by source for 2018.

Tunisia is highly vulnerable to global warming, which could lead to major consequences such as temperature increase, precipitation reduction, and rising sea levels. Therefore, significant adaptation and mitigation measures are required. It is estimated that around USD 20 billion are needed for climate change abatement measures in Tunisia (MESD, 2015).

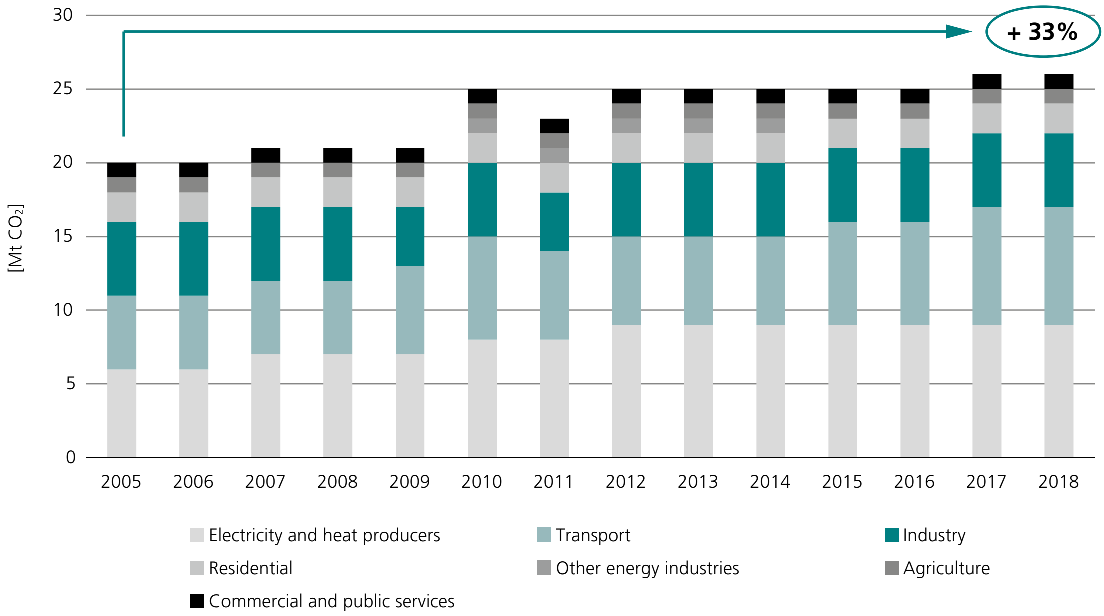
Although Tunisia's NDC targets aim at reducing CO_2 emissions by 2030, emissions are, in fact, increasing due to industrialisation and demographic change. The actions planned and executed as part of the NDCs often remain disparate and ad hoc, lacking in their concrete implementation. Despite the green growth strategy that Tunisia has developed for the purpose of structural transformation, the country still faces challenges that hugely hinder the implementation of the strategy's targets. In order to decarbonise the energy sector, which is responsible for the major share of GHG emissions, programmes targeting efficiency and REs sector-wise must be implemented and extended. Reducing GHG emissions and achieving the Paris goal will only succeed if Tunisia rapidly replaces fossil fuels with RE sources.

Efficiency

Regarding energy efficiency, many projects have been launched targeting all types of consumers, such as households and industries. Different tools and mechanisms have

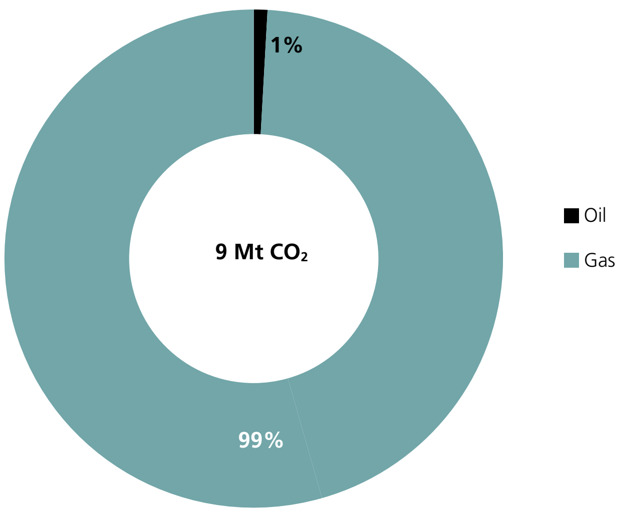
3 This amount equals between 2-5 Eurocents per kWh. https://www1.oanda.com/lang/de/currency/converter/

Figure 4-10
CO_2 Emissions by Sector (in Mt CO_2), Tunisia 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), Tunisia 2019



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

been implemented to endorse energy efficiency. These include laws, taxes, awareness campaigns, research initiatives, and investment incentives (Detoc, 2016). The creation of ANME in 1985 indicates Tunisia's long-standing history in the energy conservation policy.

