STUDY

CLIMATE CHANGE, ENERGY AND ENVIRONMENT

# SUSTAINABLE TRANSFORMATION OF MOROCCO'S ENERGY SYSTEM

## Development of a Phase Model

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

Morocco is a clear regional leader in the energy transition, and it aims to achieve an ambitious renewable energy (RE) goal of more than 52% in the electricity mix by 2030.

Morocco has considerable RE potential. This offers Morocco with an opportunity to become a regional hub for green electricity and a leading country exporting high added value green, industrial molecules.

FRIEDRICH EBERT STIFTUNG

CLIMATE CHANGE, ENERGY AND ENVIRONMENT

# SUSTAINABLE TRANSFORMATION OF MOROCCO'S ENERGY SYSTEM

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Wuppertal Institut

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# 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. MENA economies are characterized by two types of energy models: economies that produce and export oil and natural gas, and economies that are heavily dependent on imports of fossil fuels to meet their energy and growth needs. The energy sector is consistently the most important in terms of current greenhouse gas (GHG) emissions and is also the focus of Nationally Determined Contributions (NDCs) to address climate change. Whilst the sector is not the focus of Coronavirus disease 2019 (COVID-19) stimulus packages, there have been significant interventions in some countries, supported by IFIs, to stimulate the economy through energy sector investment.

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 GHG emissions under the Paris Agreement, to accelerate the implementation of country commitments within the framework of the NDCs and to decarbonise the economies of oil-producing countries. In addition, the use of RE has the potential to increase economic growth and local employment and reduce fiscal constraints and support the sustainable low-carbon and resilient development of societies in the MENA region.

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, and to avoid the incoming exigences of international trade 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 and green hydrogen, 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, and the mobilisation of new green domestic and international financing. 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 allow stakeholders to develop adapted transition strategies towards an energy system based on REs and mitigate the economic, financial and social risks of energy transition.

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 Morocco. The current state of development in Morocco is assessed and analysed against the phase model.

# 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.

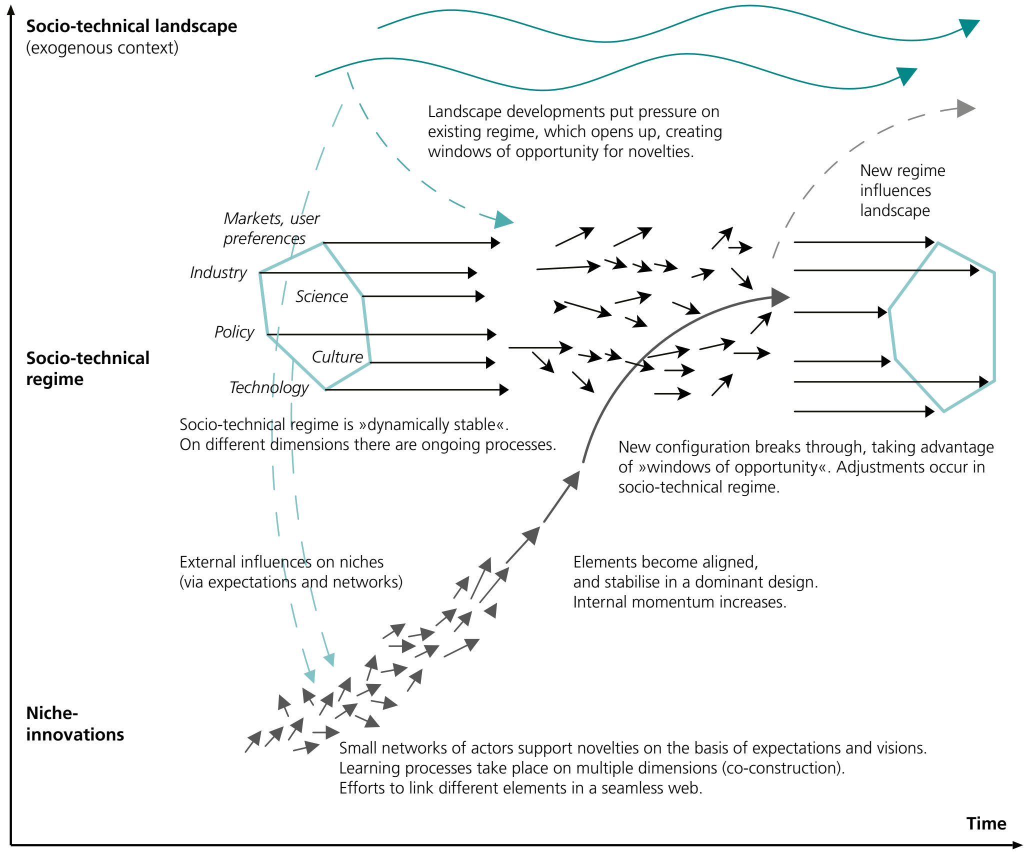
## 2.2 THE MULTI-LEVEL PERSPECTIVE AND THE THREE STAGES OF TRANSITIONS

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) this paper introduces a socio-technical approach which goes beyond technology fix or behaviour change. Systemic transitions entail co-evolution and multi-dimensional interactions between industry, technology, markets, policy, culture and civil society. A multi-level perspective (MLP. Within the transition phases, three stages can be distinguished: »niche formation«, »breakthrough«, and »market-based growth«. In the »niche formation« stage, a niche develops and matures. In the »breakthrough« stage, the niche innovation spreads and when the niche innovation becomes fully price-competitive and specific supportive policy mechanisms are no longer needed, the »market-based growth« stage is achieved. RE technologies are, at this stage, fully integrated into the system.

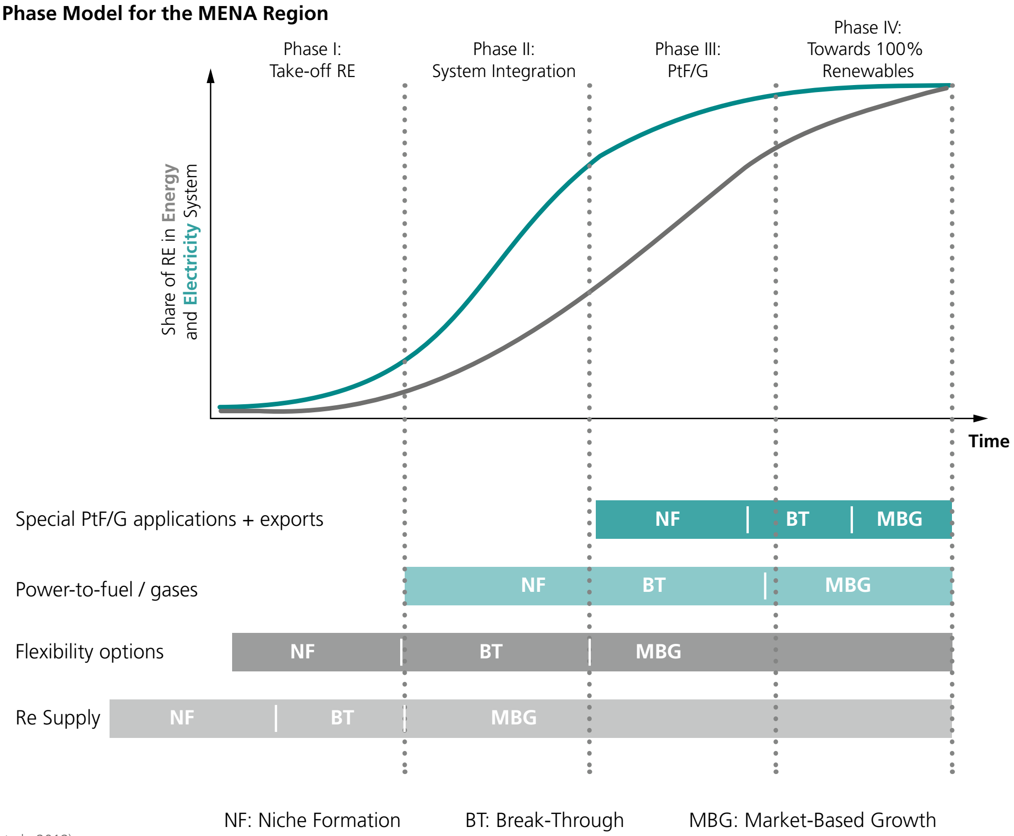
1 Text is based on Holtz et al. (2018).

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)

## 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, maritime transport 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).

# 3

# THE MENA PHASE MODEL

## 3.1 SPECIFIC CHARACTERISTICS OF THE MENA REGION

One of the fundamental differences to the German context is the growing trend in energy demand in the MENA region. According to BP (2019), the Middle East will face an annual increase in energy demand of around 2% until 2040. Furthermore, the energy intensity in many MENA countries is high, due to low insulation quality in buildings, technical inefficiencies of cooling and heating technologies, and distribution infrastructure. The electricity losses in distribution are between 11% and 15% in stable MENA countries compared to 4% in Germany (The World Bank, 2019). Although the MENA region does benefit from significant RE resources, much of the economic RE potential remains untapped. By exploiting this potential, most of the countries could become self-sufficient in terms of energy, and they could eventually become net exporters of renewables-based energy.

Another difference is that the electricity grid in Germany is fully developed, whereas most of the MENA countries have grid systems that need to be expanded, developed nationally, and connected cross-border. Physical interconnections exist, but these are mainly in regional clusters (The World Bank, 2013). Therefore, the region lacks the necessary framework for regional 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 intermittent 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 3-1 summarises the main developments in the »techno-economic« and »governance« layers, as well as on the »landscape«, »system«, and »niche« levels during the four phases.

## 3.4 TRANSFER OF THE PHASE MODEL TO THE COUNTRY CASE OF MOROCCO

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

In order to reflect the specific challenges and opportunities for the energy transition in Morocco, some adaptations to the criteria set of the MENA phase model were made on the landscape level as well. 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. A review of the relevant literature and available data was conducted. Findings from previous studies and projects conducted in Morocco are accounted for in this study. 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 data to identify the current status and future trends. The results have been reviewed by Moroccan energy experts in order to improve the model's output.

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

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

| | | | **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<br>• Niche formation flexibility option | • Market-based growth RE<br>• Breakthrough flexibility option<br>• Niche formation PtF/G | • Market-based growth flexibility option<br>• Breakthrough PtF/G<br>• Niche formation special PtF/G application and exports | • Market-based growth PtF/G<br>• Breakthrough special PtF/G application and exports |
| **Power Sector** | **Niche level** | **Techno-economic layer** | • Assessment of RE potential<br>• Local pilot projects with RE | • Assessment of regional potential for different flexibility options<br>• Experiment with flexibility options<br>• Exploration of business models around flexibility options including ICT start-ups and new digital business models for sector coupling | • Assessment of potential for different PtF/G conversion routes<br>• Local pilot projects with PtF/G generation based on RE hydrogen and carbon capture (e.g. CCU/CCS)<br>• Exploration of PtF/G-based business models<br>• 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)<br>• Tap into global experiences of PtF/G | • Experiment with PtF/G applications in sectors such as industry (e.g. steel, cement, and chemical sectors) and special transport (e.g. aviation, shipping)<br>• Invest in business models for PtF/G exports<br>• Pilot synthetic fuel exports | |
| **Power Sector** | **Niche level** | **Governance layer** | • Development of shared visions and expectations for RE development<br>• Support learning processes around RE (e.g. local projects)<br>• Formation of RE-related actor networks (e.g. joint ventures)<br>• Community-based engagement and involvement (e.g. citizen initiatives) | • Development of visions and expectations for flex-market and energy system integration (regional and transnational energy markets)<br>• Support learning processes around flexibility (e.g. local projects)<br>• 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)<br>• Development of a shared knowledge base of integrated decarbonisation pathways to enable alignment and critical mass that can help shift the entire sector | • Development of shared visions and expectations for PtF/G (e.g. strategy and plans for infrastructure development/adaptation)<br>• 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)<br>• Formation of PtF/G-related actor network (national and international) | • Development of shared visions and expectations for PtF/G exports (e.g. about target markets and locations for conversion steps)<br>• Support learning about PtF/G in sectors such as industry and special transport (e.g. experiments for using PtF/G products for glass smelting)<br>• Support learning around PtF/G exports (e.g. concerning market acceptance and trade regulations)<br>• 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 MOROCCO

| ***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 MOROCCO ACCORDING TO THE PHASE MODEL

Morocco initiated an ambitious RE programme in 2009, aiming for 42% of its installed electricity generation capacity to be based on REs by 2020 and more than 52% by 2030. As part of this strategy, the country launched the Moroccan Solar Plan (MSP), which attempts to construct a number of large-scale solar power plants. One of these flagship utility-scale facilities is $NOOR_O$ Ouarzazate, which is located in the southern Atlas region. With an installed capacity of 580 MW and an area of 3,000 ha, the CSP-PV (concentrated solar power and photovoltaics) complex is considered to be one of the largest solar power facilities worldwide.

With this strategy, Morocco is one of the frontrunners on the African continent and worldwide in terms of RE deployment. The country itself intends to become an »electricity hub for North and West Africa« (GIZ, 2017). Meanwhile, recent political debates show that Morocco also plans to engage in the developing green hydrogen economy. Through this action, the country aims to become an exporter of green hydrogen and its derivatives in the future and to respond to the domestic market needs, particularly the production of green ammoniac. Energy partnerships with European countries and international hydrogen agreements underline the political support for the development of a green hydrogen sector in Morocco. Additionally, the announcement of the European Union (EU) and Morocco to establish a »Green Partnership« highlights the intentions to cooperate in advancing the energy transition (EC, 2021).

However, Morocco currently faces challenges in the energy sector, such as growing demand and high dependencies on imported fossil fuels. A national Green Growth strategy has been defined and will be implemented at different levels in order to meet these challenges and reduce these dependencies. This strategy aims to decrease the amount of foreign energy supply, to create green employment within the local industry, and to contribute to maintaining the national stability (Günay et al., 2018). Thus, Morocco's RE targets and strategies have already been developed and include far-reaching measures. These measures are coherent with Morocco's climate change commitments that are embodied in the country's revised NDCs[2] and its New Development Model (2021–2035)[3].

Nevertheless, the country is still far from reaching a 100% renewable-based energy system. Against this background, this study provides a detailed assessment of the current status and development of Morocco's energy transition along the phase model developed, which provides a structured analysis of energy transitions towards 100% renewables in the MENA countries.

### 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 Morocco's energy system in terms of supply, demand, the oil and gas sector, RE, infrastructure, actor network, and market development.

