STUDY

CLIMATE CHANGE, ENERGY AND ENVIRONMENT

# SUSTAINABLE TRANSFORMATION OF ISRAEL'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 Israel, the study provides a guiding vision to support the strategy development and steering of the energy transition process.

The transition towards a renewable-based energy system can reduce import dependencies and increase the energy security in Israel.

Key issues that need to be tackled in order to advance the energy transition in Israel are the expansion of flexibility options, discussion on the long-term role of natural gas, increasing participation and awareness, and exploring the future role of power-to-X in the energy system.

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

Israel, with its abundant renewable energy potential, in particular wind and solar, has excellent preconditions to embark on the pathway towards a 100% renewable energy system. Accordingly, Israel has already made considerable progress with regard to the development of renewable energy capacities. But at the same time, Israel is also expanding its natural gas production. Therefore, increased efforts are required if Israel wants to advance towards a fully renewables-based energy system.

To move forward in this direction, Israel needs to be prepared to tap flexibility options in all parts of the energy system to balance the supply and demand side. Being currently limited to the power sector, the transition debate needs to be expanded to different sectors. A smooth transition requires sector coupling between all end-user sectors.

The expansion of renewable energies can make an important contribution to reducing Israel's dependence on energy imports. In this way, energy security, which is the most important pillar of Israel's energy policy, can be strengthened. The elaboration of a long-term political vision in combination with a strategic plan can moreover increase stakeholders' confidence in supporting and participating in the energy transition process.

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

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

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# SUSTAINABLE TRANSFORMATION OF ISRAEL'S ENERGY SYSTEM

## Development of a Phase Model

Wuppertal Institut

מכון הערבה
Arava Institute
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# 1

# INTRODUCTION

The MENA region faces a wide array of challenges, including a 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. Climate change for the MENA region means that the region, which is already highly vulnerable due to its geographical and ecological conditions, will become even more affected by the negative consequences in the future. In particular, 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 region's stability.

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

Accordingly, against the backdrop of rapidly growing energy demand due to population growth, changing consumer behaviour, increasing urbanisation, and other factors – including industrialisation, water desalination, and the increased use of electricity for cooling – renewable energy is gaining attention in the Middle East and North Africa (MENA) region. To guarantee long-term energy security and meet the climate change goals, most MENA countries have developed ambitious plans to scale up their renewable energy production. The significant potential in the MENA region for renewable energy production, particularly wind and solar power, gives rise to the opportunity 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 highly populated countries poses a risk in terms of energy security and public budget spending.

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

To support such understanding, a phase model for renewables-based energy transitions in the MENA countries has been developed. This model structures the transition process over time through a set of transition phases. It builds on the German phase model and is further complemented by insights into transition governance and characteristics of the MENA region. The phases are defined according to the main elements and processes shaping each phase, and the qualitative differences between phases are highlighted. The focus of each phase is on technological development; at the same time, insights into interrelated developments in markets, infrastructure and society are provided. Complementary insights from the field of sustainability research provide additional support for the governance of long-term change in energy systems along with 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 Israel. The current state of development in Israel is assessed and analysed against the phase model. Expert interviews were conducted to gain insights to specify the previously defined abstract components of the model. As a result, further steps for the energy transition – based on the steps of the phase model – are proposed. This application is based on findings from previous studies and projects conducted in the MENA region, while case study specific data was collected for this study by the local partner Arava Institute for Environmental Studies.

# 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), building 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 the German energy system transformation towards a decarbonised energy system based on renewable energies. The four phases of the models correlate with the main assumptions deduced from the fundamental characteristics of renewable energy sources, labelled as follows: »Take-off RE«, »System Integration«, »Power-to-Fuel/Gas« and »Towards 100% Renewables«.

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

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

The phase model outlines these socio-technical interdependencies of the described developments, which build on each other in temporal order. The four phases are crucial to achieving a fully renewables-based energy system. In the first phase, renewable energy technologies are developed and introduced into the market. Cost reductions are achieved through research and development (R&D) programmes and first market introduction policies. In the second phase, dedicated measures for integrating renewable electricity into the energy system, including flexibility of the residual fossil power production, development and integration of storage, and activation of demand-side flexibility, are introduced. In the third phase, to further increase the share of renewables, the long-term storage of renewable electricity to balance periods where supply exceeds demand is essential. Power-to-fuel and power-to-gas 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 entirely replace fossil fuels in all sectors. All the phases must connect smoothly to achieve the target of a 100% renewables-based energy system. To describe the long-term changes in energy systems in these four phases, the phase model is supplemented by insights from sustainability transition research concerning the dynamics of fundamental long-term change in societal subsystems such as the energy system.

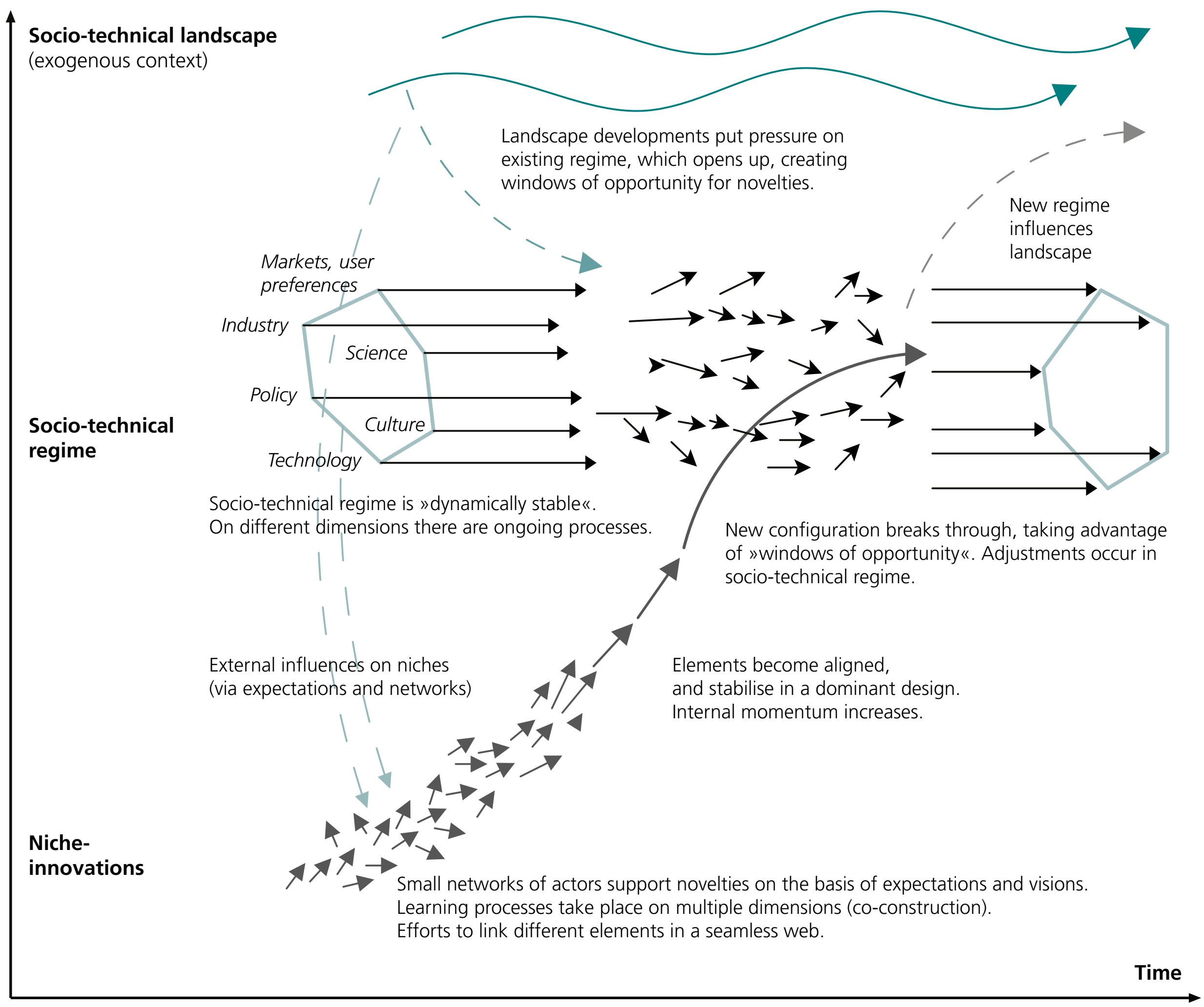
1 Text is based on (Holtz et al., 2018).

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

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

While at the »landscape« level, pervasive trends such as demographic shifts, climate change, economic crises etc., 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. The regime comprises the existing technologies, regulations, user patterns, infrastructure, and cultural discourses that combine to form socio-technical systems. To achieve system changes at the »regime« level and avoid lock-in and path dependencies, innovations at the »niche« level are incremental because they provide the fundamental base for systemic change. Niches develop in protected spaces such as R&D labs and gain momentum when visions and expectations become more widely accepted. Therefore, actor-network structures that can spread knowledge and change societal values are of crucial importance for the transition process (Geels, 2012). The governance of transitions requires experimentation and learning, continuous monitoring, reflexivity, adaptability, and policy coordination across different levels and sectors (Hoogma et al., 2005; Loorbach, 2007; Voß et al., 2009; Weber and Rohracher, 2012). The development of niches in the framework of »strategic niche management« is an essential precondition for fundamental change. Within transition phases, three stages with associated policy approaches can be distinguished: »niche formation«, »breakthrough« and »market-based growth«. In the »niche formation« stage, a niche develops and matures and may offer solutions that can be absorbed by the regime. Within this stage, expectations and visions that provide direction to learning processes are essential. Also, actor involvement and

Figure 2-1
**The Multi-Level Perspective**




(Source: Geels and Schot, 2007)

social networks can support the creation of the necessary value chains, and learning processes at different levels can advance the technology.