The main energy efficiency law is the Law 2005-82 that defines the scope of the ETF and establishes the framework to support the energy conservation actions developed by ANME. The target sectors include, in particular, industry, transportation, and buildings (Detoc, 2016).

According to the World Bank (2021), Tunisia has one of the most effective energy efficiency policies that led to a decrease in energy use rates per GDP in the course of the last decades. The Energy Efficiency Department of ANME manages the three main projects that have contributed to decreasing the energy intensity in Tunisia: Preliminary consultations with companies that seek to conserve energy, energy audits of firms, and feasibility studies for cogeneration projects (Detoc, 2016). To control the growing energy demand, ANME plans to reinforce and further promote these projects. ANME plans to extend cogeneration projects, keep energy audits as an essential part of its work, apply LED's for public lighting efficiency, certify household appliances, refurbish buildings, and develop a public system of buildings certification (Detoc, 2016). Moreover, new programmes at city and community level are being created.

In 2017, ANME adopted a low carbon strategy (the stratégie nationale bas-carbone (SNBC)). This strategy is planned to be implemented until 2050 and includes carbon pricing instruments. The overall goal of the strategy is to change current development paths in order to achieve carbon-neutrality by 2050. The Partnership for Market Readiness, United Nations Development Programme, and the World Bank are supporting Tunisia in the implementation of its NDCs and the SNBC. Additionally, the SNBC includes measures to build institutional capacity and address the planning gaps from the first round to the second round of NDC reviews in 2020 (UNDP, 2018a).

Although Tunisia has recognised that energy efficiency is an important pillar to control rising energy demand, the country still faces challenges in executing projects. Some projects have been successfully implemented, while others remain merely plans. This evaluation shows that despite the important steps taken by Tunisia towards energy efficiency, there are still significant efficiency measures needed, placing Tunisia in the first phase of the applied energy transition model.

Society

Civil society plays a particularly promising role in the future of sustainable development in Tunisia. Many civil society associations (CSAs) emerged after the revolution in 2011 to raise consumer awareness and involve society in dialogues on the potential of REs (Akermi and Triki, 2017). The main mission of the associations is to inform and encourage stakeholders and citizens to actively participate in local and international sustainable development projects focusing on RE. CSAs play a key role in anchoring the culture of environmental citizenship by organizing awareness campaigns for the public. Other formats to include society are the forum »Civil Society and Green Jobs« or the »Enersol, World Sustainable Energy Forum« launched in Tunisia in 2012 and 2014, respectively. These forums aim to create partnerships between various actors, including governments, the private sector, and civil society. Under the Tunisian-German Energy Partnership, several associations participated in a summer school to create an »Alliance of the promotion of renewable energies.« The alliance involved many associations operating in the promotion of sustainable development and REs. In addition, there are a few associations, such as the Tunisian wind power association, that support an actors network in the field of renewables (Rocher and Verdeil, 2013).

Despite these initiatives, awareness about environmental topics among the Tunisian society is still weak. Although local communities in Tunisia usually follow sustainable practices, community members still portray a not-in-my-backyard (NIMBY) attitude or oppose bigger infrastructural projects (Hammami et al., 2018). For instance, the residents of Sidi Daoud, the site of the wind farm, felt threatened by the construction of the wind power plant and responded defensively. According to Hammami et al. (2018), this type of reaction could be avoided if the local population would be actively involved in the development of projects and if incentives were created. For example, perceived benefits and psychological ownership reinforce empowerment that, in turn, lead to such projects gaining more acceptance.

Solar energy in Tunisia, for instance, is mainly found in the form of small-scale implementations, particularly in the form of rooftop PV systems or solar water heating systems. To further promote and grow these uses, a Nationally Appropriate Mitigation Actions (NAMA) support project was launched in 2020 to disseminate solar energy panels on the roofs of about 65,000 middle-income households (NAMA Facility, 2021).

Other studies, such as Kilian-Yasin et al. (2016), have analysed the social acceptance of alternative mobility systems in Tunis. The findings show that electrically driven engines have a slightly higher social acceptance than natural gas driven vehicles. However, the results also indicate that environmentally friendly features are not reasons to switch to e-mobility. Public transport could become an important sector where renewable electricity could be used (directly or indirectly). Yet, the modal share in Tunisia has shifted from public to individual transport, seeing as reach and quality of public transport remains low. This has caused customers to lose interest in public transport (Boujelbene and Derbel, 2016).