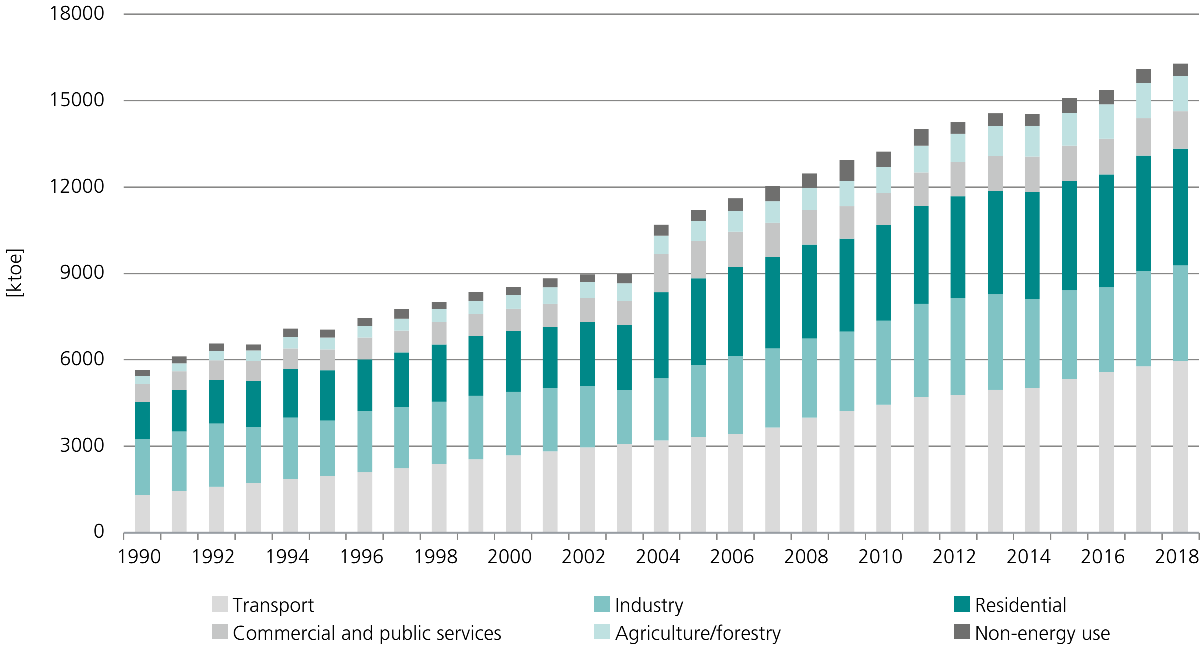
**Energy Supply and Demand**

Rapid demographic change, industrial development, urbanization, and, recently, the carbon border adjustment mechanisms (e.g. EU) are the key drivers for Morocco's rising energy demand (Terrapon-Pfaff and Amroune, 2018). In 2018, Morocco's total final energy consumption was 16,288 ktoe

2 For more information: https://www.environnement.gov.ma/images/2021/rapport/constribution_determinee_01.pdf

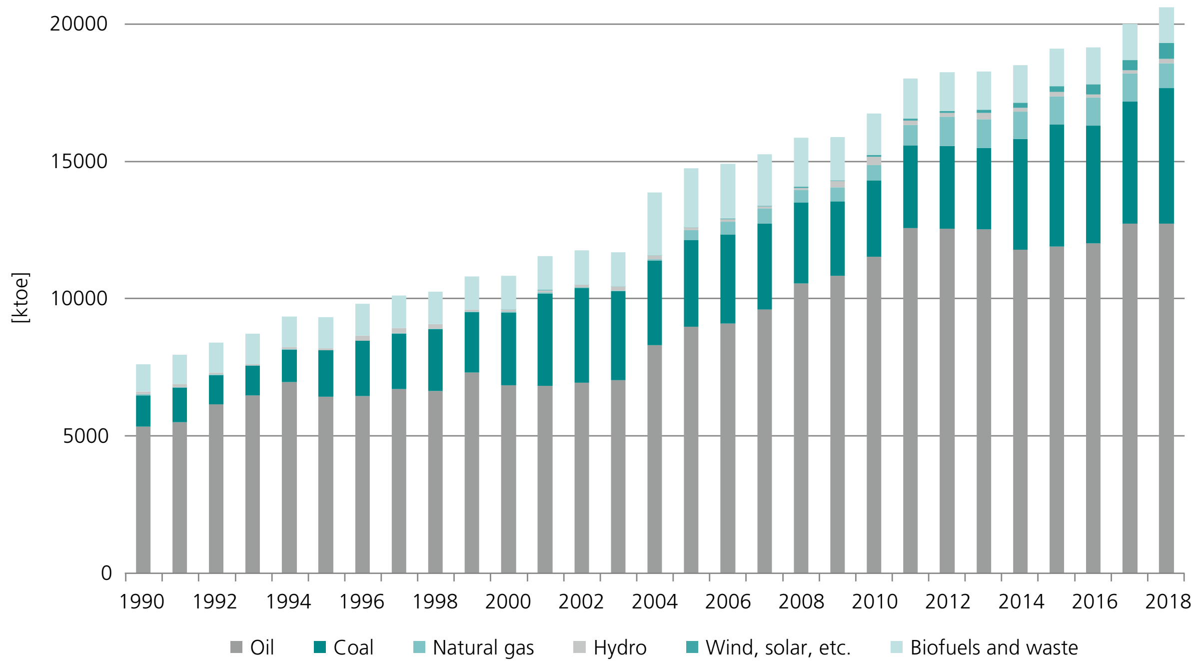
3 For more information: https://csmd.ma/documents/CSMD_Report_EN.pdf

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




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

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




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

(IEA, 2020a). Broken down by sector, transport dominated energy consumption (37%), followed by households (25%) and industry (20%), while the remainder was consumed by the commercial and public services, agriculture and forestry, and non-energy use sectors (IEA, 2020a) (Fig. 4-1).

In 2018, the energy mix was dominated by fossil fuels (Fig. 4-2), with oil accounting for 62%, coal for 24%, and natural gas for 4%, while REs had in total a share of 10% (IEA, 2020a).

The average growth of energy consumption in Morocco between 1990 and 2018 was around 3.7% and is expected to rise further, especially in the industrial sector, for instance, in the chemical industry and the construction sector. Moreover, the energy demand will grow, as desalination power plants are expected to be built in Morocco. On the one hand, these plants will meet growing drinking water demand. On the other hand, they will increase demand for irrigation and industrial water use (Terrapon-Pfaff and Amroune, 2018).

In 2020, Morocco had a total installed power capacity of 10,677 MW with a mix of coal (69%), fuel oil and diesel (19%), gas (8%), hydropower (17%), and wind power (11%) (ONEE, 2020). Electricity consumption in 2019 amounted to around 34.6 TWh, which is almost four times the electricity demand in 1990 (Fig. 4-3). The annual peak has changed from a winter peak to a summer peak due to air cooling demand, and the load curve is characterized by a peak in the evening hours between 8–10 pm (Ersoy et al., 2021). Around 5,670 MW were registered in 2014 as peak load, while in 2000 approximately 2,450 MW were counted, meaning that the load increased by almost 45%. As a consequence of economic growth, population increase with an annual growth rate of 1.25% between 2004 and 2014, modern lifestyles, rural electrification (99% access to electricity) (ONEE, 2020), and industrial development, the electricity demand is projected to further increase by five times by 2050 (Choukri et al., 2017). To tackle the increasing levels of consumption, Morocco is planning to integrate a substantial volume of RE into its power network. By 2019, the share of renewables in electricity production already reached around 19%, while 65% of electricity supply had been generated from coal, 11% from natural gas, and 2% from oil (Fig. 4-4).

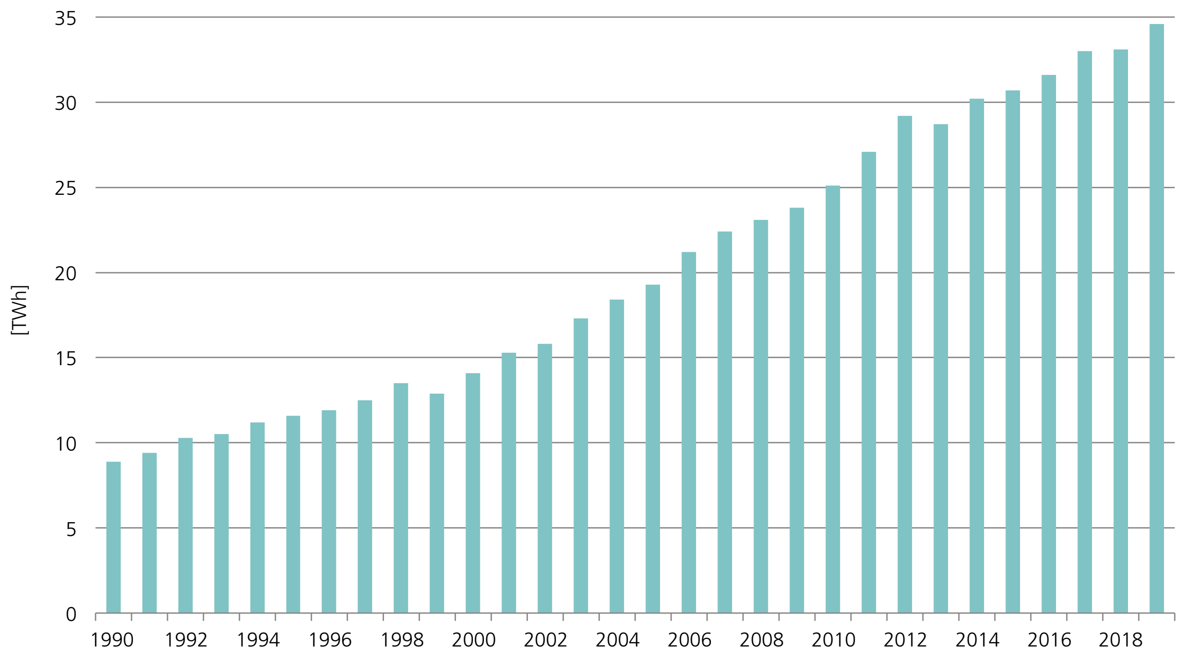
Currently, four coal power plants are in operation in Jerada (320 MW), Mohammedia (280 MW), Jorf Lasfar (1,254 MW), and Safi (1,386 MW). Yet, Morocco has pledged to increase the RE technology use. Although the construction of new coal power plants were part of Morocco's energy strategy, the country committed at the Conference of the Parties (COP26) in Glasgow to not build any new coal power plants as part of the Global Statement on the transition from coal to clean energy (UNCC, 2021). The extension of existing power plants, such as the plans for the Jerada power plant and the new construction of a 1,320 MW coal power plant in Nador, has been cancelled. Morocco has taken a bid decision to phase out coal. A preliminary study conducted by the World Bank analysed a decarbonised pathway by 2050. The results demonstrated that Morocco is able to decarbonize its power system and move towards a more than 50% renewables over the next 15 years (2020–2035). Hence, this enables Morocco to eliminate heavy fuel oil (HFO) and to reduce coal generation. Large investments in this plan are needed and would provide an opportunity for the early retirement of HFO and coal power plants (Huang et al., 2021)100 GW. Although a significant part of this capacity is aging, there are complex issues that need to be addressed including the economic viability of existing coal plants in some countries relative to renewable projects and barriers to exit of coal. We have used detailed power plant level operational cost data for ten developing countries with significant share of coal and compared these with levelized cost of renewables, to demonstrate that competitiveness of coal varies significantly across different geographies. Countries like India where renewable projects have been highly competitive and there is an aging fleet of coal plants many of which are far away from mines, are already highly uncompetitive. On the other hand, countries like South Africa that have relatively inexpensive coal plants, but the average cost of renewable projects have not yet dropped sufficiently (as of 2020. Morocco intends to internally not only cancel the new coal generation but to also explore the early retirement of existing coal power plants.

With the COP26, Morocco has received tailwind to concretise its coal phase out plans. To meet the rising energy demand and to become an energy hub for Africa, Morocco plans to go beyond 50% in the next decade. Still, renewables are not replacing fossils in the domestic power market, and coal is dominating the electricity mix. However, the new developments in Morocco and the commitment of the government support the categorisation of Morocco, in terms of energy demand and supply, to be at the very final stage of the first phase and at the beginning of the second phase, according to the applied MENA phase model.

**Renewable Energy**

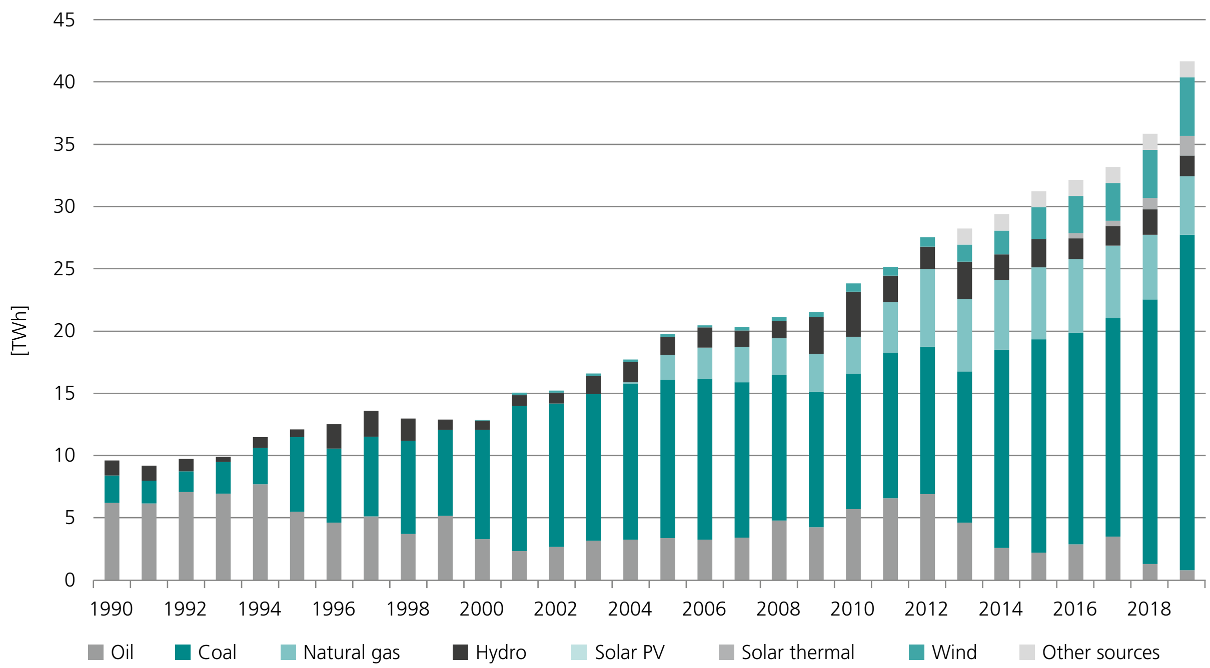
The King Mohammed VI and his Moroccan government have expressed their intention to integrate more RE sources into the energy mix. Their goal is to reach more than 52% RE share in the capacity mix by 2030 (REN21, 2019). This share includes 20% from solar energy, 20% from wind energy, and 12% from hydro energy. The development of RE projects is endorsed mostly by the MSP that is part of Morocco's energy strategy and focuses on REs as well as sustainable development. Today, the following strategies and roadmaps are being prepared that support Morocco's energy transition: Long-Term Low Emissions Development Strategy (LT-LEDS) Morocco 2050, Office of Electricity and Drinking Water (ONEE) Production Master Plan for 2040, PtX roadmap, Biomass Energy Valorisation (VEB) strategy, roadmap for the exploitation of marine energies, Cluster Green H2, National Sustainable Development Strategy (SNDD), National Energy Efficiency Strategy 2030, updated NDCs, National Climate Plan (PCN), Green Economy Strategy, National Water Plan 2050, Morocco Vision 2050, among others.