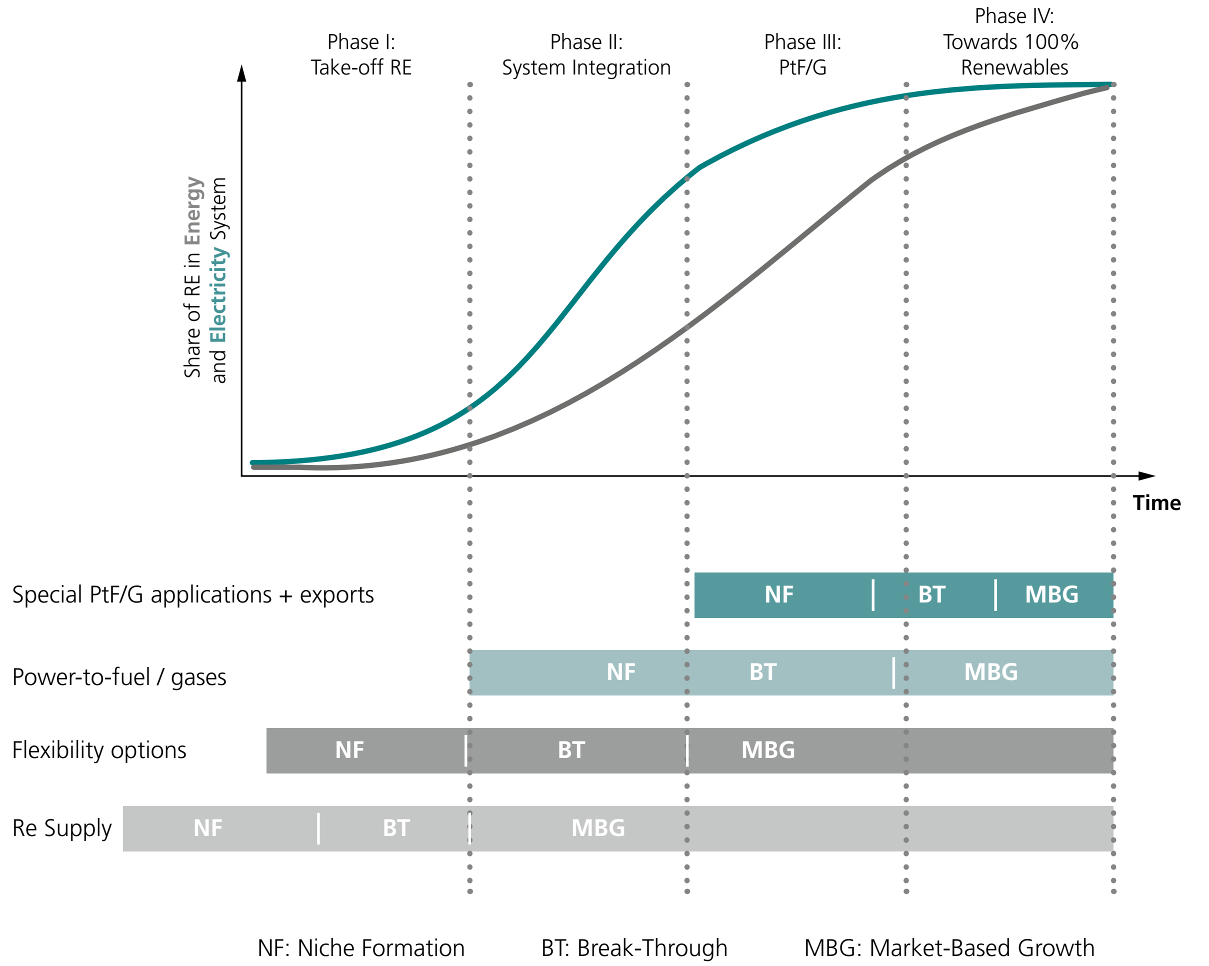
In the »breakthrough« stage, the niche innovation spreads by actors involved, market share and replication in other locations. At this stage, improved price-performance is relevant, and access to necessary infrastructure and markets must be open. Amending rules and legislation, and increasing societal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

## 2.3 ADDITIONS IN THE MENA PHASE MODEL

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

Changing the deployment of technologies across markets is described in a »techno-economic layer«, while the governance stages are captured in the »governance layer«. The aim of this layer is to connect developments in the

Figure 2-2
**Transition Phase Model for the MENA Region**




(Source: Holtz et al., 2018)

techno-economic layer to governance approaches to support the transition phases. Specific measures with a strong focus on building a renewables-based energy system are included. Factors such as capacities, infrastructure, markets, and the destabilisation of the existing fossil fuel-based regime have been added to the phase model. These aspects, however, serve as reflexivity about governance and need to be individually assessed and adapted for each MENA country.

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

# 3

# THE MENA PHASE MODEL

## 3.1 SPECIFIC CHARACTERISTICS OF THE MENA REGION

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

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

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

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

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

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

The energy systems in the MENA region are in a developmental phase; renewable energies are not only attractive in terms of sustainability but also in terms of energy security. Furthermore, they have the potential to stimulate economic prosperity. However, developing renewable energy industries is weak due to the lack of supporting frameworks for entrepreneurship and technological innovation. While in Germany, private actors play a significant role in small-scale PV and wind power plants, in the MENA region, state-owned companies are central to large-scale projects. The mobilisation of capital is an additional significant factor that would require dedicated strategies.

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

The differences between the assumptions in the original phase model and the characteristics of the MENA region result in specific adaptations to the phases of the original phase model. Based on Fischedick et al. (2020), changes to the original model were made within the four phases and their temporal description. Also, the »system layer« description is complemented by a stronger focus on the destabilisation of the regime and the »niche layer« is highlighted in each phase to prepare for the subsequent phase.

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

## 3.3 PHASES OF THE ENERGY TRANSITION IN MENA COUNTRIES

The Wuppertal Institute developed the phase model for the MENA countries based on the German phase model and the experience gained during the project, "Development of a phase model for categorizing and supporting the sustainable transformation of energy systems in the MENA Region", which was supported by the Friedrich-Ebert-Stiftung (Holtz et al. 2018, Fischedick et al. 2020). The phases for the MENA region are presented in detail in their dimensions, which are based on supply, demand, infrastructure, markets, and society. The multi-dimensional perspective of transitions research is reflected in these layers, highlighting the interrelatedness of these dimensions during the transition phases. Table 3-1 summarises the main developments in the »techno-economic« and »governance« layers, as well as on the »landscape«, »system« and »niche« levels during the four phases.

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

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

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

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

In the first phase, the characteristic development at the system level is the introduction and initial increase of renewable energy, particularly electricity generated by photovoltaic (PV) and wind plants. MENA countries could benefit considerably from the globally available technologies and the global price drops of renewable energies, facilitating the market introduction of PV and wind energy. As energy demand is growing considerably in the region, the share of renewable energy entering into the system would not replace fossil fuels at this stage. To accommodate variable levels of renewable energy, the grid must be extended and retrofitted. Laws and regulations enter into force intending to integrate renewables into the energy system and enable renewables-based electricity to be fed into the grid. The introduction of price schemes as incentives for investors enables 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 the industry) and visions are developed that broach flexibility options. At this stage, the role of sector coupling (e.g., e-mobility, power-to-heat etc.) is discussed, and business models are explored. Expected flexibility needs and sector coupling lay the ground for information and communication technology (ICT) start-ups and new digital business models.

**Phase 2 – »System Integration«**

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

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

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

**Phase 3 – »Power-to-Fuel/Gas (PtF/G)«**

At the »system« level, the share of renewables increases in the electricity mix, leading to intensified competition between renewables and fossil fuels and – temporarily – to high, negative residual loads. Green hydrogen and synthetic fuel production become more competitive due to the availability of low-cost electricity. PtF/G, supported by regulations including pricing schemes, enter the market and absorb increasing shares of »surplus« renewables during times of high supply. The mobility and long-distance transport sectors, in particular, contribute to an increase in the application of PtF/G. This, in turn, enables the replacement of fossil fuels and natural gas. The development of hydrogen infrastructure and the retrofitting of existing oil and gas infrastructure to use synthetic fuels and gases creates dedicated renewable supply facilities for international exports. Price reductions and the introduction of fees and taxes on fossil fuels negatively influence their market conditions and initiate the phase-out of fossil fuels. These developments stimulate changes in the business models. As PtF/G solutions provide long-term storage, large 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. Also, the potential to export hydrogen and synthetic fuels and gases are explored and assessed. Actor networks are established, initial learning is gained, and business models are studied.

**Phase 4 – »Towards 100% Renewables«**

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

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

The MENA phase model was exploratively applied to the case of Jordan in 2018 (Holtz et al., 2018). The model was discussed with high-ranking policymakers, representatives from science, industry, and civil society from Jordan. It proved to be a helpful tool to support discussions about strategies and policymaking for the energy transition, a tool which would also be appropriate for other MENA countries. Consequently, necessary adaptations were made and the MENA phase model was applied to the country case of Israel. The results provide a structured overview of the ongoing developments in the Israeli energy system and offer insights into the next steps necessary to transform it into a renewables-based system.

Israel's targets are energy autonomy, climate change mitigation and air pollution reduction (Ministry of Finance, 2021 and Navon et al., 2020). Having a unique status in terms of regional integration and energy infrastructure, Israel decided already in the early 2000s to encourage the deployment of renewable energy technologies. The shift to renewable energy offers Israel the opportunity to increase energy security and environmental benefits and economic development prospects.

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

## 3.5 DATA COLLECTION

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

In the Israeli case study, the local research was conducted by the partner institution Arava Institute for Environmental Studies, based in Israel.

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% | * RE share in energy system about 20%-50% | * RE share in energy system about 50%-80% | * RE share in energy system about 80%-100% |
| | | | | * Market introduction of RE drawing on globally available technology and driven by global price drop | * Further grid extension (national and international) | * Extension of long-term storage (e.g., storage of synthetic gas) | * Large-scale construction of infrastructure for PtF/G exports |
| | | | | * Extension and retrofitting of electricity grid | * ICT structures integrate with energy systems (e.g., introduction of smart meters) | * First PtF/G infrastructure is constructed (satisfying up-coming national/foreign demand) | * Phase-out of fossil fuel infrastructure and business models |
| | | | | * Regulations and pricing schemes for RE | * System penetration of flexibility options (e.g., battery storage) | * Temporarily high negative residual loads due to high shares of RE | * Consolidation of RE-based export models |
| | | | | * Developing and strengthening domestic supply chains for RE | * Direct electrification of applications in the buildings, mobility, and industry sectors; changing business models in those sectors (e.g., heat pumps, e-cars, smart-home systems, marketing of load shedding of industrial loads) | * Sales volumes of fossil fuels start to shrink | * Full replacement of fossil fuels by RE and RE-based fuels |
| | | | | * No replacement of fossil fuels due to growing markets | * No replacement (or only limited replacement) of fossil fuels due to growing markets | * Existing fossil fuel-based business models start to change | * Stabilisation of PtF/G business models and production capacities (e.g. large-scale investments) |
| | | | | | * Development and extension of mini-grids as a solution for off-grid applications and remote locations | * Increasing volumes of PtF/G in transport, replacing fossil fuels and natural gas | |
| | | | | | * Progressing the energy transition in end-use sectors (transport, industry, and buildings) | | |
| | | | | | * Progressing the energy transition in the industry sector, reducing the high carbon content of certain products and high emissions of certain processes | | |

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

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

(Source: Wuppertal Institute)

# 4

# APPLICATION OF THE MODEL TO ISRAEL

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

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

Israel has often been described as an »energy island« that is not connected with the energy infrastructure of its neighbours (Fischhendler et al., 2015; Shaffer, 2011).

Until discovering the Tamar and Leviathan natural gas fields off the Mediterranean coast, the country was almost entirely dependent on energy imports. Today, there are connections to neighbouring countries in the form of gas pipelines to Egypt and Jordan, but the main electricity is still not interconnected.

The energy mix continues to be dominated by the use of fossil fuels. The expansion of renewable energies is proceeding slowly. By signing the Paris Agreement, however, Israel has set itself the goal to reduce national greenhouse gas emissions (GHG) by 26% compared to 2005. Being vulnerable to political instability and climate change, the country has also elaborated sector-specific targets that consist of a 17% reduction in electricity consumption and a 20% reduction in kilometres travelled by private vehicles (Ministry of Environmental Protection, 2018). Israel has reduced air pollution and GHG emissions in the past years, mainly by replacing coal and other conventional fuels with natural gas. As the country pledges to eliminate the use of coal, gasoline and diesel for energy production and transport, the $CO_2$ emissions have dropped already by 20% compared to 2012 (REN21, 2019; IEA, 2020a). Despite the pivotal role of natural gas, Israel is also seeking to expand renewable energy in light of the falling prices for these technologies. The goal is primarily to increase national energy security. In this context, a flagship project was implemented in the Negev desert in the south of Israel, consisting of a parabolic trough plant with a capacity of 110 MW and a thermo-solar power plant with a capacity of 121 MW, covering 1% of Israel's electricity demand (Negev Energy, 2016). By 2030 Israel wants to reach a 30% share of renewable energy in the electricity mix (Spyridonidou et al., 2021). Current policies to uptake renewables cover feed-in tariffs (FiT) for small systems and auctions for large systems.

To move further towards an energy system based on renewable energies, Israel would benefit from increasing flexibility applications. Besides electric vehicles (EV) and grid connection improvements, enhanced cross-border cooperation would add to the beneficial development towards renewables (Abu Hamed and Bressler, 2019).