Overall, Tunisia has established a number of institutions to raise awareness about REs. However, the majority of the Tunisian society does not yet consider environmental topics as being of high relevance. Awareness-raising campaigns could contribute in this dimension. Nevertheless, it will take considerable efforts to embed these aspects in people's mindsets and change their daily habits.

Summary of the Landscape and System Level Developments

On the landscape level, the COVID-19 pandemic is expected to affect the energy transition in the short term, at least, but potentially also in the long term. Other barriers impacting the development of the energy transition at system level reflect institutional, technical, financial, and regulatory patterns. The challenging economic situation and the associated pressing problems that contribute to the recent political instability and social unrests could undermine Tunisia's ability to address the three main barriers in the energy sector (The World Bank, 2019b):

1. dependence on fuel imports,
2. high distortive subsidies, and
3. low commercial and financial performance at utility level.

Despite the challenging economic situation, energy demand increases, and STEG faces the challenge to cover the growing demand. Officially, Tunisia has opened its electricity market for IPPs to increase the private sector's participation, but the electricity market remains a single buyer market, with STEG having a monopoly. Simultaneously, STEG faces high constraints (especially when investing in the electricity infrastructure) due to its limited financial capacities.

In spite of the challenges, the transition in Tunisia is notable based on four main pillars (IRENA, 2021):

1. diversification of the energy mix and integration of REs,
2. strengthening energy efficiency,
3. rationalisation of the energy subsidy, and
4. strengthening the grid and interconnections.

By implementing the Law No. 2015-12 that regulates RE production, Tunisia has entered the first phase of the energy transition towards a renewables-based system according to the MENA phase model. However, the enactment of the law was delayed by several years, seeing as during the publication of the TSP in 2010 no regulatory law allowed the integration of the private sector into the electricity production sector. An obvious incentive barrier is that the ETF currently only provides limited support, which negatively impacts the implementation of projects and programmes. On the institutional level, the creation of CTER within the Ministry of Energy intends to improve the approval procedure for renewable projects, but has, so far, shown little effectiveness. According to different interview experts, these procedures have become complex and lengthy rather than simplified. At the same time, the creation of an independent regulatory body that would enable the private sector's integration is still missing. On the macroeconomic level, financing costs in Tunisia are relatively high, in comparison to other countries. The high costs are linked to factors such as regulatory risks, unreliable mechanisms for setting RE sales tariffs, network and transmission risk to integrate large shares of renewables, and monetary risks. At the system level, a number of other elements currently limit Tunisia's progress in the energy transition: subsidised electricity prices that contribute to the national fiscal deficit, energy market structures, hesitant support from institutional actors, and human resources barriers. Furthermore, recent problems, such as the COVID-19 pandemic and the challenging economic and political situation, could negatively impact progress or hamper further development. In addition, renewables are not yet replacing oil and natural gas due to the growth in energy demand. In fact, the opposite is true; the consumption of fossil fuels is increasing and GHG emissions are rising. To move towards a renewable-based energy system will, therefore, require much greater efforts from all sides.

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

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). Alongside the aforementioned advances made at the system level in Tunisia towards RE, 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 developments are still only taking place at a 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. Tunisia shows some progress in almost all the relevant dimensions of supply, demand, infrastructure, markets/economy, and society. However, important steps still need to be implemented by the government to move towards the full introduction of RE in Tunisian markets.

Concentrated Solar Power (CSP)

One of Tunisia's most ambitious RE projects under development, the TuNur project, includes the deployment of CSP. The TuNur project aims at producing electricity through a hybrid solar PV and CSP facility in southern Tunisia and exporting it via a transmission line to Italy and Europe from 2028 onwards (TuNur, 2020). The facility is planned to have a capacity of 2,000 MW CSP located in the Tunisian Sahara Desert and a 2 GW high-voltage direct current (HVDC) submarine cable connecting Tunisia to Italy.

Smart grid

In 2019, STEG launched a tender to install a pilot smart grid power distribution system of 400,000 smart meters in Sfax, which caught the interest of several US companies. The implementation of the project is planned for 2021.

E-mobility

Concrete measures for e-mobility are still under development. However, Tunisia started to form a National Transport Master Plan for 2040 (Ilie, 2017), which includes major investments in the transport infrastructure to improve, integrate, and coordinate the transport systems and ensure a sustainable development. Projects that support the scale up of e-mobility are also supported, particularly in the cities of Sfax, Bizerte, and Djerba. For instance, the city of Bizerte aims at becoming a smart city leader in Africa within the »Tunisia 2020« initiative, where the municipality pays special attention to e-mobility. Overall, scaling up e-mobility is seen as part of the solution to combat the increase of fossil fuel powered transportation, air pollution, congestion, and noise pollution.