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




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

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



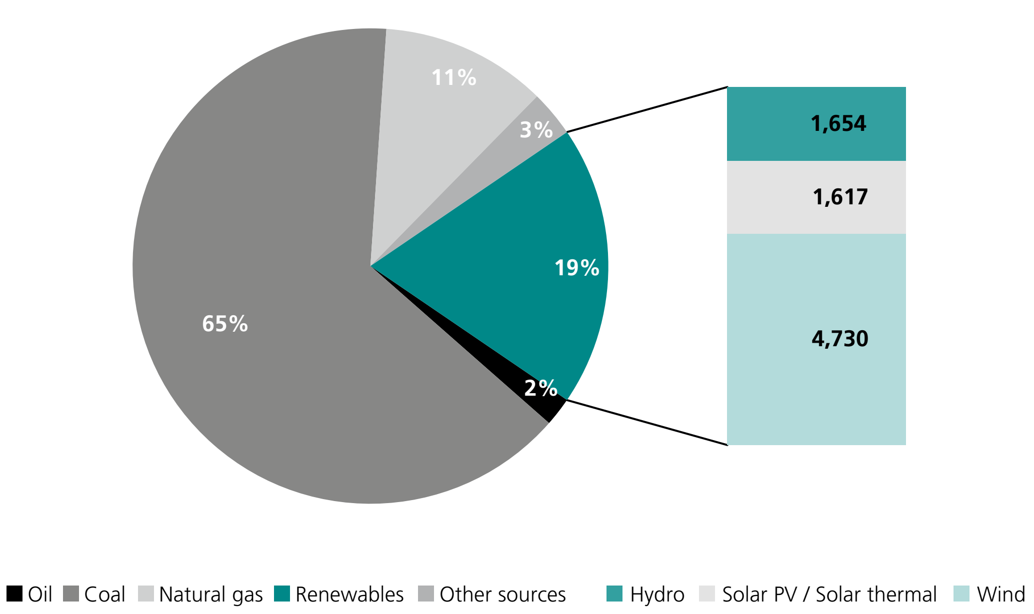

(Source: data based on IEA (2020a))

As of 2019, wind power makes the main contribution to the renewable share with 4,730 GWh, while hydropower generates 1,654 GWh, and solar PV and solar thermal power 1,617 GWh (Fig. 4-5). In 2021, 3,950 MW of RE capacity has been installed, which represents a share of 37% of the total installed capacity (MEM, 2021a).

Morocco is one of the most promising regions for harvesting solar energy, both for electricity and thermal generation. With around 3,000 sunshine hours per year in average, which equals to approximately 5.3 kWh per m² per day, Morocco is well suited for generating solar energy and has a technical potential of 25 GW (Choukri et al., 2017; IRESEN, 2020; Leidreiter and Boselli, 2015; UN ESCWA, 2018). To boost solar energy projects in the country, Morocco launched the MSP and the Solar Integrated Project that aim at implementing large-scale solar PV and solar thermal projects (Noor projects) with an overall installed capacity of 2,000 MW by 2020 and 4,800 MW by 2030 (Choukri et al., 2017). The first concentrated solar power (CSP) plant was constructed in Ain Beni Mathar that is part of the combined gas cycle power plant and has a total capacity of 450 MW. The CSP projects comprises the $NOOR_O$ Ouarzazate project that consists of four solar power plants: NOOR I (parabolic trough), NOOR II (parabolic trough), NOOR III (solar tower), and NOOR IV (PV) that together have a total capacity of 580 MW. The CSP facilities store the electricity up to seven hours after sunset. While the first plant, NOOR I, runs on a wet cooling system, NOOR II and III use dry cooling systems (Ristau, 2021). By the end of 2018, Morocco led the CSP implementation market together with China, followed by South Africa and Saudi Arabia (REN21, 2019). With regards to the water consumption of CSP plants, the Moroccan Agency for Solar Energy that was later renamed Moroccan Agency for Sustainable Energy (MASEN) decided to implement only dry cooling systems for all future RE projects to prevent the aggravation of water conflicts within local communities. Ersoy et al. (2021) underline the fact that dry cooling technologies in CSP plants can be used to reduce competition in water scarce regions, such as in Southern Morocco.

In terms of PV technology, the operational solar PV power plants are listed in Table 4-1. PV and CSP projects are mainly financed by the Credit Institute for Reconstruction (KfW), World Bank, French Agency for Development (AFD), African Development Bank (AFDB), Climate Investment Funds, EU, or through green bonds. Moreover, ONEE launched the NOOR Tafilalt solar PV projects that are in Erfoud, Missour, and Zagora. Each of these projects has a capacity of 40 MW (MASEN, 2021). On a small-scale level, Morocco has equipped around 42,200 villages with solar kits totaling around 10 MW of PV in the frame of the Global Rural Electrification Programme (PERG) (AHK, 2017; Choukri et al., 2017; FES, 2015). Furthermore, the realisation of PV projects that are connected to medium- and low-voltage consumers in the residential and tertiary sector is foreseen to reach market-based growth by 2030. PV technology is also implemented in solar powered irrigation systems in agriculture and piloted in desalination plants (AHK, 2017). The southern regions in Morocco are highly affected by water scarcity. Thus, desalination plants are expected to provide 400 million m³ of water annually in the future.

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




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

Regarding solar heat, a solar water heaters programme called »PROMASOL« was established and aimed at installing 48,000 m² of solar water heaters. The programme enabled the installation of solar water heaters in the residential sector and was financed by investment subsidies and bank loans (IEA, 2014).

The coastal regions possess suitable conditions for wind energy, with wind speeds up to 10 m/s (Choukri et al., 2017; Leidreiter and Boselli, 2015). The technical potential of wind energy is around 25 GW (IRESEN, 2020). Since wind resources, especially at the coasts, are of exceptional quality, Morocco records one of the lowest levelised cost of wind energy (LCOE) worldwide (Agora Energiewende, 2017). Morocco commissioned the first wind farms in the 2000s under a power purchase agreement (PPA). Operational wind farms in Morocco are listed in Table 4-1. Additionally, some independent power producers (IPPs) developed wind farms for industrial clients that total approximately 620 MW. Furthermore, ONEE plans to install 1,000 MW of wind power in the frame of the Moroccan Integrated Wind Programme, which intends to achieve an installed wind power capacity of 2,000 MW in 2020 and aims to reach 5,000 MW by 2030 (Choukri et al., 2017). The wind farms are to be located in Tanger, Essaouira, Laayoune, Boujdour and Taza (Table 41). Despite these efforts, the 2020 goal for wind farms could not be achieved. As of 2020, the installed capacity for wind power is approximately 1,300 MW.

Hydropower was the very first RE technology that has been widely used in Morocco. Many hydraulic hydropower plants have been constructed at rivers and basins in the northwest of Morocco. The rest of the country has only limited hydro power capacities and potential (FES, 2015). With the rise in variable solar and wind energy sources, the importance of dispatchable hydropower plants with pumped storage facilities increases. The most prominent pumped storage plant exists in Afourer with 464 MW capacity, and the largest hydropower plant currently under development is the Abdelmoumen pumped storage station in Taroudant that is expected to start operating in 2022 (Oxford Business Group, 2021). Water resources are managed by priorities, which limits the expansion of large-scale hydropower plants. The first priority is to sustain the supply of drinking water, followed by supply for agricultural irrigation, leaving power generation at dams to drive turbines as the last priority (Ersoy et al., 2021).

Bioenergy in Morocco remains rather unexplored (AHK, 2017). Although Morocco offers some potential that can be used for energy production, the government puts its efforts mainly into solar, wind, and hydropower. However, in August 2021, the Ministry of Energy, Mines and the Environment elaborated a VEB to explore the use of biomass as a RE source. MASEN also started the exploration of waste-to-energy projects, while the Institute for Research into Solar and New Energies (IRESEN) commissioned a prototype combining solar thermal collectors and biomass to produce electricity (Boulakhbar et al., 2020). The government is also planning small-scale biogas projects in big cities to combat the growing waste rates that result from population growth. Thus, legal and regulatory framework conditions for the use of bioenergy have been developed (AHK, 2017). Moreover, IRESEN plans to expand a research platform (park) dedicated solely to bioenergy and storage research (IRESEN, 2021).

Table 4-1 lists the operational and planned RE projects in Morocco.

Morocco's energy transition towards RE is endorsed by several laws and policy frameworks that have the following three main goals: 1) securing energy supply, 2) reducing energy import dependency, and 3) mitigating GHG emissions. The national energy strategy entails goals that correspond to climate change mitigation, particularly in the energy sector. Morocco has, thus, prioritised the development of renewables and energy efficiency, yet it still develops projects based on conventional energy sources, such as natural gas, to achieve energy price-optimisation (Choukri et al., 2017).

The RE framework is structured around the Law 13-09, »Renewable Energy Development Law«, which has been amended and supplemented by Law 58-15. The latter introduces net metering legislation for solar and wind power plants connected to the high and very high-voltage grid. Law 13-09 was introduced in 2009 and focuses on major innovations such as market liberalisation and allowing private companies to produce electricity from RE sources while giving them access to the national grid. Law 58-15 represents the liberalisation of the low-voltage market. Under this Law, private producers of RE power can sell their surplus output to ONEE to an amount that does not exceed 20% of the annual production. However, the application decree for the connection of RE system to the low-voltage grid has not yet been approved. In this regard, Law 16-08 from 2008 must be mentioned, for this is the first Moroccan law that authorises industrial sites to generate their own electricity in the range from 10 MW to 50 MW, thereby paving the way for self-generation. The self-consumption regime under Law 13-09 is currently under reform and will allow the selling of surplus production to the network operator within a limit of 10% of the annual production of the self-consumption installation (El Mernissi and Tork, 2020). The draft law is yet to pass through the parliament for enactment.

Law 16-09 and Law 57-09 provide the legal basis for several institutional bodies that govern the RE market. Under this legislation, MASEN was created in 2009. The Moroccan Agency for Energy Efficiency (AMEE) was also established. MASEN aims to promote and manage the RE sector nation-wide by realising the MSP (IEA, 2020a), while AMEE supports the Moroccan government in the implementation of RE and energy efficiency policies. The enactment of Law 48-15 in 2015 was a further step to open the RE market, seeing as it introduced the new independent regulatory institution, the Moroccan Energy Authority (ANRE). After its assignment by the president in 2018, ANRE started its operation in 2021. ANRE is responsible for the regulation of access and use of transmission and distribution of grids.

Table 4-1
**Operational and Planned Renewable Energy Projects in Morocco**

| | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| **Operational wind power plants** | | | | | | | | | | |
| **Site** | Tanger | Midelt | Koudia Baida (Tetouan) | Akhefnir | Fouma Alouad (Laayoune) | Amogdul (Essaouira) | Lafarge | A. Torres (Tetouan) | Tarfaya | Akhfennir II |
| **Installed Capacity (MW)** | 140 | 210 | 300 | 200 | 50 | 60.35 | 32.2 | 50 | 301 | 101.87 |
| **Site** | Khaladi | Haouma (Tanger-Tetouan) | | | | | | | | |
| **Installed Capacity (MW)** | 120 | 50.6 | | | | | | | | |
| **Planned wind power plants** | | | | | | | | | | |
| **Site** | Jbel Al Hadid (Essaouira) | Tiskrad (Laayoune) | Tanger II | Taza | Oualidia | Oualidia II | Aftissat I (Laayoune, Boujdour) | Aftissat I (Laayoune, Boujdour) | Project Parc Cap Cantin | Dakhla |
| **Installed Capacity (MW)** | 270 | 100 | 70 | 150 | 18 | 18 | 200 | 200 | 108 | 40 |
| **Status** | Under development | | | | | | | | | |
| **Site** | Project Parc Am Wind | Biranzarane | Boujdour | Ghrad Jrad | | | | | | |
| **Installed Capacity (MW)** | 100 | | 200 | | 300 | | 80 | | | |
| **Status** | Under development | | | | | | | | | |
| **Operational solar power plants** | | | | | | | | | | |
| **Site** | Noor$_O$ I Ouarzazate | Noor$_O$ II Ouarzazate | Noor$_O$ III Ouarzazate | Noor$_O$ IV Ouarzazate | Ain Beni Mathar | NoorB Boujdour | NoorL Laayoune | Noor Tafilalt (Erfoud) | Noor Tafilalt (Missour) | Noor Tafilalt (Zagora) |
| **Type** | CSP (parabolic trough) | CSP (parabolic trough) | CSP (solar tower) | PV | CSP-gas | PV | PV | PV | PV | PV |
| **Installed Capacity (MW)** | 160 | 200 | 150 | 70 | 20 (total 450) | 50 | 85 | 40 | 40 | 40 |
| **Site** | El Jadida | | | | | | | | | |
| **Type** | PV | | | | | | | | | |
| **Installed Capacity (MW)** | 1 | | | | | | | | | |
| **Planned solar power plants** | | | | | | | | | | |
| **Site** | Noor Midelt (CSP-PV) | Noor Atlas Tantan (PV) | Noor Atlas Outat El Haj (PV) | Noor Taroudant (PV) | Noor Atlas Tata (CSP-PV) | Noor Boudnib (Errachidia) (PV) | Noor Atlas Enjil (PV) | Noor Argana Boumalen (PV) | Noor Guercif (PV) | Noor Bouanane (PV) |
| **Installed Capacity (MW)** | 800 | n/a | n/a | n/a | 600 | n/a | n/a | n/a | n/a | n/a |
| **Status** | Under development | | | | | | | | | |
| **Site** | Noor Kelaa des Sraghna (PV) | Noor Bejaad (PV) | Noor Lakhtatba (PV) | Noor Lhajeb (PV) | Jerada (PV) | Tetouan (Green Power Morocco, PV) | Benguerir | Benguerir | Nouacer (PV) | Moham-media |
| **Installed Capacity (MW)** | n/a | n/a | n/a | n/a | 1 | 30 | 1 | 18 | 1.69 | 2.5 |
| **Status** | Under development | | | | | | | | | |
| **Site** | Dakhla | | | | | | | | | |
| **Installed Capacity (MW)** | 1 | | | | | | | | | |
| **Status** | Under de-velopment | | | | | | | | | |

| **Operational hydropower plants** | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| **Site** | Oued El Makhazine (Kenitra) | Afourer (Azilal) | Ahmed El Hansali (Kasbat Tadla) | Al Massira (Settat) | Step Afourer | Bine El Ouidane (Beni Mellal) | Moulay Youssef (Fes) | Tanafnit-El-Borf (Khenifra) | Moham-med V (Zaio) | |
| **Installed Capacity (MW)** | 36 | 94 | 92 | 128 | 464 | 135 | 24 | 40 | 23 | |
| **Site** | Hassan I (Demnate) | Imfout (El Jadida) | Mansour Eddhabi (Ouarzaz-ate) | Al Wahda (Ouezzane) | Asfalou (Taounate) | Allal El Fassi (Sefrou) | El Kan-sara (Sidi Slimane) | Ouljet Essoultane (Khemis-sat) | Hassan II (Midelt) | |
| **Installed Capacity (MW)** | 67 | 32 | 20 | 240 | 20 | 240 | 14 | 19 | 12 | |
| **Site** | Idriss I (Taounate) | Sidi Said Maachou (El Jadida) | Daourat (Settat) | Wirgane | | | | | | |
| **Installed Capacity (MW)** | 40 | 21 | 17 | 6.6 | | | | | | |
| **Planned hydropower plants** | | | | | | | | | | |
| **Site** | Tarmast (Azilal) | Oued Za (Taourirt) | Machra Sfa (Nador) | Tillouguite Amont (Azilal) | Tillouguite Aval (Azilal) | Imezedilfane (Khenifra) | Taskdert (Khenifra) | El Menzel (Sefrou) | Step El Menzel | Step Ifahsa |
| **Installed Capacity (MW)** | 14 | 6.7 | 30 | 8 | 30 | 63 | 38 | 125 | 300 | 300 |
| **Site** | Boutferda (Beni Mellal) | Tajemout (Fes) | Step Abdel-moumen (Taroudant) | Adgez | Imezdilfane-Taskdert-Tajemout | Machraa Sfa (Casablan-ca-Settat) | Bab Ouender (Fes-Mèknes) | Abdel-moumen | Ait Bougemaz | Merija |
| **Installed Capacity (MW)** | 18 | 28 | 350 | 18.5 | 128 | 6 | 30 | 12 | 9.8 | 6 |
| **Site** | Sidi Chahed | Tames-louhte | | | | | | | | |
| **Installed Capacity (MW)** | 1.3 | 2.5 | | | | | | | | |

(Source: data based on Bellini (2020); Kraemer (2019); MASEN (2021); Oxford Business Group (2021); MEM (2021))

On Thursday, November 11, 2021, the Government Council adopted Bill No. 82.21 in relation to the self-production of electrical energy. Presented by the Minister of Energy Transition and Sustainable Development, this bill aims, in particular, to regulate the self-production activity of electric energy for self-consumption purposes, regardless of the source of production, the nature of the network, the voltage level, or the capacity of the installation used, while ensuring the security of the national electricity network and compliance with the principles of transparency and non-discrimination between the various stakeholders.