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

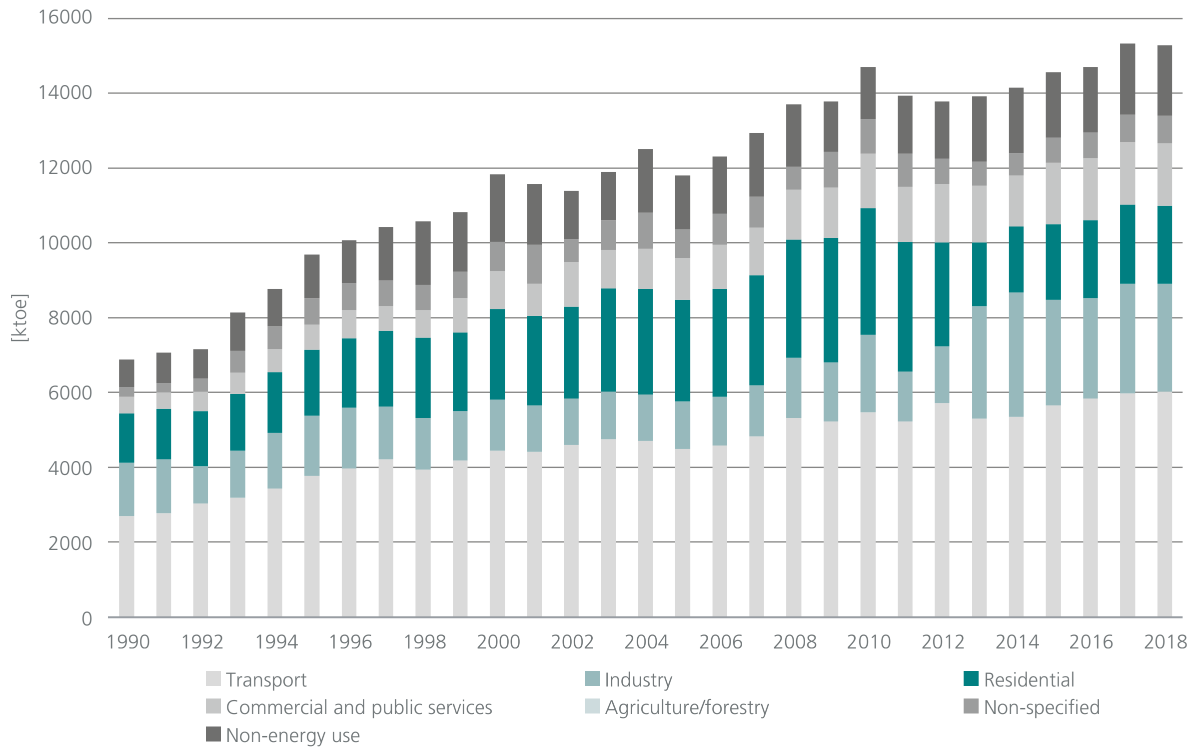
### 4.1.1 Assessment of the current state and trends at the landscape and system levels

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

**Energy demand and supply**

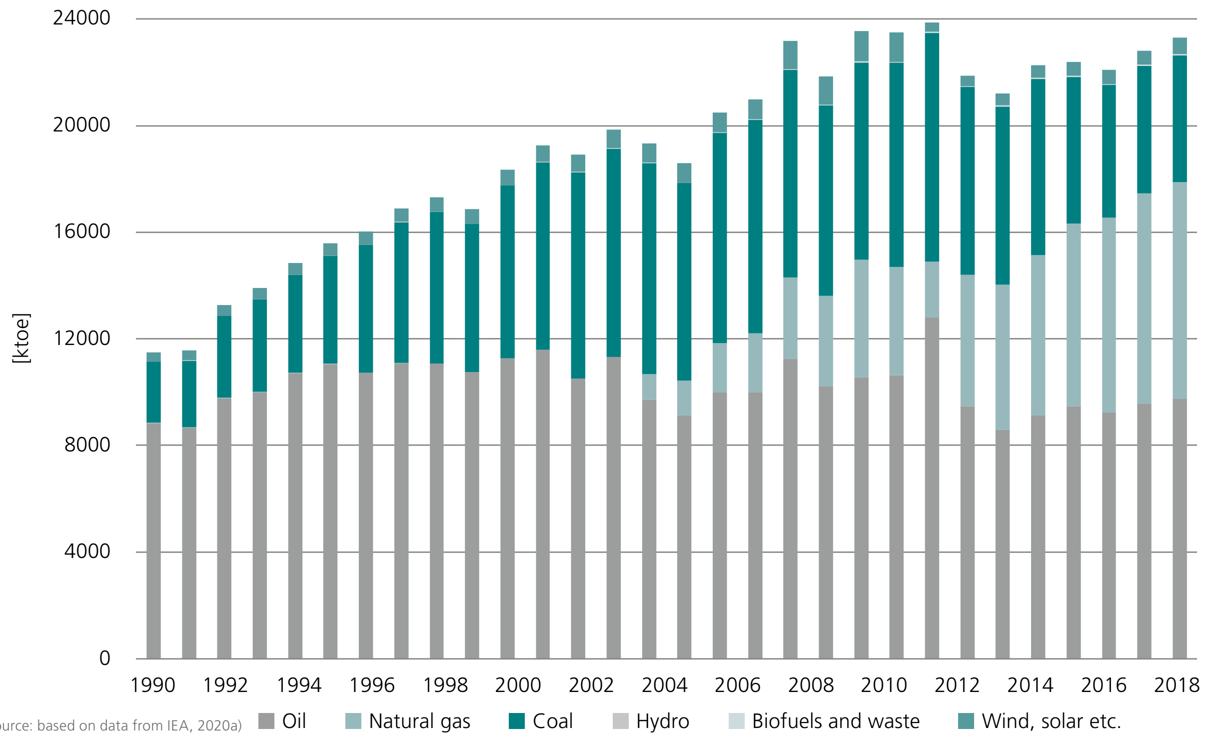
Israel's total primary energy supply in 2018 was 22.3 Mtoe (IEA, 2020a). In terms of the energy consumption by sector, the transport sector dominates, accounting for 39%, followed by the industrial sector (19%), the residential sector (13%), and the commercial and public services (11%) (IEA, 2020a) (Fig. 4-1). The energy mix is predominantly made up of fossil fuels (Fig. 4-2). In 2019, oil held a 42% share of the energy mix, natural gas accounted for 35%, and coal had a 20% share, while renewable energies held a share of around 3% (IEA, 2020a). In light of the Paris Agreement, the share of coal in the energy mix, which peaked in 2012 with 36%, has dropped constantly over the past years, with

Figure 4-1
**Total final consumption by sector (in ktoe), Israel 1990–2018**



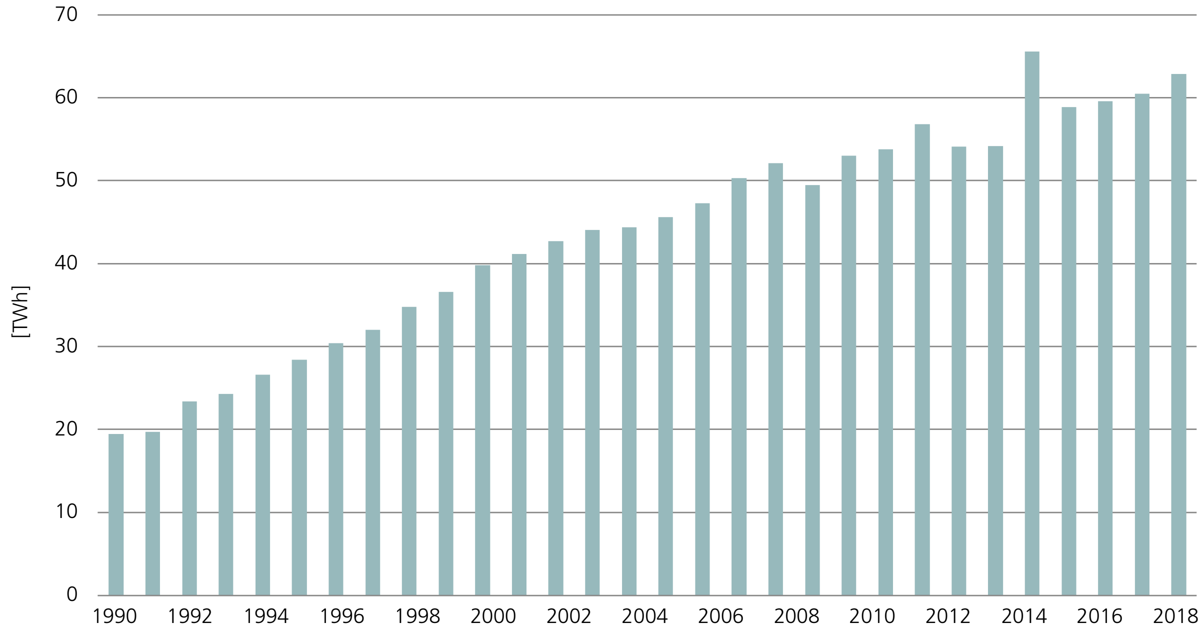

(Source: based on data from IEA, 2020a)

Figure 4-2
**Total energy supply by source (in ktoe), Israel 1990–2019**



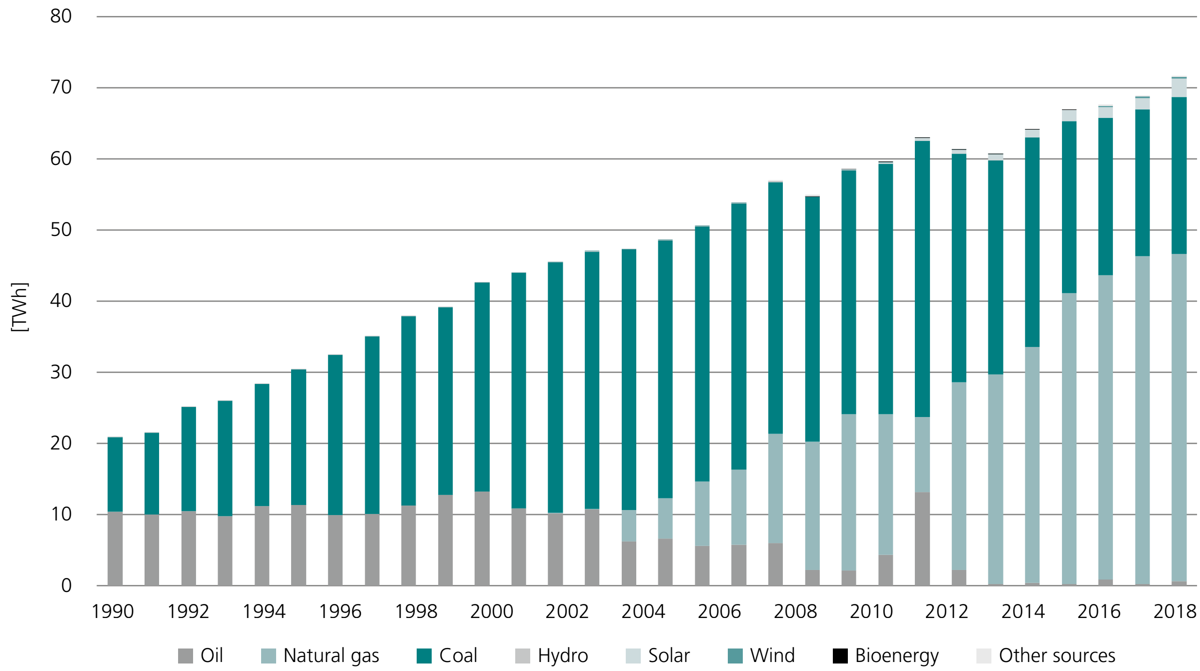

(Source: based on data from IEA, 2020a)

Figure 4-3
**Electricity consumption (in TWh), Israel 1990–2019**




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

Figure 4-4
**Electricity generation by source (in TWh), Israel 1990–2019**




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

the shutdown of four generation units at the Orot Rabin coal power plant.