Power-to-X (PtX)

Developments in the direction of PtX in Tunisia are currently at an early stage. However, the topic also gained momentum in Tunisia during the emerging international hydrogen discussion. In this context, Tunisia signed a Memorandum of Understanding (MoU) with Germany in December 2020 for the establishment of a Tunisian-German green hydrogen alliance. Also, within the framework of the Tunisian-German Energy Partnership, first conferences on the topic of

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	–11%	–13%	–13%	N/A	N/A	26 million tCO_2eq compared to 2010	
	CO_2 emissions per capita	+27%	+47%	+53%	+53%	N/A	–26% of GHG emission (from 2005)	
RE	Installed and planned capacity (MW)	N/A	120	332	358	373 (2019)		–
	Share in final energy use	14.2%	12.7%	12.6%	11.9% (2017)			–
	Share in electricity mix (existing and planned)	1.5%	1.2%	2.9%	3%			–
Efficiency	Total primary energy supply (TPES) (compared to 1990)	+68.1%	+107.7%	+119.6%	+131.5%	N/A	–	–
	Energy intensity of primary energy (compared to 1990)	–12.6%	–13.5%	–15.3%	N/A	N/A	–	–
	Total energy supply (TES) per capita (compared to 1990)	+33.3%	+66.7%	+66.7%	+66.7%	N/A	–	–
	Electricity consumption per capita (compared to 1990)	+83.3%	+133.3%	+150%	+150%	N/A	–	–
	Fossil fuel subsidies (% of GDP)	N/A	6.2 (2013)	4	N/A	N/A		–
Buildings	Residential final electricity consumption (com-pared to 1990)	+160.6%	+240.4%	+63.3%	+75.5%	N/A	–	–
Transport (Compared to 1990)	Total primary energy supply (TPES) (compared to 1990)	+68.1%	+107.7%	+119.6%	+131.5%	N/A	–	–
	Energy intensity of primary energy (compared to 1990)	–12.6%	–13.5%	–15.3%	N/A	N/A	–	–
Industry	Carbon intensity of industry consumption (compared to 1990)	–11.9%	–11.1%	–5%	–10.9%	N/A	–	–
	Value added (share of GDP)	26.6%	28.9%	24.9%	23.2%	22.7 (2019)	–	–
Supply Security	Natural gas imports (compared to 1990)	+21.6%	+122.3	+181.2%	+282%	+211% (2019)	–	–
	Crude oil exports (compared to 1990)	–13.8%	+12.2%	–45.1%	–59.4%	–51.2% (2019)	–	–
	Electricity imports (compared to 1991)	+1,100%	+1,100%	+3,400%	+3,200%	N/A	–	–
	Electricity exports (compared to 1998)	+500%	+400%	+2,050%	+2,000%	N/A	–	–
	Electricity access by population proportion	99.3%	99.5%	99.9%	99.8%	N/A	–	–
	Oil reserves (compared to 1990)	–64.7	–76.5	–76.5%	–76.5%	–84.7% (2019)	–	–
Investments	Decarbonisation investments (USD million)	N/A	N/A	N/A	4,72 (2017)	N/A	–	–
Socio-economy	Population				11,694,719 (2019)	–	–	
	Population growth	0.84%	1.03%	1.05%	1.15%	1.12 (2019)	–	–
	Urbanisation rate	65.2%	66.6%	68%	68.6 (2017)	N/A	–	–
	GDP growth	3.4%	3.5%	1.2%	2.6%	1% (2019)	–	–
	Jobs in low-carbon industries	N/A	N/A	N/A	N/A	1,637 (2019)	–	–
Water	Level of water stress	72.8%	79.1%	107.9%	121.1% (2017)	N/A	–	–

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

PtX have been conducted (PAREMA, 2020). Moreover, a first study on the opportunities of PtX in Tunisia was concluded in 2021 (Terrapon-Pfaff et al., 2021). Under the MoU, Germany is providing a grant of EUR 30 million to establish a close partnership with Tunisia for developing a green hydrogen industry and cooperating in the field of PtX. Indeed, Tunisia has the theoretical potential to become a PtX producer and exporter due to its RE potential, proximity to European markets, political and economic conditions, and availability of skilled labour. Nevertheless, there have only been first discussions about concrete PtX projects, but none have yet been launched.