Concretely, the bill gives the right for any natural or legal person of public or private law to benefit from the status of auto-producer, with a few exceptions, in accordance with the principle of neutrality. The text provides with three systems which regulate self-production in the event of connection to the electricity networks (declaration system, connection approval system, and authorization system). It also presents measures to monitor compliance with the application. Such measures include legal provisions and penal and administrative sanctions. To encourage as many people as possible to get involved, the bill provides several facilities. Potentially interested producers can simply declare their production unit to the administration.

Further still, producers can produce electrical energy at the same place of final consumption or even elsewhere. Yet, the law requires those concerned to have a smart meter, for a regulatory text will fix the method of calculating the energy produced as well as the quantities injected into the electricity network. It will also monitor the fate of the surplus that must not exceed 10% of the total production capacity of the installed electrical unit. The text established charges in the event of connection with the national electricity network to benefit from the latter's services. The bill does not set the value of these rights to be paid since they will be decided by the National Electricity Regulatory Commission. Bill 82.21 relating to the self-production of electrical energy will be transferred to the Parliament. The two Houses of Parliament will, thus, decide on the question. It remains to be seen whether the elected officials will seek the opinion of one of the constitutional consultative institutions before the final adoption of the text because of the technical aspect of the project.

The Government also started to finalise a Bill No. 40.19 amending the law No. 13-09 relating to REs. This bill will boost investments in medium voltage RE power plants, facilitate access to information on investment opportunities, and simplify the procedures for authorisations. It will allow

ONEE or MASEN to conclude PPAs with private operators or private investors. Regardless of the connection voltage of the production site, the operator can supply electricity to a consumer or a »group of consumers« connected to the national medium-voltage (MV), high-voltage (HV), and extra-high-voltage electricity (EHV) network. Another critical point is the possibility offered to MV, HV, and EHV producers to sell to distribution operators, which will encourage national and international investors. The operators of the electrical distribution network will be able to acquire a share of electricity produced from RE projects not exceeding 40% of the total energy supplied. With this share, the operators could serve customers located in their areas of competence, whose terms and conditions of acquisition will be set by regulation.

This bill was developed in a framework of consultation with the private sector, public institutions, and ministerial departments concerned. It aims to improve the legislative and regulatory framework for the development of RE projects by the private sector, while ensuring the security and sustainability of the national electricity system and the balance of its components. The policy also seeks to:

- strengthen the attractiveness of the RE sector for national and international private investments,
- contribute to the emergence of national entrepreneurships in the field of RE technologies and its industry, and
- preserve the economic and social balance for the public actors of the electric sector.

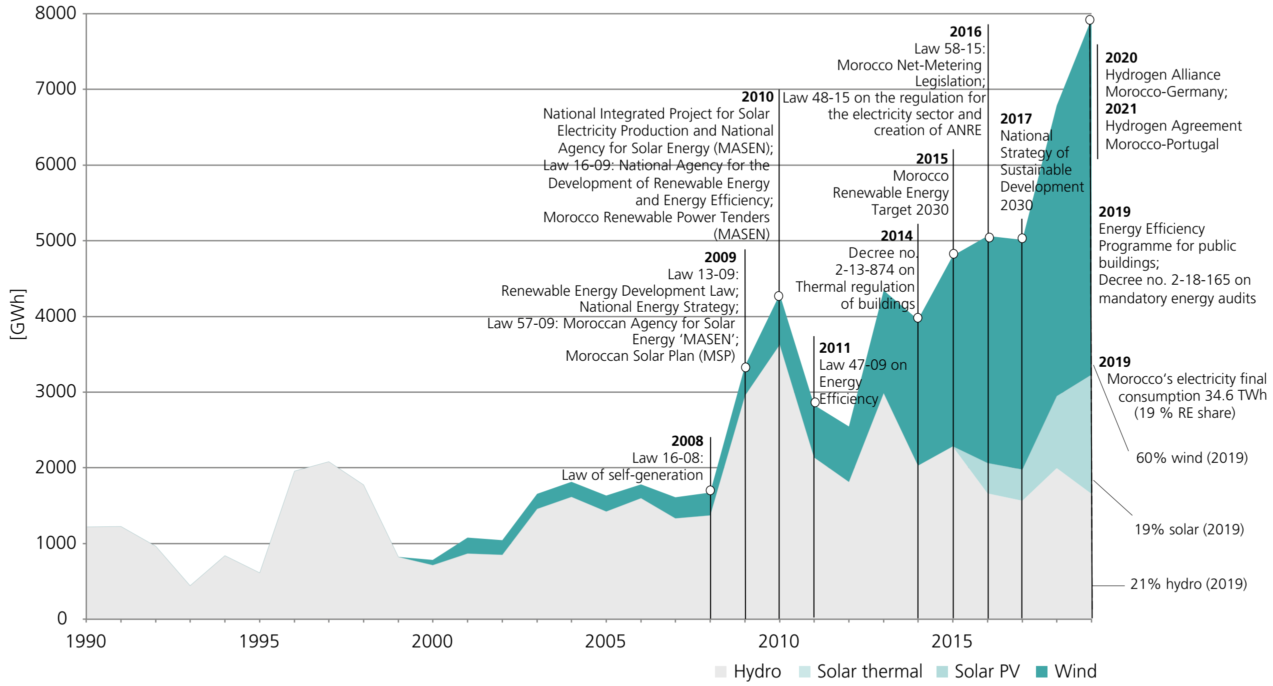
Energy efficiency is regulated by Law 47-09 from 2011 that includes several measures, such as mandatory energy audits, minimum energy performance standards for appliances, and tariffs for industries. Moreover, in 2014 the thermal regulation of buildings was introduced, while in 2019 the energy efficiency programme for public buildings was developed (IEA, 2020a).

Fig. 4-6 depicts the introduction of energy policy measures and their impact on renewable electricity generation by year. Important decisions and strategies, such as the Morocco Renewable Energy Target 2030 in 2015 or the National Strategy of Sustainable Development 2030 from 2018, are also shown in the graph.

The steady growth in RE generated since 2009 coincides with the introduction of the MSP. Financing schemes, such as net-metering, and the gradual opening of the market to private producers has also led to an increase in electricity generation from RE sources. In order to promote private investments in RE and energy efficiency, the Morocco Sustainable Energy Financing Facility (MorSEFF) and the Energy Development Fund (FDE) were created. While MorSEFF was set by the European Bank for Reconstruction and Development (EBRD), KfW, AFD, and European Investment Bank (EIB), the FDE has been supported by the Kingdom of Saudi Arabia, the United Arab Emirates, and the Hassan II Fund.

In terms of greening COVID-19 stimulus packages, Morocco's USD 4.8 billion stimulus Strategic Investment Mohammed VI Fund (Medias24, 2020; Ministry of Economy and Finance of Morocco, 2020b) will be capitalised by 49% of funds from national government and the remainder from

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




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

other shareholders. The government is seeking for partners to take a shareholder position, which could provide an opportunity to influence the processes used for consideration of project proposals. Specifically, this presents an opportunity to apply environmental and climate criteria to the proposals considered, including early retirement of fossil fuels plans and decarbonisation of the economic key sectors.

The last events in Fig. 4-6 show that Morocco established the hydrogen alliance with Germany in 2020, and in 2021 it signed a hydrogen agreement with Portugal.

In summary, Morocco has passed a number of important legislations and regulations to govern the RE market. These have resulted in the implementation of several large-scale RE projects that have already affected the national electricity mix (Shahan, 2021). However, some of the laws are still missing for the needed decree to come into force *(decrét d'application)*. Overall, Morocco has achieved major steps in establishing a sound regulation framework for REs. Therefore, it can be classified as having completed the first phase according to the applied RE transition phase model.

**Fossil Fuel Sector**

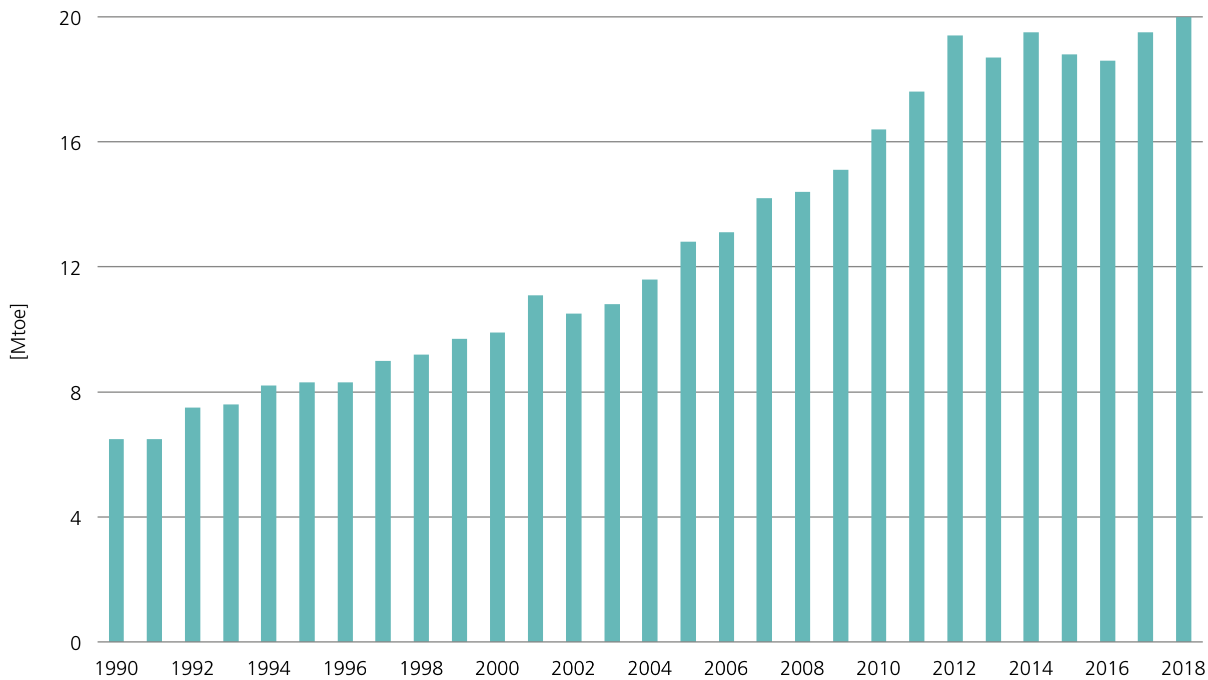
Morocco strongly depends on fossil fuel imports that currently supply 95% of the national energy needs (REN21, 2019). The main imported energy products are oil and coal to feed the country's power plants. Moreover, Morocco imports natural gas from neighbouring Algeria, as compensation for the Algerian gas pipeline that crosses the national territory for exports to Spain. While Morocco previously imported electricity from Spain, the country has become a net exporter of electricity to Spain in 2019 with the inauguration of several power generation projects, including the Safi coal plant (Ennaji, 2019; Hatim, 2021). The net energy imports have strongly increased in the course of the last years, as depicted in Fig. 4-7.

The construction of a new coal power plant in Safi at the Atlantic coast has added a 1.4 GW thermal power that satisfies 25% of the national demand to Morocco's capacities. To supply this power plant, the coal imports have strongly increased, especially from Russia. Moreover, the government of Morocco plans investments for a new port infrastructure in Casablanca to import and stock liquefied natural gas (LNG). The LNG will first be used for electricity generation. Afterwards, it will supply the industrial and domestic sectors (Bianchi et al., 2018). Four new combined cycle gas power plants are planned that should mainly balance the intermittent supply from wind and solar energy (FES, 2015).

The dependency on international energy markets constitutes a burden for the state budget. Importing energy sources costs the Moroccan government almost 10% of the national Gross Domestic Product (GDP) and represents 25% of the national imports. Moreover, the dependency can cause energy insecurity for the whole population. This situation is one of the main drivers for shifting to RE options in Morocco (FES, 2015).

Overall, Morocco's goal is to become more independent in terms of its energy supply to enable sustainable development and support social stability. While, currently, renewables cannot replace fossil fuels neither in the electricity nor energy sector, the long-term scenario of a 100% RE-based

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




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

energy system seems realistic for the Kingdom. Thus, regarding its fossil fuel sector, Morocco is considered to be in the first phase of the energy transition according to the applied phase model.

### Infrastructure

ONEE is responsible for managing and operating the transmission grid, generators, and partly the distribution network (The World Bank, 2013). Most of the electricity is generated by ONEE's power plants, although private electricity producers are also allowed to sell their electricity to ONEE in form of PPAs. The distribution companies are either private or public.

The Moroccan power network has an extent of 164,000 km (FES, 2015); 3,000 km are 400 kV lines, 9,000 km consist of 22kV lines, 147 km of 150 kV lines, and around 11,780 km of 60 kV lines (Sahbani et al., 2016). Large parts of the transmission grid components are old and inefficient, making the distribution system highly vulnerable and unsafe (ibid.). The growing demand for electricity and loading requires extensive modernisation and enhancement of the Moroccan power grid.