While the summer peak amounts to 12.9 GWh, the winter's demand peak reached 11.8 GWh for the year 2018 (Central Bureau of Statistics, 2020). During the summer months, the peak is between 11:30 am and 6 pm, while the winter peak demand is usually between 7 am–10 am and 5 pm–9 pm (IEC, 2021). Due to rising living standards, population growth and an increase in extreme temperatures during the summer months, Israeli electricity consumption has increased between 1990 and 2000 from approximately 20 TWh to around 40 TWh, representing an annual growth rate of 3.8%. In 2019, the electricity consumption amounted to around 63 TWh (Fig. 4-3). The yearly electricity growth was 2.4% between 2000 and 2019, and it is expected that until 2030 the electricity consumption will continue to increase in the same range of 2.3–2.8% (Abu Hamed and Bressler, 2019).

The energy supply in Israel was highly vulnerable to external shocks (Abu Hamed and Bressler, 2019). However, today the use of local natural gas has stabilized the energy supply in Israel. In the past, political events have threatened the energy supply in Israel. For instance, when Egypt went through the Arab Spring, the Arish-Ashkelon pipeline that supplied Israel with Egyptian gas was shut down, forcing Israel to replace natural gas with coal and oil to cover the domestic demand (Bahgat, 2011). In the course of the last decade, the use of natural gas has increased, as new gas discoveries on the Mediterranean coast have been made (Fig. 4-4). The use of natural gas in power generation, as well as in the manufacturing and large-scale commercial sector, continues to increase (Ministry of Environmental Protection, 2018).

Israel has 16 power plant stations run by the state-owned Israel Electric Corporation (IEC), which are mainly fuelled by coal and natural gas. IEC operates the five largest and oldest power stations along the Mediterranean coast: Orot Rabin, Reading, Rotenberg, Eshkol, and Haifa that utilize heavy fuel oil, natural gas, and coal (Abu Hamed and Bressler, 2019). In 2018, the total installed generating capacity was 18,096 MW. Out of this, 1.4 GW installed capacity came from renewables. For the same year, the annual peak load amounted to 12,921 MW (Central Bureau of Statistics, 2020). As the electricity growth rate slowed down between 2013 and 2015, additional power installations by private generation companies have led to a high reserve (equal to the ratio of the installed capacity above the expected peak demand). In 2012, the reserve was about 15%, still under the value of around 17-20% that the Ministry of Energy targets as a minimum (ibid.). In 2018, the reserve amounted already to 30% excluding renewables and 33% including renewables.

Climate change is a significant driver for increasing electricity consumption and production. In the dense urban centres on the Israeli coast, heat waves are expected to affect the peak energy demand. According to the Ministry of Environmental Protection (2018), 45% of the total electricity consumption can be attributed to air conditioning (Michaels and Parag, 2016; Ministry of Environmental Protection, 2018). The most significant contributors to the growing energy demand are households. Moreover, water resources are becoming scarce as a consequence of climate change.

The Israeli government has, therefore, developed a strategy to tackle the reduction of natural water resources. This strategy entails the extension of desalination plants to reach an output of 1,500 million $m^3$ by 2050 (ibid.). The current desalination capacity has increased from 277 million $m^3$ to 582 million $m^3$ between 2010 and 2018. Five existing facilities are located in Sorek, Hadera, Ashkelon, Ashdod and Palmachim and supply the agricultural and industrial sector with desalinated water (ibid.). The provided water makes up approximately 80% of Israel's drinking water (Ministry of Energy, 2019). Currently, a tender has been published that dictates the establishment of a desalination facility at Sorek with a production capacity of 200 million $m^3$ per year. The proposed price per $m^3$ is 1.6 ILS[2], which stands for 0.5 ILS less than today's lowest price paid (Ministry of Energy, 2019). Desalination is an energy-intensive process, and the additional implementation of desalination plants will certainly further increase Israeli energy consumption in the future.

A significant impact on the energy sector is experienced by the COVID-19 pandemic that has slowed down the economy, affecting the electricity sector. As a result of the strict lockdown, consumption in the industry sector has dropped approximately by 13% compared to the corresponding months in 2019. The most significant impact of the mobility restriction has been evident in the reduced household travels. As a result, the total consumption of gasoline recorded a 42%-reduction and the diesel consumption a 26%-drop compared to the same months in 2019 (IEC, 2020a; Navon et al., 2021).

To summarise, the Israeli electricity generation is dominated by coal and gas and the natural gas generation and use has been rising over the last years. Because of the vulnerable energy supply situation, which has significant implications for Israel's energy security, Israel as an »energy island« is currently relying on domestic natural gas and is striving to increase the application of renewable energy technologies. Israel can be classified according to the MENA phase model as being in the first phase.

### Renewable energy

Israel has strongly »expressed its national interest to transform (...) into a power of environmental technologies« (Ministry of Environmental Protection, 2019c; The Jerusalem Post, 2019). As pledged by Prime Minister Benjamin Netanyahu in 2011, renewable energy represents a »security necessity« plan for Israel (Bahgat, 2011). Following the strong motive of reaching domestic energy security, the government aims at increasing the share of renewable elec-

**2** Approximately 4 Euro using the currency converter https://www1.oanda.com/lang/de/currency/converter/

tricity to 10% by 2020 and 17% by 2030, which was again amended in 2021, to a 30% target for 2030 (Bellini, 2020; Spyridonidou et al., 2021). According to the Environmental Protection Minister, the momentum for Israel to enter the global cleantech market has been endorsed by the Paris Agreement. Therefore, the Israeli government is eager to invest in developing renewable energy technologies and has already reached important agreements with China in this field. To promote the construction of renewable energy power plants, the government has established several steps (Ministry of Environmental Protection, 2018):

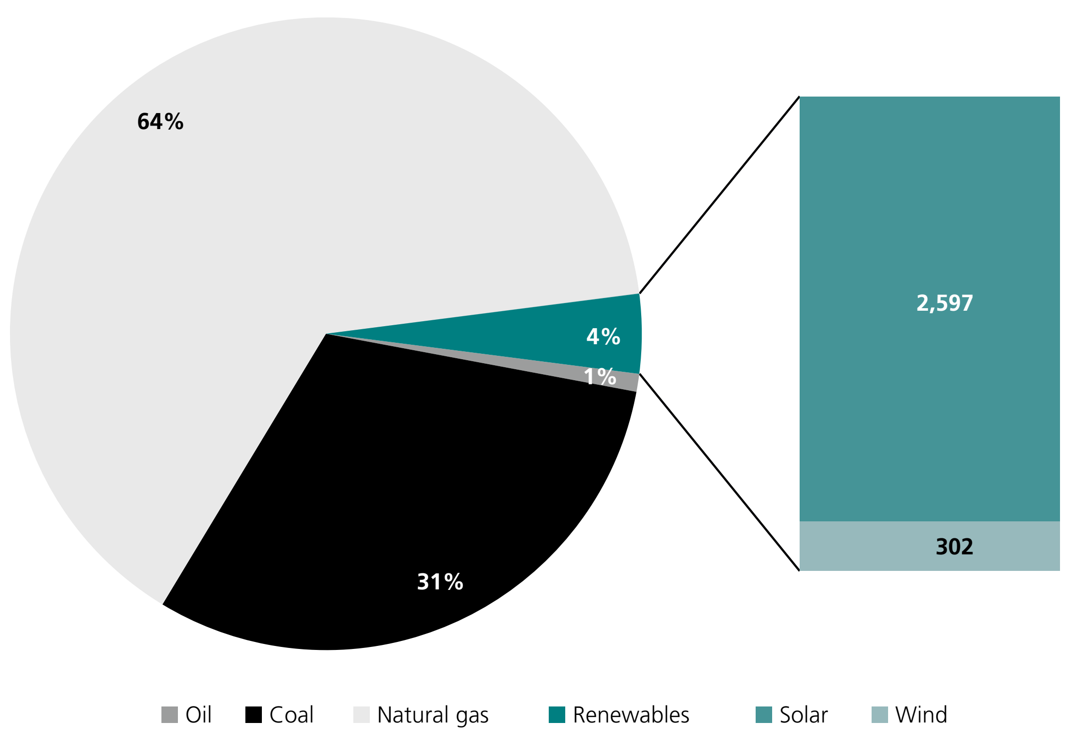
1. tax exemptions, including municipal tax, VAT, income tax and no fuel taxes for biogas
2. the expansion of approved tariff quotas, including a quota for PV power plants of 1,690 MW and a total of 3,760 MW for all renewables
3. government grants and loan guarantees to use for the emissions abatement and energy efficiency financing
4. landfilling prevention of municipal solid waste.

Renewable energy resources, such as solar and wind, are abundant in Israel. By the end of 2019, the cumulative PV power capacity reached 1.72 GW (8.7% of the national electricity demand), followed by concentrated solar power (CSP) capacity with 0.24 GW (1.2% of the electricity demand), biogas power capacity with 0.04 GW (0.15% of the electricity demand) and wind power capacity with 0.03 GW (0.15% of the electricity demand) (Spyridonidou et al., 2021). Fig. 4-5 depicts the electricity generation mix for the year 2018 where – according to the IEA – solar power produced 2,597 GWh while the wind power generation reached 302 GWh.

Being the most prominent renewable energy source, solar energy potential in Israel ranges from 5.5 to 7 kWh/m², depending on the location (Adelekan, 2012). The optimal region for solar irradiation in Israel can be found in the southern Arava region that receives yearly a range between 2,200-2,400 kWh/m² of global horizontal irradiation (DiPersio et al., 2021; Navon et al., 2020; Spyridonidou et al., 2021). From the total installed renewable energy capacity in Israel, the solar infrastructure makes up 96% (ibid.). According to Vardimon (2011), electricity generation from PV on rooftops could provide up to 32% of the national electricity consumption in Israel.

Solar collectors for heating domestic water have been already on the political agenda since the 1980s in response to its scarcity of natural resources and the increasing oil prices (Li et al., 2013). They have been widely introduced, making up to 77% of the residences' equipment today (Spyridonidou et al., 2021). The introduction of solar water heating systems has succeeded in Israel, because of the government's solar legislation of Article 9 of the Law for Planning and Building (1970). The law has been the main contributor to the advancement of solar energy use due to the mandatory installation of those systems in Israel's buildings (Grossman, 2016). Solar photovoltaic (PV) panels are being increasingly inserted in industrial processes such

Figure 4-5
**Electricity generation mix, Israel 2018 (in %, GWh)**




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

as wastewater treatment and desalination. The country's flagship project is located in the Negev desert, in southern Israel – the Negev Ashalim power plant. This utility consists of the 110 MW-capacity Ashalim Plot A parabolic trough facility and the 121 MW-capacity Ashalim Plot B tower facility, which has become operational in 2019, adding up to 1% of Israel's electricity needs (Negev Energy, 2016). Plot A and Plot B have both a thermal storage capacity of 4.5 hours using a molten salt system (Windkraft Journal, 2015). The solar tower has a height of 260 m and is considered to be one of the largest worldwide. The third unit of the Ashalim power plant consists of a 30 MW and a 40 MW-capacity PV power plant.