4.1.3 Necessary Steps for Achieving the Next Phase

Tunisia has already taken considerable steps towards a RE transition and can be categorised as being in the »Take-Off« phase of the MENA phase model. In order to integrate more renewables into the energy system (described by the phase model as the second phase) and to proceed with the energy transition, efforts in the field of RE implementation must be increased, and structural reforms are needed.

However, the difficult economic and fiscal situations present a major challenge for the progress of the energy transition. These barriers have to be addressed in order to boost private investment, trade, and entrepreneurship, in general, but also to enhance the RE sector, in particular (The World Bank, 2019b). As well as tackling these challenges, the energy sector's governance needs to be improved. One step in this direction is creating a transparent management of authorisation, which would permit and license processes with clearly defined responsibilities between the different ministries and other public institutions such as STEG. This will help to establish a climate of trust, especially with private investors (Moisseron et al., 2018). On an institutional level, it is recommended to unbundle the vertically integrated power sector to allow for more competition, promote inclusion, and attract private sector investments. Unbundling is, however, a complex process and must be carefully orchestrated. The unbundling usually starts with accounting separation, then functional separation into distinct management areas, followed by legal separation into separate companies (Foster et al., 2017). Moreover, the establishment of an independent energy regulatory agency needs to be advanced and concretised, seeing as such an institution is important to enhance trust among private actors. In this case, the first step would be to create a legal mandate to establish an independent energy regulator, which could issue licenses, set standards, and ensure competition. Setting up such an institution will require significant resources, including investments, expertise, and human capital. Support in the form of knowledge and resources (such as through programmes with existing regulators from other countries, international organisations, and development agencies) could help this development in Tunisia.

Focusing on sector coupling is also important for an energy system transformation. In this context, promoting electrification in end-use sectors, such as mobility, construction, and households, is key. To achieve this, the regulatory frameworks for these sectors should be revised to integrate energy efficiency and renewables. A first step in this direction could be establishing a dialogue between stakeholders from different sectors to identify opportunities and barriers to sector coupling in Tunisia and develop integrated sector and technology specific targets.

Equally important for the transition towards REs are subsidy reforms to reduce fossil fuel subsidies. Lifting subsidies will allow for the reallocation of resources towards welfare-enhancing products and will improve the efficiency of energy uses (The World Bank, 2019b). Subsidy reforms will, however, need to be accompanied by measures to reduce potentially negative socioeconomic impacts on the poor in Tunisia. These measures would ensure that the energy transition is both environmentally and socially sustainable, especially as fossil fuels subsidies have become embedded in the social contract between political leaders and society (Schmidt et al., 2017). As costs fall, REs become competitive with fossil energy sources, which introduces the opportunity to break up the fossil subsidy regime through widespread introduction of REs (Schmidt et al., 2017). Although there are initial theoretical assessments of possible paths for subsidy reform, it is advisable to conduct an in-depth dialogue with a broad spectrum of stakeholders to find a socially acceptable method to reduce subsidies. Such a dialogue is particularly timely, given the apparently growing dissatisfaction with STEG's existing services among customers (The World Bank, 2019b).

In terms of infrastructure development, Tunisia will need to strengthen and expand the transmission capacity to enable the integration of larger shares of RE in the long-term. While the largest load demand centres are in the north, Tunisia's highest RE potential is situated in the south. Exploiting the renewable potential, therefore, requires the extension of the transmission network lines to transport the electricity from the south to the load centres in the north to provide a reliable supply. Exporting electricity and other energy commodities could be an option to support the financing of such large infrastructural projects (The World Bank, 2019b). In order to realise the expansion of the transmission grid, it would be advisable to develop and model different scenarios together with local actors. This would help to determine the next steps and define concrete technical projects (IRENA, 2021). Moreover, the procedures for the expansion of the grid interconnections and the development of grid infrastructure projects should be accelerated by STEG to avoid long-term delay in connecting RE projects (ibid.).

Furthermore, a successful energy transition will require the participation of the citizens. Involving the wider population is crucial, as the energy transition towards 100% renewables will not only affect stakeholders in all sectors but also the ordinary citizens in their daily life. As there still seems to be a lack of information and knowledge about the benefits of REs in large parts of the Tunisian society, it is recommended to intensify awareness-raising and communication campaigns and, in particular, to involve local associations in this process (MIEM and ANME, 2014). This can include integrating energy and environmental issues more widely into school and university curricula to raise awareness and encourage participation among the younger generation. Another option could be creating citizen energy projects that could be funded by the ETF, for example. A start in this direction could be a call for project ideas or the establishment of advisory services that support interested local associations in the development of local energy projects. This could be in the form of technical knowledge, financing questions, or administrative procedures. The potential savings from renewable implementations could also be calculated. Supporting such small-scale RE projects will help to accelerate the transition process.