Morocco is interconnected with Algeria and Tunisia via the Maghreb regional interconnection, which is a high-voltage transmission connection (The World Bank, 2013). In the late 1990s, Morocco's interconnection was extended to Spain and has been synchronised with the pan-European high-voltage transmission network, the European Network for Transmission System Operators-Electricity (ENTSO-E). Like other Arab countries, Morocco aims to establish a Pan-Arab Electricity Market; this intent was marked by the mutual signing of Memorandums of Understanding (MoUs) with other Arab countries in 2017 (Matar, 2020). Discussions with Mauritania are also taking place to create a Morocco-Mauritania power network with 225 kV lines.

Morocco's plans to build more large-scale and decentralised RE projects in the coming years exacerbate the challenge to integrate intermittent solar and wind energy. Grid integration of large amounts of renewables is a special challenge for the electricity grid and represents a key barrier to Morocco's successful energy transition. Consequently, measures must be taken to improve the power grid. In this light, Morocco will need substantial investments and institutional coordination. In summary, the development of the electricity infrastructure for the integration of renewables according to phase one of the applied energy transition phase model has been initiated and advanced but is not yet complete.

### Institutions and Governance

The Ministry of Energy Transition and Sustainable Development (METSD) is responsible for the development and implementation of the energy, mining, and geology policies in Morocco. METSD supervises several companies and public institutions connected to the electricity market (METSD, 2021). METSD's primary tasks are managing the energy and mining assets, ensuring access to energy, organising the operations of the energy markets, developing RE visions and strategies, improving energy efficiency, and ensuring energy security overall. Under METSD, the Moroccan energy strategy was developed, and by consulting with other agencies and institutions, such as ONEE, MASEN, and AMEE, METSD is the main actor to design the sector. Before ANRE officially started its operation in 2021, METSD also played the role of an energy regulator. Topics in the field of energy efficiency are being coordinated together with the Ministry of Economics and Finance, the Ministry of General Affairs, and the Ministry of Interior, while the electricity and fuel prices are being regulated by METSD, Ministry of General Affairs, and Ministry of Economics and Finance (ibid.).

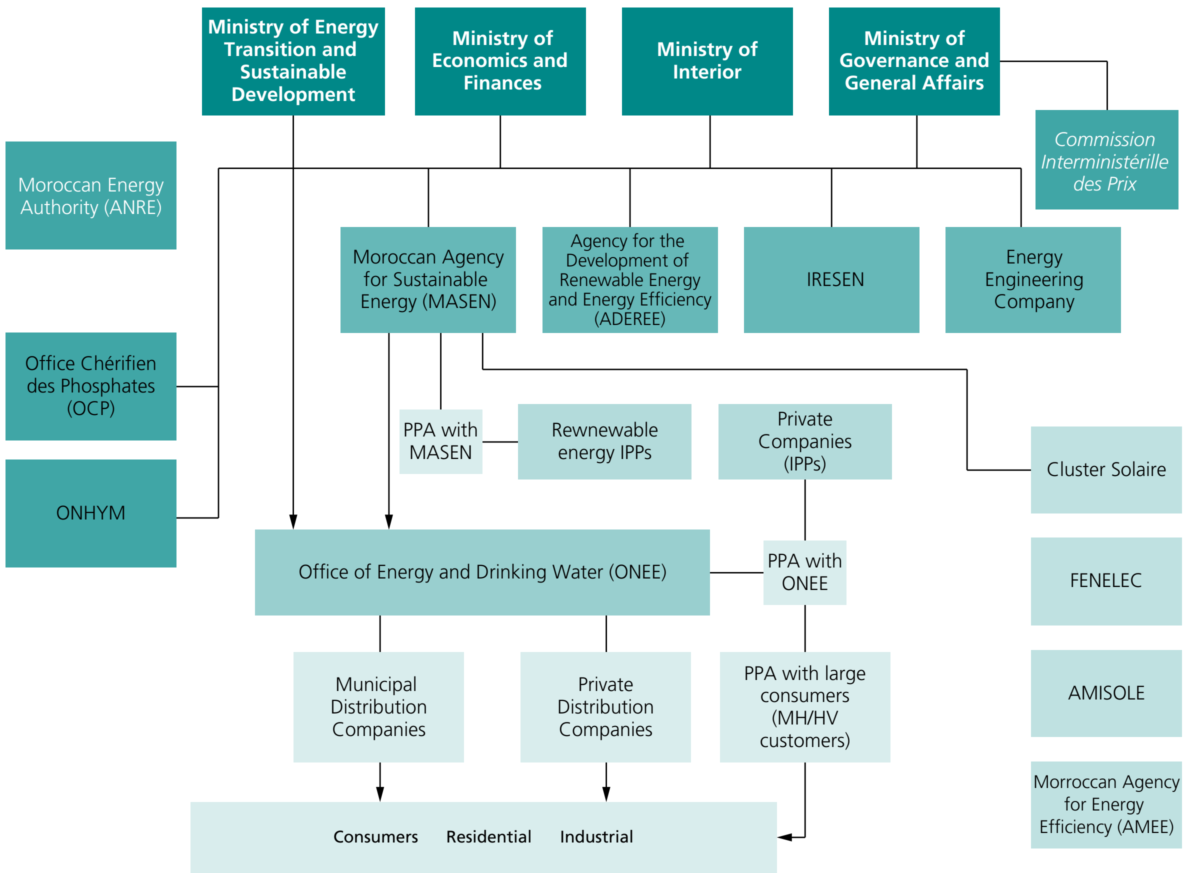
The electricity market in Morocco is structured around the national utility ONEE that holds a long-standing monopoly on the generation, transport, and distribution of electricity in Morocco. ONEE is a state-owned operator that functions as a single buyer of electricity. The main share of the generation capacity stems from ONEE, while the transmission network is completely owned by ONEE. The distribution network is also largely owned by ONEE. All tasks related to the grid network, particularly construction, operation, and maintenance fall under the responsibility of ONEE. Furthermore, ONEE is mandated by the government to implement the wind energy programme and to increase the hydropower capacity (FES, 2015). The distribution of electricity happens through private or public energy providers. The private distributors are: 1) Lydec in Casablanca, 2) Redal-Veolia in Rabat, and 3) Amendis-Veolia in Tanger-Tetouan. The public distributors are as follows: 1) RADEEM in Meknès, 2) RADEEMA in Marrakesh, 3) RAK de Kénitra in El Jadida, 4) RADEES in Safi, 5) RADEEL in Larache, 6) RADEEF in Fez, and 7) RADEEJ in El Jadida (GIZ, 2017).

Promulgated by Law 48-15, ANRE was established in 2015 and began operation in 2021. ANRE is tasked as an independent supervisory authority that regulates the electricity sector and monitors the electricity market. ANRE ensures that producers have fair access to transport infrastructure and defines tariffs and conditions for grid access (Oxford Business Group, 2021).

Moreover, AMEE is the national agency for the development of RE and energy efficiency that supports the Moroccan government with the setting and implementation of RE policies and energy efficiency measures. The agency was officially created in 2009 by Law 16-09 from the former Centre for the Development of Renewable Energy in Marrakesh. AMEE develops national, regional, and sectoral plans and coordinates RE and energy efficiency programmes.

In frame of the Law 57-09, MASEN was established, which has a legal status of a public shareholding company. The company has been given a mandate by King Mohammed VI to realise the Moroccan RE programme by implementing projects, such as the $NOOR_O$ Ouarzazate solar complex. The projects are structured according to the build, own, operate and transfer (BOOT) model, where the IPP obtains the con-

Figure 4-8
**Electricity Market Structure with Relevant Authorities and Companies**




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

cession from MASEN to design, finance, build, operate, and maintain the production for a fixed period of time (Bentaibi and Pape, 2021). Furthermore, MASEN is responsible for contributing to the national expertise and proposing regional and national plans on solar and other RE technologies.

IRESEN is yet another institute and was created in 2011 with the aim to promote research, innovation, and development in the energy sector. Based in Rabat, IRESEN coordinates research and development (R&D) activities in Morocco and cooperates with international partners from France, Germany, and Spain. The institute also has centres at the Green Energy Park in Benguerir and will expand to other cities, establishing different thematic research centres, such as smart grids, bioenergy and storage, and water-energy-nexus topics (IRESEN, 2021).

The national interest company Energy Engineering Company (SIE)[4] that was created in 2009 aims at promoting private investments in RE and energy efficiency. SIE manages assets of the FDE, which are largely allocated to RE projects and to projects dedicated to energy efficiency.

AMEE is responsible for implementing and coordinating energy efficiency programmes. AMEE is considered a strategic public institution that intends to reduce energy dependence and preserve the environment by piloting demonstration projects and promoting energy efficiency measures. It also represents a network hub between institutions, civil society, and the private sector, and it promotes international cooperation.

Several other associations or federations exist that endorse REs, such as National Federation of Electricity, Electronics and Renewable Energy (FENELEC)[5] or Moroccan Association of the Solar and Wind Industry (AMISOLE). Additionally, the Solar Cluster *(Cluster Solaire)*[6] that was set up by MASEN supports the development of a competitive local industry. In particular, the Solar Cluster aims at reinforcing the skills of local companies, promoting decentralised PV systems and qualification programmes, and supporting green entrepreneurships.

Fig. 4-8 depicts the Moroccan institutional framework of the electricity and energy market.

4 For more information: https://www.sie.co.ma/apropos/

5 For more information: www.fenelec.com
6 For more information: www.clustersolaire.ma

Several actors are involved in the Moroccan electricity market, and there is clear evidence that private actors, in particular, are becoming more active participants. Although some processes are bureaucratic and lengthy, and ONEE still operates the whole value chain (generation, transmission, distribution), the Moroccan government aims to unbundle its electricity market structure. In order to do that, the government has been taking certain measures, such as introducing the new operational energy regulator, ANRE. The role played by ANRE is exceptional in the MENA region. However, the communication and cooperation between institutions and ministries in the electricity market is still impeded by hierarchical structures, which can make processes inefficient. Overall, the current state of development and effectiveness of the institutional framework places Morocco between the final stage of the first phase and the beginning of the second phase towards a renewable-based energy system according to the MENA phase model.

**Energy Market and Economy**

The electricity tariffs in Morocco are determined by a structure that is variable according to the consumption level, with six blocks *(tranches)* in which the price rises, as the consumption of electricity increases. The tariff increases from 0.80 DH[7] per kWh up to 1.45 DH[8] per kWh in the following consumption categories: 0–100 kWh, 101–150 kWh, 151–210 kWh, 211–310 kWh, 311–510 kWh, and over 511 kWh. The tariff for medium voltage (MV) consumers varies according to different time periods of the day (regular hour, peak hour, off-peak hours or fixed tariff) between 0.92 DH[9] and 449.68 DH[10] per kWh (IEA, 2014; Redal, 2017).

On the producer's side, private producers that generate renewables-based electricity up to 50 MW can directly sell the electricity to industrial users on the very high/high voltage (VHV/HV) grid. So far, medium and low-voltage (MV/LV) producers are not allowed to use the grid. Wind and solar projects usually enter a tendering process. While private wind project developers sign a PPA with ONEE over 20 years, private solar project developers enter a 25-year PPA at a fixed tariff with MASEN, which then sells the electricity to ONEE. Normally, the fixed tariff and the electricity market price differ, and the difference is covered by the FDE. As yet, the lowest bids in Morocco have been witnessed in wind auction results. Large-scale wind farms located in Tanger, Midelt, Boujdour, Jbel Lahdid, and Laayoune registered LCOEs between 2.5 Euroct and 3.4 Euroct per generated kWh, whereas large-scale solar energy prices are somewhat higher. For example, $NOOR_O$ I (CSP) has a LCOE of 15 Euroct per kWh, $NOOR_O$ II (CSP) 12 Euroct per kWh, $NOOR_O$ I (CSP) 13 Euroct per kWh, and $NOOR_O$ I (PV) has a LCOE of approximately 4 Euroct per kWh. However, the hybrid CSP-PV NOOR Midelt I complex has a LCOE price set at 6 Euroct per kWh (MASEN, 2021).

Energy subsidies have a long tradition in Morocco. The original pricing structure has put fiscal pressures on the government, which removed the subsidies allocated to fuel used in power generation or in the industrial sector (FES, 2015). Moreover, the government introduced a fuel price indexation mechanism for diesel, gasoline, and industrial fuel oil in 2013, hence removing the subsidies (Bousselmame, 2017). Natural gas (bottled gas) is still subsidised, but it is currently being debated whether these subsidies can be phased out.

In summary, Morocco has gradually removed subsidies after they reached over 6% of the GDP (Bousselmame, 2017). Integrated communication strategies and the incremental price growth has supported public acceptance of the subsidy phase out. With record low bids, Morocco has achieved the lowest LCOE for wind power generation internationally. This information indicates that Morocco can be classified as being in the beginning of the second phase of the transition phase model.

**Greenhouse Gas Emissions**

The energy sector (particularly the electricity generating sector) is responsible for most of the GHG emissions. The energy sector emits 67% of GHG emissions, followed by agriculture (17%) and industry (10%) (Terrapon-Pfaff and Amroune, 2018). The growing energy demand is mirrored in Morocco's total $CO_2$ emissions, which have risen by 45% in 2018, compared to the year 2005. While Morocco generated 40 Mt $CO_2$ in 2005, the total amount in 2018 was 58 Mt of $CO_2$ (Fig. 4-9). Fig. 4-9 depicts the Moroccan $CO_2$ profile, while Fig. 4-10 illustrates the resulting emissions from heat and electricity generation by source for 2018.

The emission growth in Morocco is characterised by a steady increase, which is mainly attributed to energy-related emissions (Terrapon-Pfaff and Amroune, 2018). Although the emissions intensity, which is relative to the GDP, has decreased, the per capita emissions have increased by more than 50% compared to 1990 (ibid.). This can be due to the changing behaviour and living standards of the Moroccan society.

When Morocco submitted its NDC targets, it committed to reduce its GHG emissions conditionally by 42% by 2030 rather than adopt a »business as usual« scenario. In June 2021, Morocco submitted updated NDCs and increased its conditional target to up to 45.5% (Climate Action Tracker, 2021). Morocco is, thus, one of the leading countries in the MENA region in terms of climate change mitigation and adaptation. However, mitigation actions also focus on the expansion of natural gas uses, especially in the power sector. The Moroccan government justifies the use of natural gas as necessary to provide back-up capacities for

7 This amount equals 0.07 Euro. https://www1.oanda.com/lang/de/currency/converter/
8 This amount equals 0.13 Euro. https://www1.oanda.com/lang/de/currency/converter/
9 This amount equals 0.08 Euro. https://www1.oanda.com/lang/de/currency/converter/
10 This amount equals 41 Euro. https://www1.oanda.com/lang/de/currency/converter/

intermittent solar and wind power in the grid, even though significant amounts of GHG emissions result from natural gas consumption (Terrapon-Pfaff and Amroune, 2018).

To monitor GHG emissions, Morocco established a National Greenhouse Gas Inventory System (GHG-IS) that provides information on potential Monitoring, Reporting, and Verification (MRV) systems for the five Nationally Appropriate Mitigation Actions (NAMAs).