Additionally, four solar projects, Beersheba, Yeruham, Sde Boker and Mitzpe Ramon, having a capacity of 300 MW are planned in the surroundings of Ashalim forming the »Solar Energy Valley of Israel« (Negev Energy, 2016). The Ashalim power plant combines both institutional financing, such as the former Overseas Private Investment Corporation (OPIC) and the European Investment Bank (EIB), and local commercial banks and runs in a power purchase agreement (PPA) scheme over 25 years. The largest operational PV power plant in Israel is currently the 120 MW Zeelim solar park, located in the Negev desert (Bellini, 2021a). This project was finalised in 2019 as a joint venture between Belectric and the local company Solel Boneh (Enkhardt, 2019). However, the planned Dimona solar plant in the Negev desert is expected to be the largest PV facility in Israel, after completion in 2023. The plant is expected to have a capacity of 300 MW with a storage option (Enkhardt, 2019; Ministry of Energy, 2019). Furthermore, seven PV facilities have been installed on water reservoirs with an installed capacity of around 6 MW approved for operation (Ministry of Energy, 2019). In the southern Arava region, in Eilat Eilot, 15 solar power plants of medium to large-scale are currently in operation adding up to 180 MW that supply the regional communities with electricity (DiPersio et al., 2021). These power plants are playing an essential role in the regional council's strategic plan to develop 400 MW renewable energy capacity by 2040, to reach the region's goal to become 100% energy independent (ibid.).

The wind speeds in Israel vary between 5 and 7 m/s, depending on the location (Evwind, 2020). The most prominent wind facility has been the 6 MW Har Bnei Rasan wind farm at the Golan Heights, which produces approximately 12,000 MWh yearly. In the region of Gilboa, 14 Gamesa wind turbines are operational with a total nominal power of around 12 MW. The Sirin I wind farm, also located in the northern region, has an installed capacity of 9 MW, consisting of 11 Gamesa wind turbines (The Windpower, 2019). Wind farms in Israel face high barriers due to limited land availability and difficulties in connecting them to the grid (Mor et al., 2009). Furthermore, wind turbines increasingly face objections from the local citizens due to noise pollution (Peri et al., 2020). However, despite these oppositions, the government plans to construct wind farms in the northern region worth 72 million USD (Evwind, 2020), adding up to an overall 730 MW capacity (Peri et al., 2020).

Biomass energy in Israel consists of two different forms: biogas and biomass combustion. As the potential is limited, biomass will likely not play a substantial role in the Israeli renewable energy future. The installed capacity of biogas power plants amounts to around 30 MW (Central Bureau of Statistics, 2020). Biogas production includes anaerobic digestion from agricultural crops, organic waste from landfills, and municipal solid waste.

The application of hydropower is very limited in Israel due to scarce water resources. A few hydropower plants in the Galilee region generate less than 10 MW as of now. Concerning pumped storage, Israel has one paramount plant with a capacity of 300 MW – the Mount Gilboa Pumped Storage project (Maruzewski et al., 2016). By 2020, the plant started its operation and is expected to generate 3,000 MWh of electricity yearly (Hydro Review, 2020). Composed by two 2.5 million $m^3$ reservoirs and connected by a 500 m-deep shaft and large pipes, the powerhouse contains two turbines, each of 150 MW capacity. The essential advantage for Israel by implementing pumped storage power is that it adds reserve to the IEC's system and enhances the flexibility to meet peak demand (Electra, 2021).

Officially, the renewable energy market was formed in 2002 when the government first set a national goal of 5% renewables share to be reached within the electricity production by 2016 (IEA, 2020a; Ministry of Finance, 2021). The renewable energy production goal was amended in 2009, setting the goal to reach 10% of renewables in the electricity mix. The new target was endorsed by the cabinet at the end of October 2020 to generate 30% of Israel's electricity from renewable sources by 2030, after criticism put pressure on the Ministry of Energy (Surkes and Staff, 2020). The path for the development of renewable energy is outlined in the country's ‚Policy on the integration of renewable energy sources into the Israeli electricity sector« (PIRES) of 2010 that aims to increase Israel's energy independence and security and reinforce a culture of environmental awareness. The political strategy presents the legal basis for the introduction of the renewable tariff and tax benefits among other supporting policies that aim to help the uptake of renewables. Special attention is put on the research and development (R&D) sector (IEA, 2020a; OECD, 2020). Programmes such as communal car sharing have been introduced in 2016 to support the introduction of electric cars and hybrid vehicles. Turning to the financial mechanisms, in 2004, the Electricity Authority approved a state subsidy for electricity generation from renewables that benefits producers who sell their electricity to the IEC and private consumers through the IECs grid (ibid.). The first regulative feed-in tariff (FiT) framework has been introduced by the Public Authority Utility (PAU) for small-scale PV systems in the residential and commercial sector in 2008 (Green Energy Association of Israel, 2021). Having set first a quota of 50 MW for commercial consumers, this quota was increased up to 120 MW, in 2010, while the residential consumers received an unlimited quota in 2011 (ibid.).

Table 4-1
**Operational and planned renewable energy projects in Israel**

| | | | | |
|---|---|---|---|---|
| **Operational wind power plants** | | | | |
| **Site** | Har Bnei Rasan | Gilboa | Sirin I | |
| **Installed Capacity (MW)** | 6 | 12 | 9 | |
| **Planned wind power plants** | | | | |
| **Site** | Golan Heights | Suez Gulf | | |
| **Installed Capacity (MW)** | 189 | 500 | | |
| **Status** | PPA to be signed | – | | |
| **Operational solar power plants (CSP and PV)** | | | | |
| **Site** | Ashalim Plot A | Ashalim Plot B | Ashalim | Zeelim |
| **Type** | Solar thermal (parabolic trough) | Solar thermal (solar tower) | PV | PV |
| **Installed Capacity (MW)** | 110 | 121 | 30 | 120 |
| **Planned solar power plants (CSP and PV)** | | | | |
| **Site** | Dimona solar power plant (PV) | | | |
| **Installed Capacity (MW)** | 300 | | | |
| **Status** | (under tendering) | | | |
| **Operational hydro-electric power plants** | | | | |
| **Site** | Ein HaNatziv | Gesher Snir | Kfar HaNassi | Neve Yaakov |
| **Installed Capaci-ty (MW)** | 1 | 2.2 | 3.45 | 0.11 |
| **Operational hydro-electric pumped storage power plants** | | | | |
| **Site** | Gilboa | | | |
| **Installed Capacity (MW)** | 300 | | | |
| **Planned hydro-electric pumped storage power plants** | | | | |
| **Site** | Nesher, Jordan Star and Menara | | | |
| **Installed Capacity (MW)** | 800 (total, 300 MW already met with Gilboa) | | | |
| **Status** | (under tendering) | | | |

(Source: based on Enkhardt, 2019; Evwind, 2020; Negev Energy, 2016; The Windpower, 2019; Verma, 2020; Israel Government, 2019a)

Medium-scale facilities for rooftop and ground installations also fall under the FiT framework. The FiT was introduced for small-scale wind turbines with a 30 MW quota in 2009 and large-scale turbines with an 800 MW quota in 2011. The FiT framework for biomass and large-scale CSP and PV has been approved in 2011 (Green Energy Association of Israel, 2021). The FiT was closed in 2013, but has been re-introduced in 2017 for rooftop PV up to 50 kW amounting to 0.12 USD-cents/kWh in 2020. In 2013, the net-metering regulation framework was introduced. Under this regulation, the scheme supports a cap of 400 MW renewable energy capacity for self-consumers who are solely charged for the grid balancing costs (IEA, 2020a). Indeed, the net-metering scheme has boosted PV electricity generation.

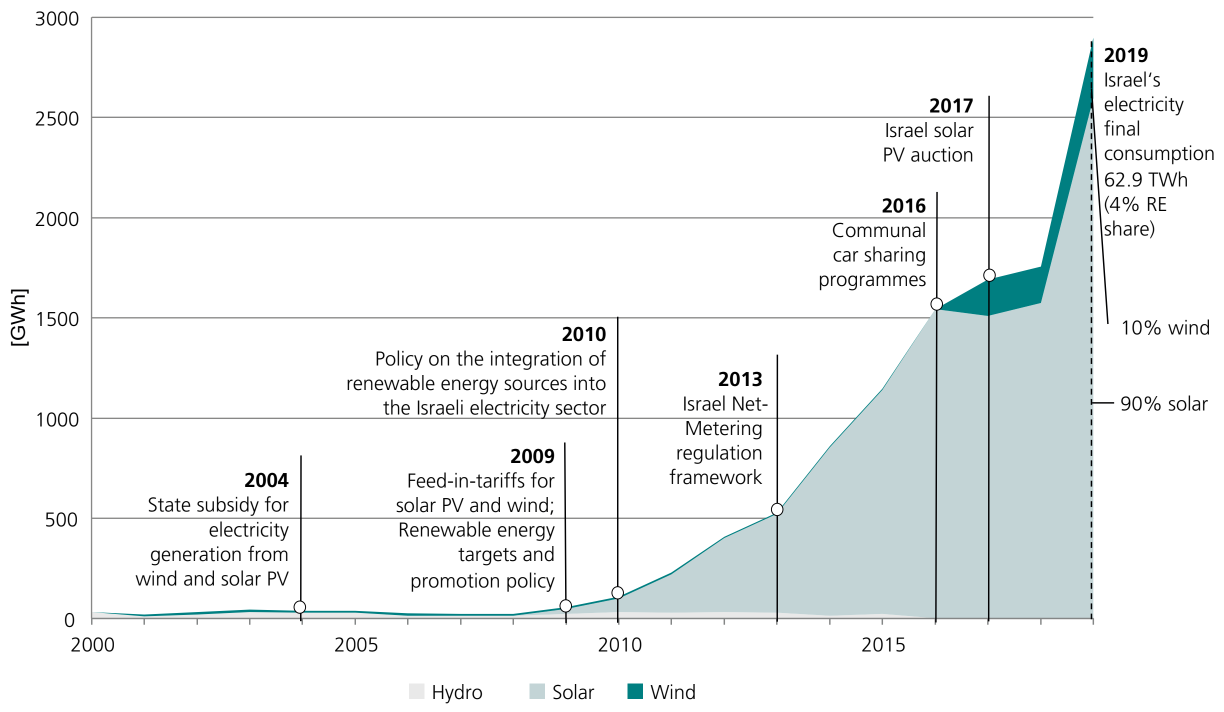
The FiT system was substituted later by auctions. With the introduction of the first solar PV auction in 2017, the Israeli government has brought the country closer to achieve its renewable energy targets. The Electricity Authority's approved quotas have been expanded for PV to 1,690 MW and 3,760 MW for all renewables, enabling a further increase in renewables installed capacity (Ministry of Environmental Protection, 2018). While in 2010, the installed capacity of renewables was 99 MW, in 2019, it already amounted to 1,500 MW; specifically, solar capacity made up 1,438 MW, bioenergy 28 MW, wind 27 MW and hydropower 7 MW (IRENA, 2020b). Fig. 4-6 shows the development of renewables-based electricity generation by source related to the introduced energy policy measures.

Despite its significant renewable energy potential and progress in implementing renewable technologies, Israel still has a long way ahead. Israel's share of renewables is negligible in comparison to its significant potential. Nevertheless, driven by natural resources scarcity and by energy security considerations, renewables have moved to the top of the agenda of the Israeli government. Overall, Israel can be classified as being in the first phase, but at an advanced stage, according to the phase model.

### Fossil fuel sector

Israel is not connected to the electricity infrastructure of its neighbouring countries and is, therefore, perceived as being isolated with regard to the energy supply (Fischhendler et al., 2015). Historically, Israel's status of an »energy island« is grounded in its state of war and conflict with most of its regional neighbours (Shaffer, 2011). This is despite the fact that until the discovery of the Tamar and Leviathan natural gas fields off the Mediterranean coast, the country was almost entirely dependent on energy imports. Today, there are connections to neighbouring countries in the form of

Figure 4-6
**Development of renewables-based electricity generation by source (in GWh) and introduction of energy policy measures, Israel 2000–2019**




(Source: data based on IEA, 2020a)

gas pipelines to Egypt and Jordan, but the main electricity is still not interconnected.