Another factor is decentralisation to achieve a reliable and secure energy supply, while allowing wider parts of the society in the rural zones as well to participate and benefit from the energy transition. To support a decentralised development in local communities, ANME should develop concepts and institutional structures, and it should include regional programmes to promote decentralised energy systems (Döring et al., 2018). According to the interviewed stakeholders, the environment in Tunisia is favourable for the creation of such micro-projects in the field of REs and energy efficiency.

Likewise, energy efficiency is critical to moving towards a sustainable energy transition. Although Tunisia has taken steps to increase energy efficiency, the implementation of energy efficiency policies and measures must be accelerated (Moisseron et al., 2018). This includes measures such as insulating buildings, improving lighting, as well as fostering behavioural changes through capacity building and training. Making consumers aware of their actual energy consumption through certain measures could help them change their behaviour to save energy. These measures include using smart meters or highlighting consumption in the form of innovative billing, which is less resource-intensive. Concrete exchanges between other energy suppliers, retailers, and distributors about best practices on how to create awareness could be a first step. Formally, the STEG could also be obliged to set concrete savings targets, as it is the case in the EU with the introduction of Energy Efficiency Obligation Schemes (EEOS) (European Commission, 2016). In parallel to raising awareness, concrete support for efficiency measures must be strengthened through the establishment of advisory services that guide households as well as businesses in identifying savings potential. These services would also provide advice on practical implementation. Another option would be to create different direct financial incentives for the implementation of efficiency measures, but this may be difficult to achieve as long as energy prices remain low due to high subsidies.

Furthermore, for long-term development, PtX technologies should also be considered in Tunisia's energy strategy in sectors where direct electrification is not feasible. Developing PtX technologies would also provide the country with the potential to export energy in the future (Terrapon-Pfaff et al., 2021). However, the export of energy derivatives from RE sources should not happen at the expense of the domestic energy transition.

4.2 OUTLOOK FOR THE NEXT PHASES OF THE TRANSITION PROCESS

Overall, the expansion of REs can make an important contribution to increase energy security and reduce fuel imports to Tunisia. Although Tunisia set an ambitious target to achieve 30% of renewables share in the power sector by 2030, the progress will require enhanced political and institutional support within Tunisia as well as financial and technical assistance. This includes support for the design of the necessary framework conditions to encourage civil participation and to attract investment from the private sector.