Morocco's NDCs are, indeed, ambitious, particularly for the MENA region. Nevertheless, GHG and $CO_2$ emissions have still increased in the past years. New investments in coal and gas infrastructures entail the risk of lock-ins and could hinder the overall GHG mitigation efforts. Morocco's electricity mix relies heavily on coal, which must be phased out much earlier than planned. Thus, further efforts are required to achieve the NDC goals, such as specifying and extending detailed actions. The updated NDCs have already incorporated additional sub-sectors, such as the industry (cement and phosphate production). However, the NDCs have yet to formulate an absolute emissions level and reduction target below a fixed year instead of a reduction target below a business-as-usual (BAU) scenario (Climate Action Tracker, 2021). The NDCs also fail to include the net zero emissions target. Accordingly, Morocco can be classified as still being in the first phase, but at an advanced stage, of the applied energy transition model.

**Efficiency**

Based on its updated NDCs, the government aims to achieve an energy saving of 20% by 2030 compared to the trend. Energy efficiency measures span across all sectors: energy, agriculture, forest, transportation, waste, industry, residential, and commercial sectors. The government intends to reduce in energy consumption in buildings, industry and transport by 5% by 2020 and 20% by 2030. By 2030, energy savings would be 17% for industry, 24.5% for transport, 14% for the city, housing and tertiary sector, and 13.5% for agriculture and sea fishing. Morocco has coupled its energy efficiency strategy with far-reaching activities that contribute to reaching the country's climate change commitments.

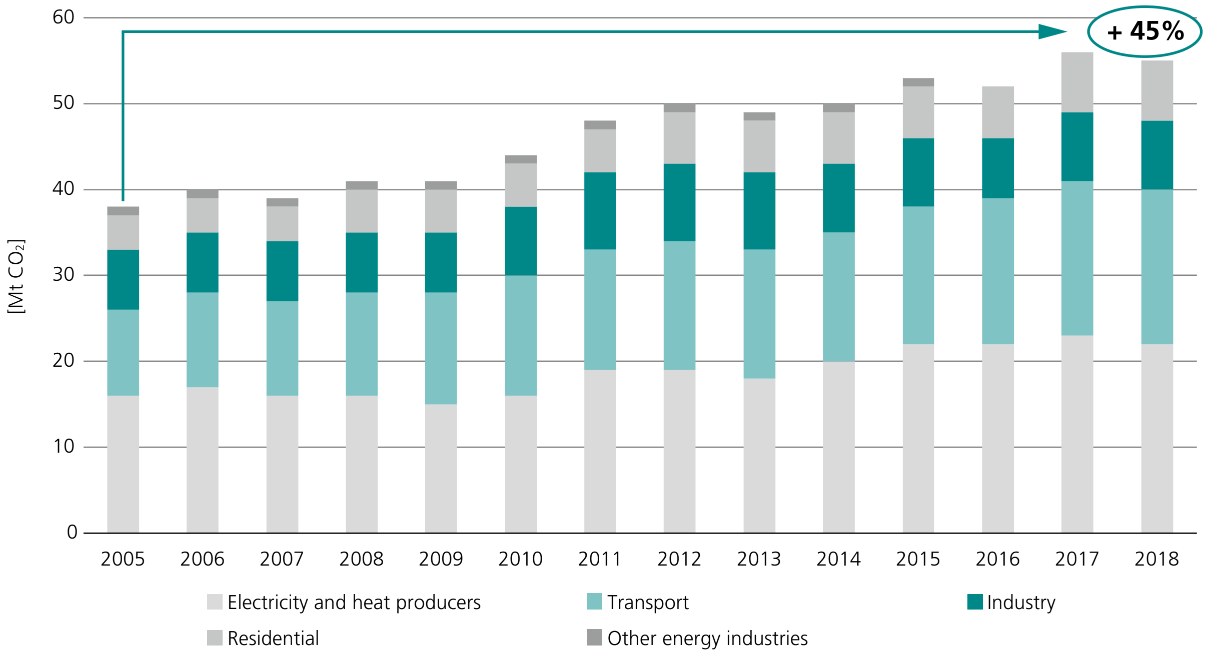
For example, a Thermal Regulation of Construction in Morocco (RTCM) has been developed for public and private buildings that has a mitigation potential of 2.4 Mt $CO_2$ between 2016 and 2035; this framework applies to new constructions (Terrapon-Pfaff and Amroune, 2018). The industrial sector is also involved in reducing GHG emissions; this sector's mitigation efforts are mainly focusing on indirect energy-related emissions from electricity consumption. Other measures that involve carbon capture and storage or use options (CCS/CCU) in the cement or phosphate sector are not yet being applied. In the transport sector, mitigation actions are coupled with energy efficiency measures. In this sector, a national strategy for the logistic development and the upgrade of utility vehicles has been implemented. Studies were conducted and political discussions were held to determine the best approach to shift from fossil fuels to low-carbon fuels and other energy carriers in the transport sector. Moreover, Morocco has already taken first steps regarding the development of green cities (AHK, 2017). Prominent examples of green city projects undertaken by Morocco include the »Green City Mohammed VI« outside of Benguerir, the »Green Mine Khouribga City«, the »Green Mazagan City«, »Cité Mohammed VI Tanger Tech«, and the »Eco City of Zenata« (Terrapon-Pfaff and Amroune, 2018). There are also local initiatives, such as the »Green Mosques« that are funded by the German Corporation for International Cooperation (GIZ). They aim at disseminating energy efficiency and RE technologies and increasing the positive local impact of these measures (GIZ, 2021b). In the residential sector, Morocco intends to install 14,700,000 low-energy bulbs that should cost around USD 18 million. Moreover, a »Public Lighting Energy Efficiency Programme« exists, which focuses on Moroccan cities. Regarding resource efficiency, Morocco also plans to recycle household waste through co-incineration and mechanical biological treatment under the »National Household and Similar Waste Programme« (Terrapon-Pfaff and Amroune, 2018). In the Long-Term Low Emissions Development Strategy (LT-LEDS) Morocco 2050, the concept of a circular economy is strongly mentioned.

An evaluation of the steps taken by Morocco regarding energy efficiency shows that the government has recognised efficiency as an essential part of energy transition. Morocco's adoption of a regulatory framework has allowed for energy efficiency measures to be implemented at the political level. Hence, regarding the energy efficiency layer of the energy transition, Morocco can be classified as having completed the first phase of the applied energy transition phase model.

**Society**

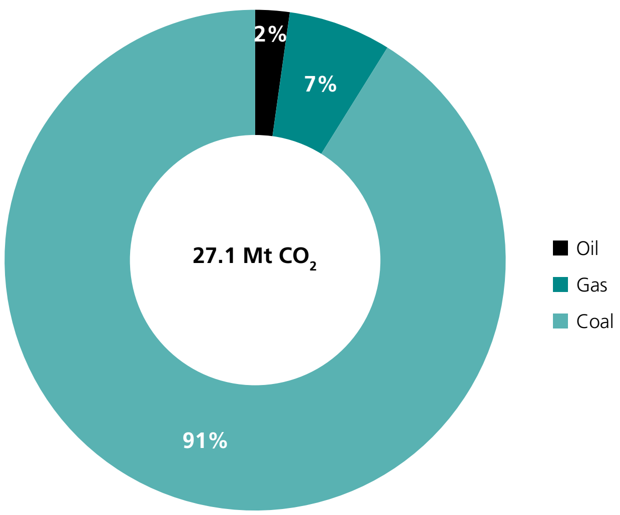
Morocco's solar strategy emphasises the construction of PV and CSP, which are usually constructed in the south of the country, while the management as well as production and construction industries are in the north. In order for the local communities in the south to also benefit from such projects, a number of strategies and policies have been implemented to improve development at local scale. These include campaigns organised to raise awareness of large energy projects or programmes that concentrate on assisting communities in increasing energy efficiency. Other activities entail the establishment of local energy information centres, such as those in Tata and Chefchaouen, to raise awareness and visibility of energy topics. Furthermore, there are training programmes, organised mainly by the Training Institute for Professions in Renewable Energy and Energy Efficiency (IFMEREE), to prepare technicians to work at CSP sites. These measures are important, for studies have shown that although large-scale CSP projects can have a significant impact on local communities, they do not automatically foster local economic development (Terrapon-Pfaff et al. 2017, 2019). Law 12-03 does, indeed, require that project developers conduct an environmental and social impact assessment in the beginning to identify potential impacts. However, additional programmes must also be introduced, which consider the needs of the local communities. These

Figure 4-9
**$CO_2$ Emissions by Sector (in Mt $CO_2$), Morocco 2005–2018**




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

Figure 4-10
**$CO_2$ Emissions from Electricity and Heat Generation by Energy Source (in Mt $CO_2$), Morocco 2019**




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

programmes would create development benefits in the locations where the RE facilities are sited (ibid.). For example, in the case of the $NOOR_O$ solar complex in Ouarzazate, communities received compensations for land acquisition which, in turn, have been spent for social actions and infrastructure developments. For instance, they were used for irrigation systems or improvement of the water supply systems. Another encouraging example is the Siemens factory in Tanger that produces wind turbines. The establishment of the factory in Northern Morocco has created 700 direct jobs (Bianchi et al., 2018). Yet, other NOOR projects and wind projects, such as the Taza wind park, experienced delays due to unclear land acquisition rights (AHK, 2017). This issue underlines the importance of integrating and managing the expectations of local communities in the development process.

In terms of acceptance, studies indicate that the development of solar infrastructure is usually received positively by local communities; members of the communities feel proud that some of the largest energy projects in the world are built in their region (Terrapon-Pfaff et al. 2017, 2019). Regarding the local development beyond the energy sector, Ouarzazate has potential to develop its touristic sector with particular focus on eco-tourism.

A critical aspect for social acceptance, however, is the water demand of solar power plants in the dry regions of the South. Although all future CSP plants besides $NOOR_O$ I are supposed to use dry cooling technologies, which require less water than wet cooling technologies, the amounts of water needed can still be critical. The same applies to the generally low water requirements of PV plants, which can also be problematic in the event of water shortages (Ersoy et al., 2021). Although the power plants require only small amounts of water, the population's perception can be different. For instance, if shortages occur in the water supply for agriculture or drinking water, people's perception of large-scale energy projects can become negative, as protests in Ouarzazate have demonstrated (Al-Talbi, 2021). Water resources in Morocco, especially in the south, are highly vulnerable to climate change. Therefore, water for energy production remains a major challenge and can cause conflict. As a result, water issues should always be considered when developing large-scale RE projects.

Regarding the overall awareness of REs, Morocco has several incentives to raise awareness of energy and environmental topics with a number of institutions working in this field. However, according to experts, the Moroccan society, in general, does not yet consider environmental topics as being of high relevance. There is a small group of the society (mainly people with an academic background) that is well informed on such topics. Nevertheless, considerable efforts are required to convince other people in the society about the importance of environmental and RE aspects and to have them integrate environmentally-friendly actions in their daily lives.

Yet, in order to progress towards a 100% RE system, social acceptance alone will not be sufficient; citizens and businesses must also become more actively involved. So far, the energy transition in Morocco is mainly driven by the state in a top-down manner, focusing on large-scale projects. Indeed, several initiatives exist that intend to foster the local development in the energy sector, and they are related to small PV systems for water pumping in agriculture. However, overall small and medium-sized market actors have only limited opportunities and incentives to participate, and citizens and decentralised approaches are largely lacking. Decentralisation is part of Morocco's sustainability agenda, but its impact and implementation has been limited (Ben-Meir et al., 2021). Fostering more active engagement in the energy transition will be key to a successful and holistic sustainable energy transition.

**Summary of the Landscape and System Level Developments**

On the landscape and system level, Morocco has already taken considerable steps towards energy transition. Although there are some uncertainties currently due to the pandemic, it is expected that Morocco will reach its medium-term renewables target by 2030. However, some barriers remain resulting from existing technical, financial, regulatory, and social patterns.

One barrier is that private producers are not yet allowed to connect to the low tension network, which is limiting the renewables expansion. Another critical point is that while renewables reach extremely low cost levels in Morocco, the national energy strategy also foresees the expansion of natural gas in the energy mix. This does not only contradict the efforts to reduce import dependencies but can also create technological lock-in effects and lead to stranded investments. Moreover, cooperation and communication between institutions must be improved to increase the efficiency of the work-flow. On the regulatory level, laws that support RE development need to be applied at a faster pace. Hence, political decision makers must implement decrees quicker. Also, in terms of land acquisitions for RE projects, clear regulations need to be in force, seeing as land rights are often unclear, which can lead to project delays and can impede the energy transition.

In summary, several factors at the system level currently limit Morocco's progress in the energy transition, and renewables are not replacing the use of coal and gas in the energy sector due to growing markets. However, Morocco's efforts can be classified as very ambitious and exceptional for the MENA region, making the country a clear frontrunner for renewables. Table 4-2 summarises these current trends and goals for 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 3-1). Morocco has already made considerable progress in almost all the aforementioned dimensions. Furthermore, on a political and technological level, Morocco initiated a strategy discussion on hydrogen and PtX, which allows for the integration of green electricity in sectors where direct electrification is not feasible in industrial applications, heavy duty transport, or aviation. Furthermore, Morocco is investigating and testing flexibility options, supporting e-mobility, and studying smart grid solutions. The following section provides detailed descriptions of these developments at the niche level.

**Storage**

Since the government embarked on the MSP in 2009, solar and wind power have become increasingly important in the electricity generation mix. Along with the increase of these intermittent and variable sources, energy storage is also gaining more importance, especially to meet load peaks when electricity is most needed. In this light, the government has realised the importance of the role CSP plays, seeing as the technology allows the storage of energy from heat, which can then be used to generate electricity even after sunset. Since Morocco has already implemented and planned several CSP plants, experts are hoping for the technology costs to further fall due to the »economies of scales.« This would make the technology even more attractive. For example, CSP-PV hybrid systems at NOOR Midelt show that these plants can be cost-effective and dispatchable solutions. Another advantage of hybrid systems is their reduced water demand for cooling or cleaning purposes. Other storage options in Morocco are pumped hydro storage systems, including at coastal locations using sea water. Likewise, gas fired power plants that are easy to ramp up and that stabilise the grid, acting as backup for wind and solar systems, are becoming important pillars in Morocco's energy strategy as part of the Gas-to-Power Programme (IAEA, 2018). However, the discussed EU carbon border adjustment tax could be a strong driver to prevent further expansions of coal or gas power plants (Bentaibi and Pape, 2021).

### Grid Stabilisation and Smart Grids

Despite the increasing share of renewables in the electricity mix, coal still plays the most important role in meeting Morocco's energy baseload needs. However, renewables are becoming more important in the energy mix (target 52% by 2030). Thus, Morocco needs to adequately prepare its grid network in order to balance the growing share of intermittent sources. To this end, several grid network studies are being prepared to optimise the network and secure a stable and reliable electricity supply. Projects around grid stabilisation and flexibility options are currently present (GIZ, 2021a). ONEE also started to conduct several experiments towards smart grids at distribution level. For example, ONEE is testing supervisory control and data acquisition (SCADA), distribution management systems (DMS), and smart meters in several cities (Sahbani et al., 2016). Furthermore, IRESEN is expanding the research centre to a Green & Smart Building Park, which is an innovative platform dedicated to research on green buildings, energy efficiency, and smart grids (IRESEN, 2021).