With the exception of the El Arish-Ashkelon natural gas pipeline, Israel imports most of its fossil fuels mainly from Russia, Angola and Norway (Abu Hamed and Bressler, 2019). Oil is mainly imported from Russia, Angola, Colombia, Mexico and Norway. Due to embargoes by Arab oil producers in history, Israel always fears supply shortages (Shaffer, 2011). Given the tense geopolitical state coupled with low domestic natural resources, any disturbance in Israel's energy supply can have huge impacts ranging from blackouts to domestic water supply disruptions (Spiritos and Lipchin, 2013). Consequently, the Israeli energy policy is intertwined strongly with the water supply policy, as Israel produces a significant amount of its water supply by seawater desalination, which needs a crucial quantity of energy (Shaffer, 2011).

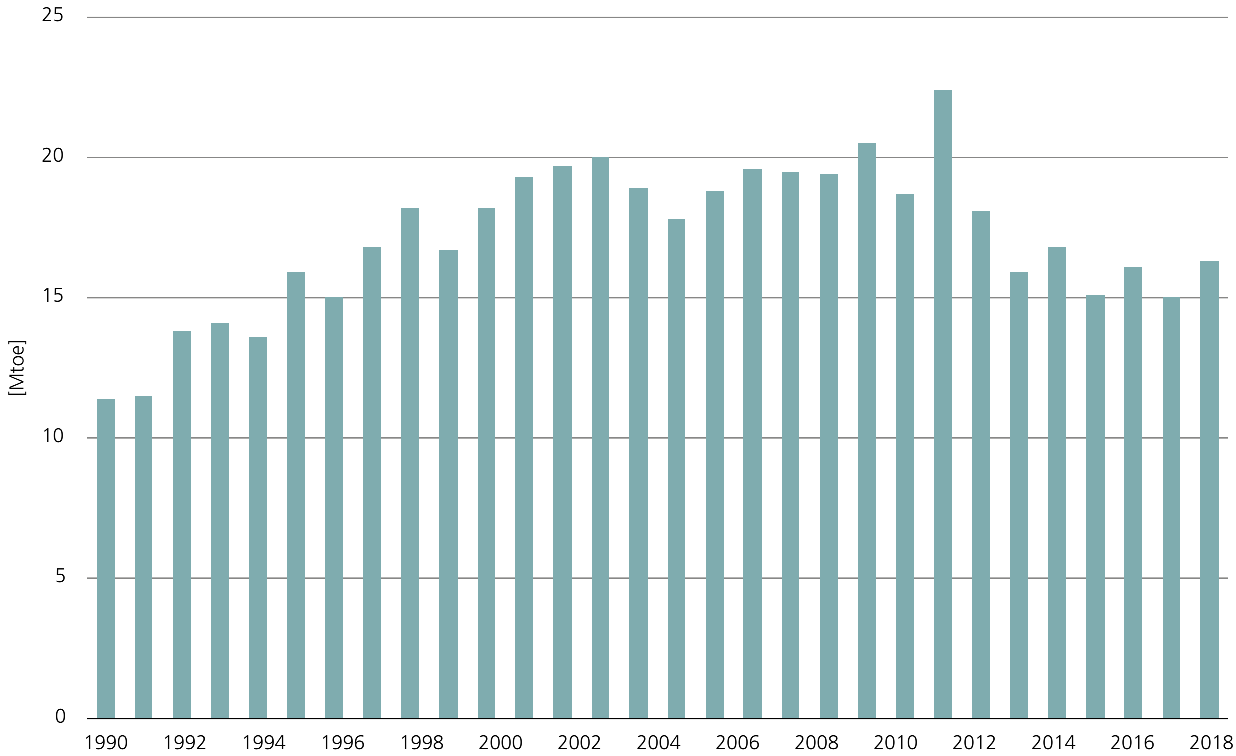
Before discovering natural gas and after severe blackouts in 2002, the Israeli state has moved towards an energy diversification strategy in terms of sources to generate electricity. By replacing most coal imports with natural gas from Egypt, Israel and Egypt signed an agreement of a 15-years gas supply provision in 2005. However, when terrorists repeatedly attacked the pipeline, the natural gas supplies from Egypt were closed permanently in 2012 (Fischhendler et al., 2015). As a consequence, Israel fired up two coal power plants to the maximum capacity and converted several gas stations to heavy fuel oil and diesel to avoid supply disruptions (Bahgat, 2011).

With the natural gas field discoveries in the Levantine Basin in 2009 and 2010, Israel's energy import picture changed. Against this backdrop, three important questions have arisen on a political level (Shaffer, 2011):

1. What is the future share of natural gas in Israel's energy and electricity mix?
2. How to use natural gas beyond the electricity sector?
3. Which quantities are to be used domestically, and which volumes are to be exported?

In the last decade, a substantial amount of coal imports have been substituted by domestic natural gas. In 2009, 32 bn $m^3$ of natural gas in the Tamar fields and, in 2010, 460 bn $m^3$ of natural gas in the Leviathan fields have been discovered. These reserves are expected to supply Israel for at least 25 years (Abu Hamed and Bressler, 2019). Moreover, these discoveries shifted the Israeli position almost from a gas importer to an exporter of natural gas. In this regard, Israel started to supply Egypt with natural gas at the beginning of 2020. Israel will provide 200 million cubic feet of gas per day to Egypt. Egypt's strategy is to re-export the gas to Europe as liquefied natural gas (LNG). Furthermore, Israel signed a 15-years gas supply contract with Jordan that started at the beginning of 2020 (Al-Khalidi, 2020a). On the other hand, the off-shore discoveries have also spurred the conflict between Lebanon and Israel regarding border demarcation, and involved third parties such as Iran (Shaffer, 2011).

Figure 4-7
**Net energy imports (in Mtoe), Israel 1990–2018**




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

Next to gas, coal imported by the National Coal Supply Company is used for electricity generation (Ministry of Environmental Protection, 2018). Around 78% of fossil fuels have been imported in 2019 (Abu Hamed and Bressler, 2019), while today, a year later, the import share dropped to 65% (IEA, 2020b). According to the Ministry of Environmental Protection (2018), fuel oil decreased from 11% in 2010 to 4% in 2016, while the use of natural gas increased for the same period from 5.4 to 9.66 bn $m^3$. Fig. 4-7 presents data on the historical net energy imports of Israel from 1990–2019 by year. Plotted on the graph, the energy imports peaked in 2012 with 22.4 Mtoe, dropping from then on and reaching 16.3 Mtoe by 2019.

As Israel shifts to become a natural gas exporter, several agreements with various countries are under discussion. Israel signed two agreements:

1. EastMed that aims at bringing together Israel, Greece, Cyprus and Italy in partnership with the EU, and
2. EMGF (East Mediterranean Gas Forum) that represents the Gas Forum of Middle Eastern countries.

The former aims to sponsor and support ambitious and innovative projects of establishing a pipeline that distributes natural gas from Israel via Cyprus and Greece to the EU market. The latter targets the development of the natural gas sector (Ministry of Energy, 2019).

The Israeli Cabinet decided that overall, 40% of the country's reserves can be exported (EIA, 2016). The domestic markets are anticipated to expand and the gas sector in Israel is expected to become a pivotal economic pillar in the short- and mid-term. This presents an obstacle to an energy transition towards a 100%-renewable energy-based system, as this might cause lock-in effects in fossil fuel-based technologies. Regarding the use of fossil fuels, Israel can be classified to be in the first stage of the transition towards a renewable-based energy system according to the applied phase model.

## Infrastructure

Israel shares no electrical transmission connection with its regional neighbours. Therefore, the biggest challenge is that Israel has to integrate electricity stemming from renewable energies into its grid without the option of balancing the fluctuating generation from renewables by electricity imports or exports.

Currently, the Israeli transmission infrastructure consists of 5,661 km of high and ultra-high voltage transmission grid with 11 switching stations and 204 substations. For the distribution sector, 5,661 km of upper and extra-high voltage transmission lines are accounted, 28,689 km medium voltage lines exist, and the low voltage lines make up around 37,981 km that supply around 2.9 million customers directly with electricity. The capacity of distribution power transformers amounts to 25,344 MVA. In 2019, 66% of the generation belonged to the IEC that operates 16 power stations, mostly conventional power plants (Central Bureau of Statistics, 2020). The IEC installed generation capacity accounts for 13.3 GW, while the installed capacity of private generators was 3.4 GW of which 1.4 GW were from renewables in 2018 (ibid.). While the highly urbanised coastal area of northern Israel is connected to 400 kV lines, the remote zones in the south and east are interlinked with 161 kV lines. The average losses (1.7%) weigh 6% for facilities in the transmission network and 1% for facilities in the distribution network by the »ratio« capacities between the transmission and distribution network (Central Bureau of Statistics, 2020).

A reliable and secure transmission system is of paramount importance to the Israeli infrastructure for two reasons: 1) the missing interconnections to its neighbours, and 2) for being a smaller sized country and more sensitive to any potential disturbances (Navon et al., 2020). In this regard, adequacy and security represent the main grid design criteria. While adequacy considers the system to provide secure electricity to consumers, security relates to the survival of electrical failures without any supply interruptions (ibid.). As the most significant solar potential is found in the south of Israel, a primary barrier represents congestion in the transmission system. In the south of Israel, both conventional energy power, mainly in combined-cycle power plants, and renewable energy power, primarily large-scale PV plants, is produced (Navon et al., 2020). As both types of power plants are operated at maximum power for most of the year, the total installed and generated power in the south is higher than the demand, resulting in overloaded power lines that pose a risk to grid stability and cause blackouts. Stemming from this fact, the IEC is reluctant to accept new solar systems until the grid system is upgraded (ibid.). However, an electrical transmission system upgrade is a costly and long-standing procedure.

As Israel is not connected to any regional grid infrastructure, the government aims at connecting its electricity network to the EU in the short-term. In this regard, Israel, Cyprus and Greece have signed a memorandum of understanding to construct an electricity grid being 1,208 km long and operational by end of 2023. Contributing with 647 million Euro, the European Commission has already approved the project in 2016 (ORF, 2021).

Considering that Israel's electrical grid infrastructure is not part of any subregional interconnection plan, the transmission system planning requires strong institutional cooperation within the Israeli network. According to Navon et al. (2020), institutional planning of location and sizing of new solar power plants reduces the reliability risk and enable a prompt growth in solar power use. The upgrade of the network and introduction of smart grids seem a non-trivial short-term solution that needs to be advanced in a timely manner, if Israel wants to reach its 2030 goals.