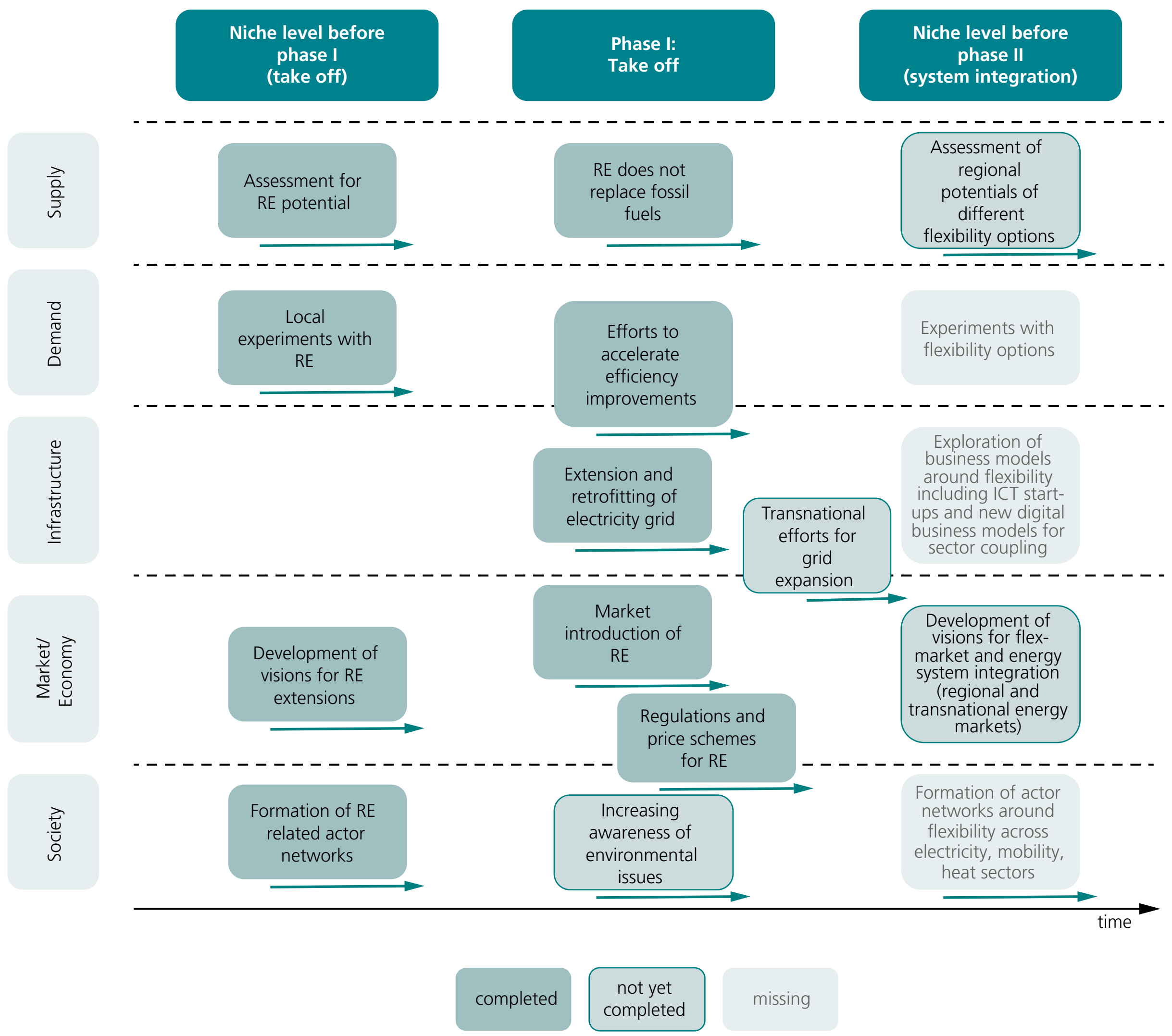
However, to embark on this path, the Tunisian government must address three major challenges: the difficult economic situation, the current political crisis, and the high dependence on fossil fuels. These intertwined challenges impede Tunisia's energy transition and will largely affect the country's path towards a 100% renewables energy system. Experts also stress the fact that Tunisia's energy transition is deeply intertwined with its political transition. Yet, the willingness from policy makers to support the energy system transformation has often been limited. Consequently, institutional, regulatory, and procedural reforms in the energy sector are only slowly being adopted. Yet, Tunisia would be well advised to try to increase the speed of the energy transition, as it can bring great economic and social benefits by reducing the national budget deficit for future generations. Currently, rising gas and oil prices increase the financial burden on the public budget, as natural gas and electricity prices are highly subsidised. The use of domestically generated RE could not only reduce costs for the country, but it could also provide socio-economic benefits, such as lower household energy expenditure through small decentralised systems, the development of new value chains, the creation of skilled jobs, and new business opportunities in the RE sector. The energy transition is, thus, also of high social and political relevance. It should not only be discussed from a technical and economic point of view but rather with a broad spectrum of stakeholders, focusing on the societal implications.

In terms of technology implementation, it will be critical for Tunisia to develop large-scale RE projects alongside decentralised application of RE. This would significantly increase the share of renewables in the electricity mix and support the move towards the next phase of the applied phase model. Simultaneously, decentralisation could give local communities more ownership and sovereignty in energy matters, according to the interviewed experts. To improve the framework conditions for both large-scale RE projects and stronger decentralisation efforts, the electricity market structure must be reformed, seeing as the monopoly of STEG and the utility's focus on fossil fuel assets are hindering innovations in the field of REs (Moisseron et al., 2018). The next phase in the energy transition will require a stronger focus on flexibility options and sector coupling. This process should start with experiments, followed by the development of new business models in this field.

To initiate the next transition phase, it will be crucial to prepare immediately for these next steps. This includes working on increasing societal support for renewable-based power generation technologies, focusing the discussion on flexibility options, and exploring the future role of PtX in the energy system. A long-term policy vision for 2050 that includes these aspects and increases the confidence among stakeholders and investors will be essential to attain these goals.

The phase model analysis could offer guidance for further discussion and development of such a long-term strategy that takes into account the entire energy system and its transition to a fully RE-based system. Fig. 4-12 summarises Tunisia's current status in the energy system transition and gives an outlook on the following steps.

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



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 Tunisia 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 Tunisian context.

The model, which includes four phases (»Take-off RE«, »System Integration«, »PtF/G«, and »Towards 100% Renewables«), was applied to analyse and determine where Tunisia 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 there is high interest in REs in Tunisia, and the Tunisian government has set itself ambitious REs targets. Although the legal framework and expansion planning for REs is well developed, structural challenges persist and limit the scaling up of renewables. Given that fossil fuels and, in particular, natural gas play a major role in the Tunisian power generating sector and in the economy as a whole, the pathway to a RE-based energy system needs strong government support at all levels to succeed.