### E-mobility

The GHG emissions caused by the transport sector are likely to more-than-double between 2015 and 2050 despite the measures taken by the government (ITF, 2021). By supporting e-mobility, Morocco has taken first steps towards system integration via direct electrification. According to the kingdom's sustainable development strategy, clean cars are predicted to constitute 30% of the fleet by 2021 (Boulakhbar et al., 2020). Morocco has been selected as one of the countries to be studied within the »E-Mobility Programme« that was launched by EBRD with a total financing amount of USD 482 million. In this regard, feasibility and market studies are being conducted (Transitec, 2021). Furthermore, the Electric Mobility Master Plan (2022–2030/2035) will be launched in 2022 to reduce GHG emissions from the transport sector by 35% in 2030.

Fifteen Total EV recharging stations were installed in Tanger-Agadir highway, Agadir, Marrakesh, Casablanca, Rabat, and Tanger in July 2018. In total, 92 charging stations were mapped across the country (Electromaps, 2021), and another 5,000 recharging stations are planned to be installed by 2022 from the »iSmart« project. The charging station is developed by technicians of the Green Energy Park (IRESEN) and is locally manufactured. In addition, two charging units that are coupled to PV in Rabat have been implemented (Boulakhbar et al., 2020). Moreover, the Chinese electric car producer BYD Company Limited is planning to open a factory to build e-cars in Morocco (Terrapon-Pfaff and Amroune, 2018).

Other alternative transport mediums are also being promoted. For instance, first bike-sharing schemes have been piloted in Marrakesh and are being expanded to other cities (ITF, 2021).

### Hydrogen and PtX[11]

Morocco has already taken leadership in advancing the development of renewables and has created new industrial markets in the country. The country is now adopting green hydrogen, which has become a critical element in the decarbonisation strategies on both the national and international scale. By promoting the use of hydrogen and PtX, Morocco has taken the first important steps towards sector coupling. To advance the domestic ambition towards green hydrogen, METSD has already signed relevant agreements with international institutions and countries. For instance, the Moroccan government has signed the Hydrogen Alliance with Germany in June 2020, a Hydrogen Agreement with Portugal in the beginning of 2021, and formed a strategic partnership with IRENA to boost renewables and green hydrogen development in June 2021 (DW, 2020; IRENA, 2021; Takouleu, 2021). Under the German-Moroccan Hydrogen Alliance, the construction of the first hybrid power plant with a combined desalination plant and 100 MW electrolysers is envisaged, which shall cost around EUR 325 million. The project is currently suspended due to political tensions (Záboji, 2021).

As well as these agreements, several other steps have been taken for hydrogen development. For instance, Morocco established a National Hydrogen Commission in 2019 and is currently developing a hydrogen strategy. Furthermore, the Energy Minister is planning to build the Green Hydrogen and Ammonia Park (Green H2A), which is a platform dedicated to innovate the green hydrogen sector. IRESEN and the Mohammed VI Polytechnic University will be responsible for constructing the park (Takouleu, 2021). Moreover, infrastructure development and capacity building around green hydrogen is growing, and the industry and private sectors are becoming more involved (IRESEN, 2020). In March 2021, the Green H2 Cluster was launched to support the green hydrogen industry and to promote knowledge transfer through cooperation between national and international partners. Further development of PtX will be very important for Morocco on several levels. Morocco would become a green ammonia producer to replace imported fossil-based ammonia with green ammonia. Also, the country would solve the storage problem of intermittent wind and solar

11 For more information: https://www.mem.gov.ma/Lists/Lst_rapports/Attachments/36/Feuille%20de%20route%20de%20hydrog%C3%A8ne%20vert.pdf

Table 4-2
**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 | +17% | +12% | +1% | N/A | N/A | −45.5% (NDC)# | |
| | $CO_2$ emissions per capita | +63% | +75% | +100% | +100% | N/A | – | – |
| **RE** | Installed and planned capacity (MW) | N/A | 1,560 | 2,304 | 3,263 | 3,950 (2021) | 2,000 MW solar CSP and PV, 2,000 MW wind, 2,000 MW hydro (by 2020) | |
| | Share in final energy use | 9.9% | 8.1% | 7.2% | 7% (2017) | N/A | – | – |
| | Share in electricity mix (existing and planned) | 8.26% | 18% | 15.4% | 18.94% | 42% | 52% | 100% |
| **Efficiency** | Total primary energy supply (TPES) (compared to 1990) | +94.6% | +124.1% | +156.4% | +170.2% | N/A | – | – |
| | Energy intensity of primary energy (compared to 1990) | +15.2% | +3.9% | −2.9% | N/A | N/A | – | – |
| | Total energy supply (TES) per capita (compared to 1990) | +66.7% | +66.7% | +100% | 100% | N/A | – | – |
| | Electricity consumption per capita (compared to 1990) | +50% | +100% | +125% | +125% | N/A | – | – |
| | Residential final electricity consumption (compared to 1990) | +158.4% | +263.2% | +371.9% | +416.8% | N/A | −20% (NDC target) | |
| **Buildings** | Total final energy consumption | +156.5% | +242.7% | +311.8% | +359.4% | N/A | −20% (NDC target) | |
| **Transport (Compared to 1990)** | $CO_2$ emissions in transport sector | +150% | +250% | +300% | +350% | N/A | – | – |
| | Number of electric vehicles (EVs) | N/A | N/A | N/A | N/A | 30% of the fleet in 2021 | | |
| **Industry** | Carbon intensity of industry consumption (compared to 1990) | −4.9% | −4.7% | −9.3% | −11.1% | N/A | – | – |
| | Value added (share of GDP) | 26.2% | 25.6% | 26% | 25.8% | N/A | – | – |
| **Supply Security** | Natural gas imports #(compared to 2005) | 0% | +54.1 | +178.6% | +151.9% | N/A | – | – |
| | Oil products imports #(compared to 1990) | +21.6% | −7.7% | −52.6% | N/A | N/A | – | – |
| | Electricity imports #(compared to 1990) | +677.8% | +4,277.8% | +4,811.1% | +3,455.6% | N/A | – | – |
| | Electricity exports #(compared to 2010) | N/A | 0% | −74.5% | −45.5% | N/A | – | – |
| | Electricity access by population proportion | 79.5% | 91.5% | 99.6% | 100% | N/A | – | – |
| | Coal imports#(compared to 2008) | N/A | −4.5 | +44.9% | +89.9% | +127.2% (2019)# | | |
| **Investments** | Decarbonisation investments (USD million) | 178,4810 | 8,3154 | 223,5089 | 114,1071 (2017) | N/A | – | – |
| **Socio-economy** | Population | | | | 36,029,138 (2018) | | – | |
| | Population growth | 1.1% | 1.3% | 1.4% | 1.2% | N/A | – | – |
| | Urbanisation rate | 55.1% | 58% | 60.8% | N/A | N/A | – | – |
| | GDP growth | 3.3% | 3.8% | 4.5% | 3.2% | N/A | – | – |
| | Jobs in low-carbon industries | N/A | N/A | N/A | N/A | 14,022 (2019) | – | – |
| **Water** | Level of water stress #(compared to 2005) | 0% | +60.4% | +50.7% | +50.7% | N/A | – | – |

(Source: based on data from BP (2020); FAO (2020); IEA (2020a); IRENA (2020); Statista (2020); The World Bank (2020a)) energy with the help of hydrogen. Finally, Morocco would foster a green economy that converges economic interests and environmental concerns.

Several studies about PtX and green hydrogen have already been conducted (Eichhammer et al., 2019; Jensterle et al., 2020; Touili et al., 2018). The elaboration of a sectorial roadmap for PtX in Morocco is currently under preparation. According to first results, the green hydrogen production in Morocco has a levelised cost of hydrogen (LCOH) between USD 1.96 and 2.65 per kg (IRESEN, 2020). Thus, the green hydrogen production costs are at the lower end of the range of globally estimated production costs of USD 1.5–6 per generated kg (IEA, 2019; IRENA, 2019). The low costs in Morocco are due to the low costs of generating electricity from RE sources; electricity costs account for about 60% of the cost of producing green hydrogen. The hydrogen production costs in Europe in 2030 are expected to be about EUR 0.50–1 per kg higher than in North Africa (Wijk et al., 2019).

### Industry and Sector Coupling

The industry and the mineral sector play an essential role in Morocco's economy, with phosphate being the most important mineral product used. The state-owned company Office Chérifien des Phosphates (OCP), which mines and processes phosphate in Morocco, plans to increase its RE use and aims to achieve energy self-sufficiency in the medium-term (Terrapon-Pfaff and Amroune, 2018). Seeing as phosphate rock processing is a carbon-intensive process that produces around three quarters of the industry's emissions, OCP aims to better monitor its emissions and is actively implementing energy efficiency measures. For example, the company installed $CO_2$ analysers in drying ovens (ibid.). Lee et al. (2020) studied phosphate mining in the region of Khouribga to evaluate the impact of the phosphate industry on the water, energy, and food sectors.

Similar to the phosphate sector, the cement industry is a major GHG emitter, and the sector is expected to grow in the long run as a consequence of rapid urbanisation and ongoing infrastructure development (Terrapon-Pfaff and Amroune, 2018). The cement industry is, however, taking measures to mitigate its emissions. For example, the sector has installed 37 MW of wind energy; the cement factory Lafarge has built a 32 MW wind farm at its cement park in Tetouan; Ciments du Maroc has a 5 MW wind farm at its park, and it has applied a 3 MW-solar thermal pilot farm in Ait Baha to use the generated heat as process heat for the clinker production (ibid.). The self-generation by these cement companies has been enabled through Law 16-08.

Currently, the Ministry of Industry, METSD, and ONEE are in the process of launching a national strategy for the decarbonisation of the industry. The strategy aims to provide the industrial zones with RE projects, particularly solar energy. The strategy will include measures to mitigate the impacts of the EU Carbon Border Adjustment Mechanism.

### Electricity Exports

Traditionally, Morocco has been a net electricity importer. However, since 2019, Morocco has been able to export approximately 1,207 GWh to Europe. This is due to the installation of the Safi thermal power plant that started operating in December 2018. Morocco is connected to the Spanish grid via two transmission lines. The construction of a third interconnector with Spain and a new interconnector with Portugal is being discussed. The interconnection could increase electricity exports to Europe in the future. The adoption of the project Xlinks, which aims at developing a new 3 GW submarine cable that would link Morocco to the United Kingdom (UK), is also being considered. If implemented, the connection could transport electricity in the range of 6% of UK's electricity demand (Boulakhbar et al., 2020). This development would, however, require Morocco to expand its renewable capacities well beyond its domestic demand to be sustainable. Otherwise, RE would be exported while the domestic demand would be only partly met by coal and gas. Studies that analyse Morocco's potential to export electricity and other energy carriers, such as hydrogen or synthetic fuels, are currently being conducted by international and local research institutions[12].

## 4.1.3 Necessary Steps for Achieving the Next Phase

Based on the MENA energy transition phase model, Morocco complies with most of the model's benchmarks for the first phase. It has already taken essential steps on the system level, signifying that it has entered the second phase. On the niche level, the country has taken the first steps toward the third phase of the transition to a RE-based system. Yet, to further advance the energy transition towards system integration and sector coupling, including the application of PtF/G technologies (described as the second and third phases in the MENA energy transition model), Morocco's efforts need to be increased on several levels.

Morocco's power sector is still a conventional power system, where coal is used to provide baseload electricity. With the planned 52% share of renewables in Morocco's energy system, Morocco needs to prepare to balance the supply and demand side. In order to ensure stability of the electricity system, flexibility options must be harnessed in all parts of the power system, including generation, transmission, and distribution, as well as through adequate storage systems. Improving and retrofitting the national grid network is essential to integrate a significant amount of renewables. In order to achieve a successful renewables integration, the power grid needs to be redesigned, as large parts of the network are still inefficient, outdated, and subject to stress effects (Boulakhbar et al., 2020; UN ESCWA, 2018). The grid must be expanded, seeing as most wind and solar farms are in the south, far from the main power grid network and the demand centres in the north and coastal strips. Against this background, new challenges arise for transmission system

12 For more information: https://wupperinst.org/en/p/wi/p/s/pd/789

operators. For example, grid congestion may occur, as some regions will be exporters while others will be importers. Flexible modes of production are required to guarantee that the grid is stabilised at all times. Also, decentralised energy systems will play a key role in global and local optimisation (Boulakhbar et al., 2020). Moreover, the development of regional and international interconnections to boost intercontinental electricity trading can help in balancing between supply and demand.

Digitalisation of the power network will also be essential for a successful energy transition; different digitalisation and communication technologies can aid in matching production and peak demand (Boulakhbar et al., 2020). For example, smart grids can increase the correlation between electricity generation and demand. The grids would need to be developed to successfully achieve the national target of 52% renewables.

In addition, existing flexibility options must be fostered, and new ones must be introduced to further advance the achievements regarding system integration. For example, e-mobility needs to be further established through concrete political actions, such as subsidies that encourage consumers to invest in EVs. It is also crucial to ensure that the charging infrastructure will be further developed. To this end, cities, researchers, and car manufacturers must collaborate. However, it also must be ensured that the adoption of e-mobility will be based on the local conditions (Boulakhbar et al., 2020).

Furthermore, the energy transition must occur at all levels and not just on the large-scale. Hence, a successful transition will also depend on decentralisation efforts. The deployment of small-scale decentralised energy systems will be crucial for Morocco's energy transition for different reasons. Most of the development of REs is large-scale, while small-scale developments involving communities or households are currently of secondary importance. However, decentralised systems are very important for the grid stabilisation and play a key role in reaching a 100% RE supply. Also, small-scale projects provide a larger part of the society with the opportunity to participate in the energy transition and to benefit from it.

Decentralisation is needed in the institutional and governance structures of Morocco as well. Political interference and overlapping competencies within different institutions are major barriers that can result in inefficiencies. This is reflected, for example, in the delays in opening the medium and low-voltage market (Bianchi et al., 2018). In order to improve the effectiveness of the electricity market's operation, the role of actors such as ONEE and MASEN needs to be clearly defined. Therefore, reorganising ONEE and changing its business model by separating the value chain activities is well advised (Boulakhbar et al., 2020). Likewise, the implementation of a regulator, such as ANRE, is necessary to provide effective operation of the market.

Moreover, vertical and horizontal dialogue is essential for building alliances between different governance levels and promoting cooperation between various stakeholders (Leidreiter and Boselli, 2015). Also, stronger inter-ministerial cooperation and exchange are recommended, given the decentralised nature of RE systems and the new actors entering the energy market. In this context, the nexus approach as well should receive more attention on the institutional level. Integrated planning is of high importance for countries such as Morocco, where water and energy are closely interlinked.

Equally important is a robust regulatory framework that increases trust and fosters a long-term energy planning. For example, Law 13-09 and its amendment Law 58-15 contain only vague formulations to regulate renewables injection into the low voltage grid. Many laws, particularly Law 58-15, fail to include an implementing decree, which is necessary for the law to become effective. The Bill No. 40.19 that amends Law No. 13-09 enables producers of electricity from renewables to supply MV, HV, and EHV to consumers, while Bill No. 82.21, the self-production law, is still to be adopted. Due to pending technical questions, the Bill is not yet implemented, although it is crucial for Morocco's energy transition.