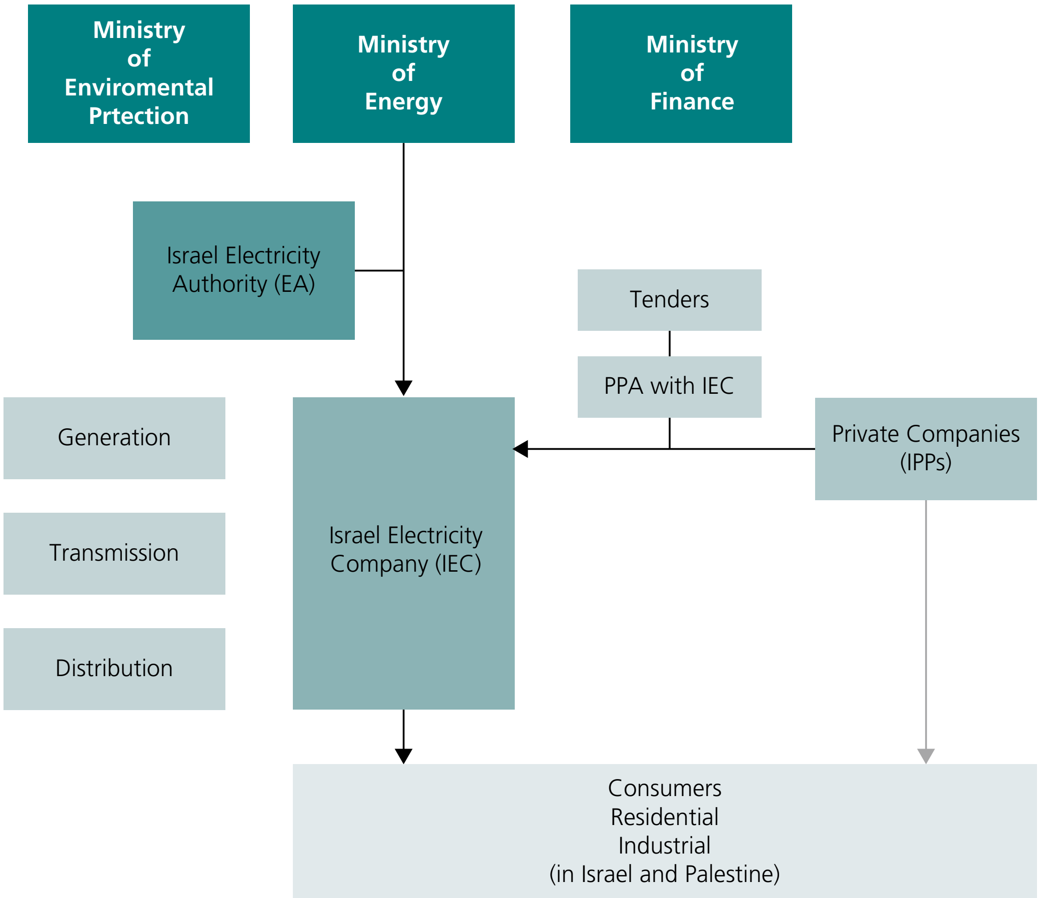
Due to the current status of the infrastructure, especially the electricity network, Israel can be classified as being in the first phase of the energy transition, according to the phase model.

**Institutions and governance**

Besides some momentous changes to reform Israel's electricity market, it structurally remains strongly centralised and vertically integrated. The Ministry of Energy emerged from the former Ministry of National Infrastructure, Energy and Water Resources. As a governmental body, its function is to supervise the energy and natural resources management. The Ministry regulates and manages the electricity supply, liquid fuels, natural gas, water, energy conservation, exploration and production. The main goals on the Ministry's agenda comprise long-term energy policy planning, energy security, stimulation of investments in the private sector, environmental impact mitigation and the development of R&D. The Ministry is structured into several departments, one being the Natural Gas and Oil Department which regulates the exploitation of gas and oil in Israel and actively promotes the Israeli »gas revolution« (Ministry of Energy, 2021).

Formed by the Ministry of Energy, the Israel Electricity Authority (EA) is the regulatory body for electricity services, provision and supervision. The EA sets electricity tariffs, is responsible for the licensing, and defines the criteria for the quality standards (The government of Israel, 2021). The sole electric utility provider in Israel is the IEC – a vertically integrated, centralised and state-owned company that is regulated by the Ministry of Energy and the EA. IEC is responsible for electricity generation, transmission and distribution and supplies the majority of the electricity used in Israel (Ministry of Environmental Protection, 2018; Shaffer, 2011; Teschner et al., 2012). Approximately 2.9 million residential, commercial, agricultural and industrial customers are being served by the IEC, which delivers electricity to East Jerusalem and the Palestinian Authority (PA) as well. Lately, the Israeli electricity market opened up for the private generation sector as a consequence of growing electricity demand. The structural reform that started in 2018 is going to be implemented over the course of 8 years (2018–2026) aiming at decentralising IEC among other goals (US Department of Commerce, 2019). Hence, by 2016, about 20% of the electricity generation capacity could be traced back to private producers (IPPs) and the EA expects that the installed capacity of private producers will increase by 55% until 2025 (Central Bureau of Statistics, 2020). Consequently, the IEC's installed capacity is expected to become smaller in the following years from 13.3 GW in 2018 to an estimated 8.6 GW by 2025, mainly due to selling power stations to private producers as part of the ongoing reform (Central Bureau of Statistics, 2020). This is expected to encourage competition and efficiency and allow IPPs to widen their client-base from high voltage customers to the direct supply of low voltage clients. Tenders based on quotas for renewable energy installations, e.g. solar PV projects, are open to IPPs (Navon et al., 2020). The tenders are promoted by the joint-inter-ministerial tenders committee represented by the Ministry of Finance, the Ministry of Energy and the EA (Ministry of Finance, 2021). IPPs that win a tender, automatically receive a long-term contract of around 25-years in form of a build, operate and transfer (BOT) scheme.

Figure 4-8
**Electricity market structure showing relevant authorities and companiess**




(Source: own creation)

In the light of the gradual IEC reform (separation of the electricity generation, transmission and distribution into three separate companies) that was already passed by law in 2003, the transmission and distribution, as well as the grid management, will continue to remain under IEC's supervision (Meitar, 2018; Shaffer, 2011). This is to guarantee the IEC's financial stability, enabling the company to invest in the transmission and distribution infrastructure, which requires substantial upgrades. Therefore, it is planned that IEC invest approximately 1 bn USD annually over the next years to develop a smart and modern grid (US Department of Commerce, 2019). Fig. 4-8 depicts the institutional setting of the Israeli electricity market.

The institutional framework for the electricity sector is characterised by vertical integration with the IEC covering 80% of the sector's activities. The process of corporatizing the electricity sector has been passed by law. However, delays in the realisation are evident. Private and independent institutions could help to support the transition with different perspectives enriching the transition pathways. As Israel has a short-term plan to further open the electricity market for IPPs and to invest in the grid reinforcement with an additional smart grid vision, the transition of the energy system towards renewables has a chance to become an integral part of Israel's energy development. This reinforces Israel's classification in the phase model as being in the first transition phase, although in a more advanced stage.

### Energy market and economy

According to the EA, the structure of the home tariff can be divided into generation and fuel, transmission, distribution and system operator costs. Comparing the cost structure along three consecutive years of 2017, 2018 and 2019, the evidence shows that the generation component in the home tariff has increased by 7% while the costs for the other components dropped between 1-3% (Central Bureau of Statistics, 2020). The increase in the home tariff occurred at the beginning of 2019, mainly due to the fuel price rise, the changes in the exchange rates and the increase in renewable energy installations (ibid.). Usually, the price is uniform for households or business consumers that pay according to the consumption level. However, there is a rate that depends on the system load rate and usage time that applies occasionally, which takes into account the different seasons and peaks with different prices. As of this system, the summer tariff can vary between 31.59-96.41 Agorot[3] per unit

3 Approximately 0.07-0.24 Euro using the currency converter https://www1.oanda.com/lang/de/currency/converter/

kilowatt-hour, in winter between 33.94-87.59 Agorot[4] per unit kilowatt-hour and in spring and fall between 30.60-43.79 Agorot[5] per unit kilowatt-hour, depending on peak, high and low usage (IEC, 2020b).

Moderate growth in the investments within the transmission and distribution sector is evident over the last years. While the investments in the transmission sector were 0.9 million ILS[6], the investment sum in the distribution sector amounted to 1.5 million ILS[7] for the year 2018. The generation sector includes mainly investments in facilities reducing greenhouse gas emissions to which natural gas utilities account for as well (Central Bureau of Statistics, 2020).

Between 2011 and 2014, the electricity supply was short, leading to high costs for the demand side management, peaking in 2012 with 128 million ILS[8]. With the increase in installed power capacity, the average cost of the demand side arrangements dropped by approximately 58 million ILS[9] in the years 2016 to 2018 (Central Bureau of Statistics, 2020).

With the introduction of the net-metering scheme in 2013, citizens are encouraged to reduce their electricity consumption or reduce their electricity bill by installing private renewable energy systems. This arrangement allows customers to subtract the produced electricity from the bill and balance the production surpluses with the consumption surpluses (Public Utility Authority, 2012).

The investments in demand-side management and, in particular, the net-metering system show the willingness of Israel's EA to shift towards a renewable energy system. Moving into a market where the consumer can actively participate in the renewable electricity production and have an active part in energy efficiency measures, underline Israel's advances in the first phase of the energy transition, according to the applied phase model. First developments relevant to the second phase of the energy transition phase model are already visible in Israel.

**Greenhouse gas emissions**

Moving towards its commitment to mitigate climate change, Israel has significantly reduced its GHG emissions. While in 2016, the reduction of GHG amounted to 6.2 million tonnes, in 2017, the reductions accounted for 7.6 million tonnes (Ministry of Environmental Protection, 2019b). In 2018, the $CO_2$ emissions were 58 Mt $CO_2$, representing an absolute decrease of 20% relative to 2012, the peak emissions year (Fig. 4-9). Due to a natural gas supply shortage in 2012, the emissions and the use of more GHG intensive fossil fuels for power generation peaked in this particular year. Once the natural gas supply resumed in 2013, emissions started to decline (Ministry of Environmental Protection, 2018). Over 50% of the emitted $CO_2$ can be traced back to the electricity and heat sector, while the transport sector stands in second place of the most significant $CO_2$ emitters, followed by the industry sector. Out of 34 Mt $CO_2$ emissions from electricity and heat generation, 54% are caused by coal, 45% by gas and 1% by oil which is graphically presented for the year 2018 in Fig. 4-10. In general, the emissions intensity has shown an overall declining trend both in $CO_2$ emission per unit of GDP and $CO_2$ emission per capita (Table 4-2).

Israel developed a national monitoring, reporting and verification (MRV) system to facilitate the mitigation progress, the measurement of GHG-reduction policy effectiveness, revisions and the public availability of reports (Ministry of Environmental Protection, 2020). This monitoring system is a substantial move to concretise the Paris goals. In its National Determined Contributions (NDCs), Israel has set an economy-wide unconditional target to reduce the GHG emissions to 7.7 tonnes $CO_2$ per capita by 2030, representing a 26% reduction relative to 2005 emissions of 10.4 tonnes $CO_2$ (ibid.). The government aims to reach an interim target of 8.8 tonnes $CO_2$ per capita by 2025, which equals an expected reduction of in total 86.6 Mt $CO_2$. Significant reduction was already achieved after the shutting down of the coal-fired units 1-4 in the Orot Rabin power stations which represent a total capacity of 1,440 MW and 30% of the Israeli coal power generation capacity (Ministry of Environmental Protection, 2018, 2019b).

Thus, Israel's emissions are decreasing mainly due to the shift of fuel sources in the power generation sector, growing demand for solar energy, and new natural gas power installations that can potentially reverse the emission trend. With the MRV system, the government sends the adequate signs to move towards an emission reduced energy system, being consistent with the Paris Agreement. This supports Israel's classification as being in an advanced stage of the first energy transition phase in the applied phase model.

**Energy efficiency**

In the frame of the Paris Agreement, the Israeli government has approved the National Plan to Reduce Greenhouse Gas Emission and Increase Energy Efficiency that dictates sector-specific targets to increase energy efficiency by 2030. The specific targets for 2030 include (Ministry of Environmental Protection, 2018; Spyridonidou et al., 2021):

1. 17% reduction in electricity consumption
2. 30% renewable energy share in the electricity mix
3. 20% reduction of travelled kilometres by private vehicles.