To gain broader political support, decision-makers must recognise the long-term opportunities that RE offers for economic and social development. Tunisia has sufficient RE potential to meet its own energy needs and produce further RE for export. RE exports could be an interesting option for the country due to its proximity to the developing markets for renewables-based energy commodities in Europe. A transition to 100% RE, therefore, not only offers the possibility of eliminating the current energy deficit and reducing dependence on energy imports, thus increasing energy security, but it also offers economic development opportunities. Hence, the Tunisian government would be well advised to take measures to promote investment in low-carbon energy technologies, and the transition to a 100% RE system ought to become the country's long-term goal.

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

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LIST OF ABBREVIATIONS

AFD	French Development Agency
ANME	Agence Nationale pour la Maîtrise de l`Energie (National Agency for Energy Management)
ANPE	National Agency for Environmental Protection
APIA	Agency for the Promotion of Agricultural Investments
APII	Agency for the Promotion of Industry and Innovation
BOO	Build, own, and operate
CCS	Carbon capture and storage
CCU	Carbon capture and use
CIPIE	Interdepartmental Commission of independent power generation
CITET	Tunis International Centre of Environmental Technologies
CSA	Civil society association
CSPIE	Higher Commission of independent power generation
CTER	Technical Commission of private renewable power generation
CNG	Compressed natural gas
COVID-19	Coronavirus disease 2019
CRTEn	The Research and Technologies Centre of Energy
CSP	Concentrated solar power
DGE	General Direction for Energy
DSM	Demand-side management
EBRD	European Bank for Reconstruction and Development
EEOS	Energy Efficiency Obligation Schemes
ETAP	Tunisian Enterprise of Petroleum Activities
ETF	Energy Transition Fund
EU	European Union
EV	Electrical vehicle
FIPA Tunisia	Foreign Investment Promotion Agency
FiT	Feed-in tariff
FTE	Energy Transition Fund
FTI	Tunisian Investment Fund
GDP	Gross Domestic Product
GHG	Greenhouse gas
ICT	Information and communication technologies
IMF	International Monetary Fund
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
NAMA	Nationally Appropriate Mitigation Actions
NDC	Nationally Determined Contribution
NGO	Non-governmental organisation
NIMBY	Not-in-my-backyard
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
SNBC	Stratégie nationale bas-carbone
STEG	Société Tunisienne d'Électricité et du Gaz (Tunisian Company of Electricity and Gas)
STIR	Tunisian Company of Refining Industries
TES	Total energy supply
TIA	Tunisia Investment Authority
TND	Tunisian Dinar
TPES	Total primary energy supply
TSP	Tunisian Solar Plan
USD	US-Dollar

LIST OF UNITS AND SYMBOLS

%	Percent
CO_2	Carbon dioxide
GW	Gigawatt
GWh	Gigawatt hour
HVDC	High voltage direct current
kgoe	Kilogramme of oil equivalent
ktoe	Kilotonne of oil equivalent
kV	Kilo Volt
kW	Kilowatt
kWh	Kilowatt hour
m^3	Cubic Metre
m/s	Metre per second
Mt	Megatonne
Mtoe	Millions of tonnes of oil equivalent

LIST OF TABLES

LIST OF FIGURES

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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 TUNISIA'S ENERGY SYSTEM

Development of a Phase Model

A clear understanding of socio-technical interdependencies and a structured vision are prerequisites for fostering and steering a transition to a fully renewables-based energy system. To facilitate such understanding, a phase model for the renewable energy (RE) transition in the Middle East and North Africa (MENA) countries has been developed and applied to the country case of Tunisia. 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 Tunisia has already taken important steps towards a RE transition. According to the MENA phase model, Tunisia can be classified as being in the ›Take-Off Renewables‹ phase. Nevertheless, natural gas still plays the dominant role in Tunisia's highly subsidised electricity generation. In addition to the elevated political uncertainty, there are numerous structural, political, social, and economic challenges within the energy sector that hinder progress in the transition to REs.

Strong support at all levels is needed to promote the breakthrough of RE. This includes more detailed long-term planning and improving the regulatory framework, as well as reducing off-taker risks to improve the bankability of RE projects in order to attract private investment. Furthermore, institutional buy-in needs to be increased and the engagement of key non-state stakeholders must be strengthened.

In light of the growing domestic energy demand and with the on-going global decarbonisation efforts in favour of sustainable fuels, Tunisia would be well advised to embark on a sustainable energy path sooner rather than later to seize economic opportunities that can arise from RE development.

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

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