Moreover, a smooth transition requires sector coupling between all end-user sectors. This includes PtX developments to store electrical energy in a more flexible manner and provide solutions for sectors where direct electrification is not feasible. Such areas of concern include industrial processes, heavy duty transport, or aviation. Direct energy use for heat generation from renewables (i.e. CSP), or alternative fuels from biomass and waste, as well as CCS/CCU, particularly in the cement industry, should also be considered (Terrapon-Pfaff and Amroune, 2018). Global decarbonisation efforts and the increasing importance of PtX in the international debate are presenting Morocco with opportunities to become a producer and exporter of green hydrogen and its derivatives. To this end, a roadmap for hydrogen and PtX products should be created that goes beyond the year 2050, and the establishment of a regulatory framework will also be crucial for such a development (Boulakhbar et al., 2020; Touili et al., 2018).

Energy efficiency measures must also continue to be implemented for Morocco to move forward in the energy transition. Law 47-09 that regulates energy efficiency on the national level should be extended to include all end-user sectors. Sector-specific targets with minimum energy performance requirements should be set.

Finally, to harness the full potential of renewables, societal support will be key. It is essential for Morocco's energy transition to promote the active participation of the population in the energy transition. Overall, people and citizens seem to be barely involved (Bianchi et al., 2018). Large-scale projects are indispensable to meet Morocco's renewable targets, but they should be accompanied by small-scale and decentralised solutions that contribute to people's active involvement (Ben-Meir et al., 2021). Bottom-up and participative approaches can help to foster energy efficiency, provide innovative solutions to local communities, reinforce the decentralisation, and increase the deployment of renewables. To achieve broader participation, decentralised small-scale initiatives, such as household or small business applications of renewables, as well as local and citizen-owned projects, should be more widely supported. This support includes tailor-made counselling services and better financing options for small-scale applications. Furthermore, demonstration projects are essential to create more awareness by clarifying the economic benefits of renewables and allowing people to better understand how the technologies function and how they can be maintained. Overall, stronger societal involvement could also lead to a greater consensus, which would support the energy transition (Bianchi et al., 2018).

## 4.2 OUTLOOK FOR THE NEXT PHASES OF THE TRANSITION PROCESS

The energy transition in Morocco is currently present. Ample evidence of this can be found, for example, in the construction of one of the world's largest solar complexes $NOOR_O$ in Morocco and the commissioning of the independent regulatory authority ANRE in 2021. Accordingly, Morocco is one of the leading countries in energy transition, especially on the African continent. As the costs of renewables are expected to further fall, the potential for Morocco to become an innovator in the field of renewables and CSP is high.

The drivers for the deployment of REs in Morocco can be summarised as follows: reducing the fossil fuel imports dependency, increasing energy security, decreasing energy consumption, meeting the growing energy demand, achieving a fuel mix optimisation, encouraging foreign investments, and promoting regional integration with Europe and Algeria.

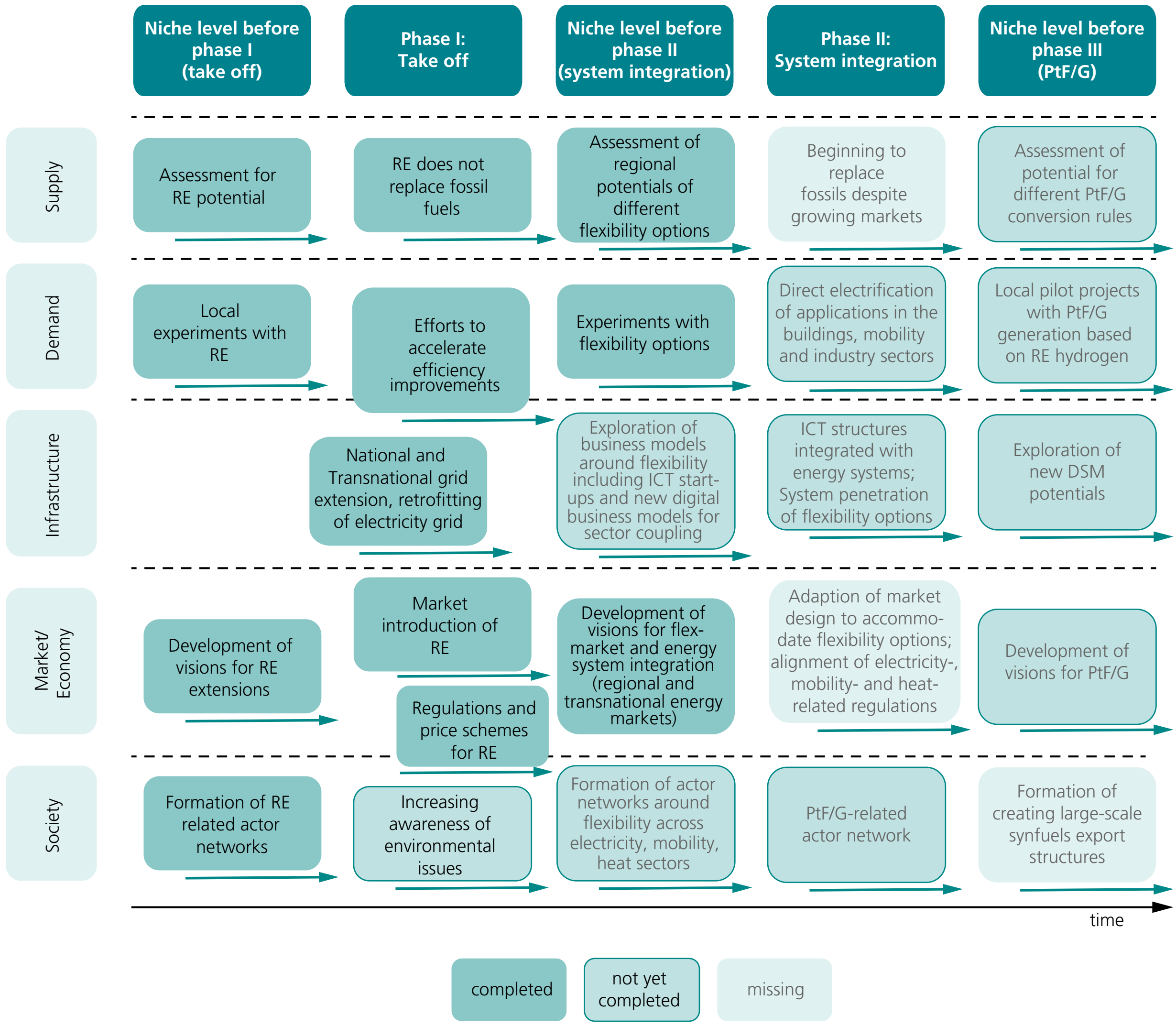
The vision stating that »in 10 years, Morocco shall be one of the leading countries exporting high added value green (industrial) molecules« (IRESEN, 2020) clearly indicates where Morocco sees itself in the near future. Still, the country must ensure that potential exports of green hydrogen and its derivatives do not happen at the expense of the national energy transition.

Morocco, however, remains dependent on natural gas imports and the challenges that come with it. This is especially because the country lacks indigenous gas resources, and gas remains one of the main pillars of the country's future energy mix. Hence, natural gas should be considered only as a transitional option towards a decarbonised energy system but not as a long-term option. The same holds true for coal; although some coal power plants were commissioned recently, the phase out of this technology is already being discussed. After the COP26 in Glasgow, Morocco stated its plans to cease the issuance and construction of new coal-fired power plants.

The energy system transition in Morocco to a 100% renewables-based energy system will require significant investments, wider and deeper political commitment, the mobilisation of stakeholders, and allocation of resources towards a common vision (Khatib, 2018). It is important to prepare today for the next steps in the energy transition, which are crucial for the third and fourth phases in the applied phase model. The creation of a long-term policy vision towards 100% renewables with a strategic plan can increase the trust among stakeholders and society to support and participate in this development.

The applied MENA energy transition phase model can assist these discussions on long-term strategies, and it serves as a guiding tool for a development towards a 100% RE transition. Fig. 4-11 summarises Morocco's current status in the energy system transition and provides with an outlook on the following steps.

Figure 4-11
**Overview of Morocco'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 Morocco 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 Moroccan 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 Morocco 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 shows that Morocco is well advanced in the energy transition and has one of the most ambitious energy transition programmes, making the country a pioneer in the international energy transition.

Several large-scale wind and solar projects are in operation and RE costs have reached record lows in Morocco. A number of large-scale renewable power projects are being considered to further guarantee the national energy security. This complements plans to achieve decarbonisation and climate-neutrality. Furthermore, by considering decentralised energy systems alongside large-scale developments, Morocco could seize the opportunity to enable economic development across a wider group of society. Especially, Morocco has the potential to become an exporter of green electricity or PtX products in the future within a decarbonising world economy that includes the EU. The EU plans to import more than 40 GW of green hydrogen and its derivatives from neighboring countries to achieve its net zero target by 2050.

To move forward in this direction, renewables must become fully integrated in the energy system. This requires the consideration of flexibility options in all end-user sectors. PtX and hydrogen will be the decisive vectors for economic development in the near future. Hence, a concrete roadmap will be needed to achieve their increasing deployment. In addition to these strategic and infrastructural tasks, it will be equally important to not only ensure social acceptance but to mobilise the wider population to participate more actively in the energy transition design and implementation. This will require increased support for decentralised and small-scale RE development.

While Morocco has already made significant progress in the energy transition, further efforts are still required to achieve a successful sector coupling. The results of the analysis along the transition phase model towards 100% RE are intended to stimulate and support the discussion on Morocco's future energy system by providing an overarching guiding vision for the energy transition.

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# LIST OF ABBREVIATIONS

| | |
|---|---|
| AFD | French Agency for Development (Agence Française du Développement) |
| AFDB | African Development Bank |
| AMEE | Moroccan Agency for Energy Efficiency |
| AMISOLE | Moroccan Association of the Solar and Wind Industry (Association marocaine de l'industrie solaire et éolienne) |
| ANRE | Moroccan Energy Authority (Authorité Nationale de Régulation de l'Energie) |
| BAU | Business-as-usual |
| BOOT | Build, own, operate and transfer model |
| CCS | Carbon capture and storage |
| CCU | Carbon capture and use |
| CNG | Compressed natural gas |
| COP26 | Conference of the Parties |
| COVID-19 | Coronavirus disease 2019 |
| CSP | Concentrated solar power |
| EBRD | European Bank for Reconstruction and Development |
| EIB | European Investment Bank |
| Euroct | Eurocent |
| DMS | Distribution management system |
| ENTSO-E | European Network for Transmission System Operators-Electricity |
| EU | European Union |
| EV | Electric vehicle |
| FDE | Energy Development Fund (Fonds de développement de l'énergie) |
| FENELEC | National Federation of Electricity, Electronics and Renewable Energy (Féderation Nationale de l'Electricité, de l'Electronique et des Energies Renouvelables) |
| FiT | Feed-in tariff |
| GDP | Gross Domestic Product |
| GHG | Greenhouse gas |
| GHG-IS | National Greenhouse Gas Inventory System |
| GIZ | German Corporation for International Cooperation (Deutsche Gesellschaft für Internationale Zusammenarbeit) |
| HFO | Heavy fuel oil |
| ICT | Information and communication technologies |
| IFMEREE | Training Institute for Professions in Renewable Energy and Energy Efficiency (Institut de Formation aux Métiers des Energies Renouvelables et de l'Efficacité Énergétique) |
| IPP | Independent Power Producer |
| IRESEN | Institute for Research into Solar and New Energies (Institut de Recherche en Energie Solaire et Energies Renouvelables) |
| KfW | Credit Institute for Reconstruction (Kreditanstalt für Wiederaufbau) |
| LCOE | Levelised cost of energy |
| LCOH | Levelised cost of hydrogen |
| LNG | Liquefied natural gas |
| LPG | Liquefied petroleum gas |
| LT-LEDS | Long-term Low Emissions Development Strategy |
| MASEN | Moroccan Agency for Sustainable Energy |
| MENA | Middle East and North Africa |
| METSD | Ministry of Energy Transition and Sustainable Development |
| MLP | Multi-level perspective |
| MorSEFF | Morocco Sustainable Energy Financing Facility (Ligne Marocaine de Financement de l'Energie Durable) |
| MoU | Memorandum of Understanding |
| MRV | Monitoring, reporting and verification system |
| MSP | Moroccan Solar Plan |
| NAMA | Nationally Appropriate Mitigation Action |
| NDC | Nationally Determined Contribution |
| OCP | Office Chérifien des Phosphates |
| ONEE | Office of Electricity and Drinking Water (Office National de l'Electricité et de l'Eau potable) |
| ONHYM | National Hydrocarbons and Mines Office (Office National des Hydrocarbures et des Mines) |
| PCN | National Climate Plan |
| PERG | Global Rural Electrification Programme |
| 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 |
| RTCM | Thermal Regulation of Construction in Morocco |
| SCADA | Supervisory control and data acquisition |
| SIE | Energy Engineering Company (Société D'Ingénierie Energétique) |
| SNDD | National Sustainable Development Strategy |
| UK | United Kingdom |
| USD | US-Dollar |
| VEB | Biomass Energy Valorisation |

# LIST OF UNITS AND SYMBOLS

| | |
|---|---|
| % | Percent |
| $CO_2$ | Carbon dioxide |
| GW | Gigawatt |
| GWh | Gigawatt hour |
| HV | High voltage |
| kgoe | Kilogramme of oil equivalent |
| ktoe | Kilotonne of oil equivalent |
| kV | Kilo Volt |
| kW | Kilowatt |
| kWh | Kilowatt hour |
| LV | Low voltage |
| m/s | Metre per second |
| Mt | Megatonne |
| Mtoe | Millions of tonnes of oil equivalent |
| MV | Medium voltage |
| MVA | Megavolt-ampere |
| VHV | Very high voltage |

# LIST OF TABLES



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## ABOUT THIS STUDY

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

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

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# SUSTAINABLE TRANSFORMATION OF MOROCCO'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 MENA countries has been developed and applied to the country case of Morocco. It is designed to support the strategy development and governance of the energy transition and to serve as a guide for decision makers. Such a phase model could be shared widely as part of Morocco's engagement in international platforms of multilateral collaboration, such as the Energy Transition Council (chaired by the United Kingdom (UK) and managed by the British Embassy – Rabat).

The analysis shows that Morocco has fully embarked on the energy transition. According to the MENA phase model, Morocco can be classified as being in the second phase »System Integration of Renewables«. Nevertheless, Morocco plans to considerably increase the use of natural gas in order to back up intermittent solar and wind energy sources. The diversification of energy sources and a diverse portfolio of storage options, including solar thermal power and hydrogen, can foster flexibility options. To this end, a roadmap for power-to-X (PtX) should be considered for a smooth transition of the Moroccan energy supply and demand system.

The expansion of local REs can significantly contribute to reducing Morocco's high fossil fuel imports that are causing a high fiscal burden. With this regard, energy security can be strengthened. Next to large-scale deployment, decentralisation of the energy system must be built to encourage an energy transition on all societal levels. The results of the analysis along the transition phase model towards 100% RE are intended to stimulate and support the discussion on Morocco's future energy system by providing an overarching guiding vision for energy transition and the development of appropriate policies.

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

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