4 Approximately 0.08-0.22 Euro using the currency converter https://www1.oanda.com/lang/de/currency/converter/

5 Approximately 0.07-0.10 Euro using the currency converter https://www1.oanda.com/lang/de/currency/converter/

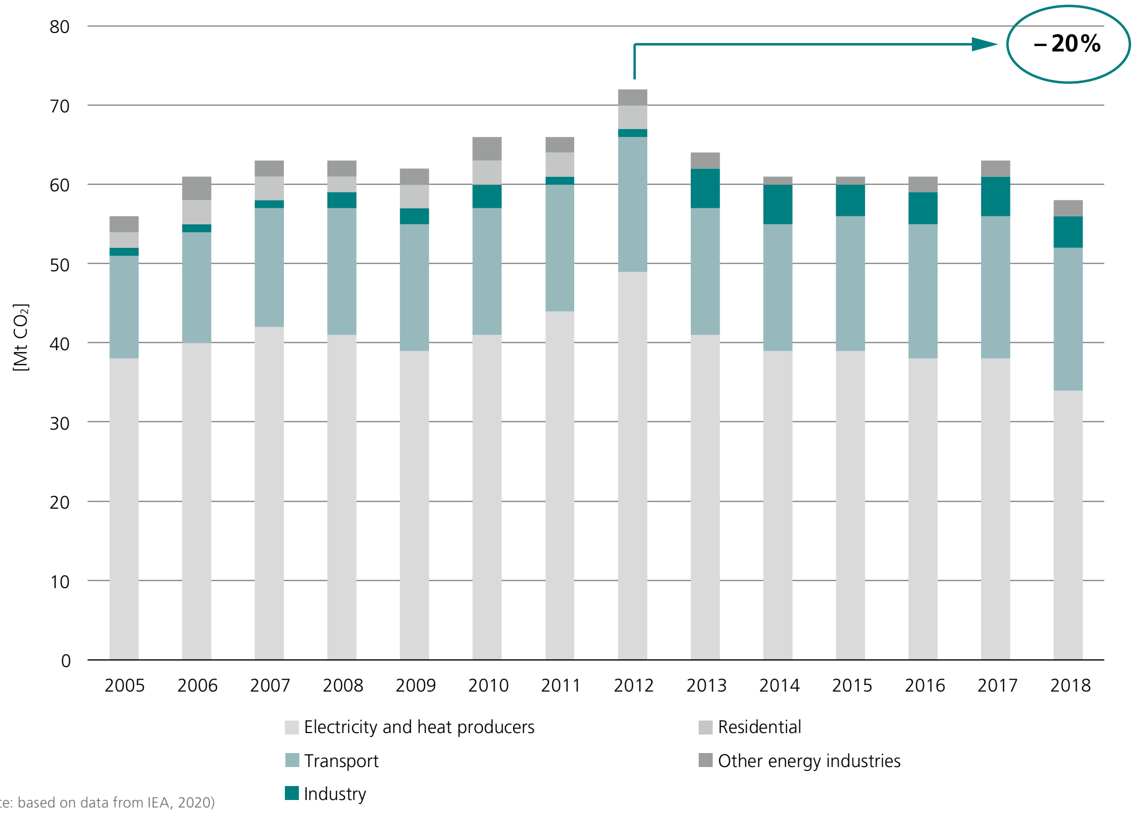
6 Approximately 0.25 million Euro using the currency converter https://www1.oanda.com/lang/de/currency/converter/

7 Approximately 0.37 million Euro using the currency converter https://www1.oanda.com/lang/de/currency/converter/

8 Approximately 32 million Euro using the currency converter https://www1.oanda.com/lang/de/currency/converter/

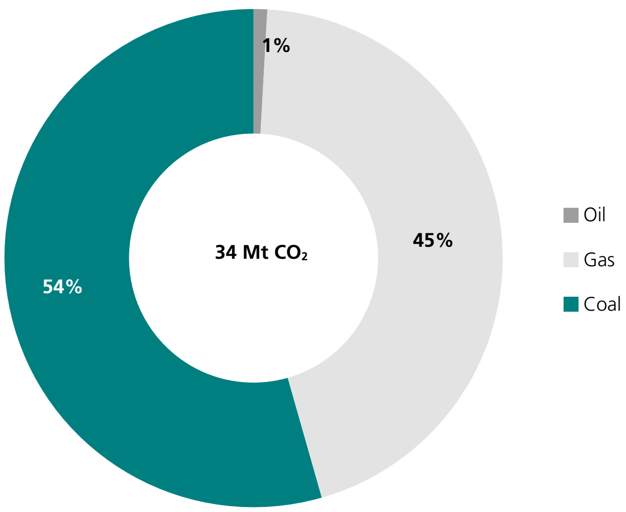
9 Approximately 15 million Euro using the currency converter https://www1.oanda.com/lang/de/currency/converter/

Figure 4-9
**$CO_2$ emissions by sectors (in Mt $CO_2$), Israel 2005–2018**




(Source: based on data from IEA, 2020)

Figure 4-10
**$CO_2$ emissions from electricity and heat generation by energy source (in Mt $CO_2$), Israel 2018**




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

To achieve these energy efficiency goals and the GHG emission reduction, the government has awarded projects worth 190 million NIS[10] (Ministry of Environmental Protection, 2018). Within the national plan, the conversion from old oil-based power plants into gas-fueled energy power plants, and the installation of new cogeneration power plants with the aim to increase efficiency up to 80%, are part of the government's endeavour.

The Ministry of National Infrastructure has developed various regulations to encourage the efficient use of energy. For example, it has established an energy standard for the fuel-fed water-heating boiler that specifies the maximum combustion energy input used in a water-heating boiler or has implemented the energy efficiency level standard in the electrical generator engines. Regarding standards and labelling, the Ministry of Industry Trade and Labor is officially responsible for implementing mandatory energy standards and labelling. In this regard, mandatory labelling and energy performance classification are required for devices, such as refrigerators, freezers, heaters and air-conditioning appliances. In 2005, a new voluntary green building standard was introduced that includes a directive of building materials, building design, internal infrastructure and technology used (among others) with the aim of constructing energy-efficient buildings.

The Israeli government is at an advanced stage of recognising energy efficiency efforts as an essential pillar for the energy transition. A fundamental requirement for achieving a smooth energy transition is the implementation of constantly updated energy efficiency measures. The evidence supports the assumption that Israel is moving ahead with its energy efficiency plans, showing that the country is in an advanced stage of the first transition phase, according to the applied phase model.

**Society**

In Israel, energy campaigns or energy efficiency topics in educational programmes do not enjoy a high priority. However, the IEC distributes some information on energy conservation to its customers with the bills. Yet, the awareness of environmental, energy systems transition and energy efficiency topics among the Israeli society is still moderate to high. Compared to energy conservation issues, water topics are more present among the public. Water-saving devices are regularly installed in public and private places and various policies are implemented to promote water conservation, so that the awareness of water conservation is even higher.

According to a survey conducted by the Arava Institute for Environmental Studies, 45% of the Israeli public believe that climate change impacts their lives, while 15% believe that climate change has no impact on their lives in the short term.

The survey also indicates that solar and wind energy are the most known renewable energy sources in Israel. 52% of the surveyed people consider themselves very aware of the pros and cons of solar energy. This may be attributed to the large-scale use of solar water heaters in the country. However, the survey shows a very low level of public awareness regarding Israeli policies on climate change and renewable energy goals: only 15% of the public is aware of these policies and goals and only 8% of the public is familiar with the regulations and standards for renewable energy. However, one-third of the surveyed public believe that they can influence the decision-making processes regarding state policies and goals for renewable energy and climate change. This data is the result of an unpublished survey with 1,500 samples commissioned by the Arava Institute for Environmental Studies and carried out in March 2021.

Noel and Sovacool (2016) indicated that Israel has an active environmental community with more than a hundred active and legally registered non-governmental organisations (NGOs). This community emerged as a response to the severe threat of energy security and the effects for the people. Despite a general moderate to high awareness, little action can be conceived that has been taken to conserve the environment (Noel and Sovacool, 2016). Most of the citizens may not »connect the dots« of energy security implications and environmental impacts of their energy usage, leading to only passive participation in these matters (ibid.). Another study carried out by DiPersio et al. (2021), comes to the conclusion that in the southern region of Arava, communities are quite open to renewables, in particular solar energy technology as it adds to energy independence.

Some other authors, such as Michaels et al. (2016) claim that Israelis have, in general, little interest in experiments to facilitate load shifting by e.g. remote controlled household appliances. As a matter of weak trust in remote institutions and privacy concerns, most people show very little interest in these technologies, according to the survey in the study (Michaels & Parag, 2016). The same study concludes that smart meters are also not well perceived by the population. However, the authors indicate that behind this hidden message might stand a broader mistrust of governmental institutions. Although the public generally shares a more pro-novel technology attitude, this lack of confidence may also be derived from little promotion and communication regarding smart meters. According to the authors, a »collective effort« could be a more convincing approach to reach the people.

The Israeli government promotes energy related research and development by offering research grants, funding in new policy research and expert advice. Transferring innovative technologies is rooted in Israel's well-established scientific community that is concentrated in the private sector's high-tech industry and in the diverse research institutions. Several institutes are concentrated on renewable energy research, e.g., the Weizmann Institute of Science for solar energy or the Technion Israel Institute of Technology.

**10** around 47.5 million Euro using the currency converter https://www1.oanda.com/lang/de/currency/converter/

Regarding platforms that offer dialogue formats to promote the energy transition, several organisations in Israel exist that follow this purpose, e.g., the Israel Energy Forum, Israel Smart Energy Association, Green Energy Association of Israel, Heschel Center, Life and Environment, Ignite the Spark among others. These associations support the dialogue by organising events, meet-ups, reporting and advocating with governmental bodies. One successful bottom-up initiative has emerged out of the representative work of an NGO, the »Israel 2050« programme, which envisions strategic goals to be reached by 2050 in the different sectors of transportation, energy, buildings and urban planning, industrial trade, and waste (Ministry of Environmental Protection, 2019a).

To summarize, Israeli society is already aware of environmental issues, which is a paramount requirement for succeeding in the energy transition. Regarding energy topics, it seems that more campaigns could support the wider uptake of energy efficiency and conservation measures. Hence, according to the phase model, Israel's classification in the first phase is also validated for the social dimension.

**Summary of the landscape and system level developments**

On the landscape level, the natural gas field discoveries around the 2010s are expected to affect the energy transition at least in the short term, but potentially also in the long term. It can be assumed that the focus on the exploitation of natural gas resources has slowed down the development of renewable energy projects. Israel's energy security has taken precedence over environmental concerns.

In addition to this, the COVID-19 pandemic is having a significant impact on the energy sector in general and the electricity sector in particular. Evidence shows that the pandemic outbreak has led to decreased energy consumption. The extent of the decline varies according to the type of fuel and sector. Time will tell to what extent the effects of the pandemic will only have a short-term impact or will also have a direct or indirect effect on the energy transition in the long-term.

Furthermore, some technical and regulatory challenges are impacting the energy transition at the system level. Not being connected to the energy infrastructures of neighbouring countries represents a challenging starting point to integrate a large share of renewables. Commonly with many MENA countries, the energy sector is characterised by a single buyer market, with the IEC having a monopoly with regard to power generation, transmission and distribution. Though the legal framework is set to restructure the market, progress is very slow.

In summary, several factors can be identified at the system level that currently challenge Israel's progress in the energy transition: the tense regional and geopolitical situation resulting in serious energy security issues, the current pandemic, the institutional set-up, and a lack of social willingness to change the energy use behaviour – all hamper Israel's ability to reach its transition goals. Moreover, renewables are not currently replacing the use of fossil fuels. On the contrary, natural gas is being expanded, which is likely to create future technological lock-ins. On the other hand, with the introduction of the PIRES in 2010, which creates the legal basis for a renewable energy tariff and tax benefits, Israel has shown the political will to increase the use of renewable energy. This represented a milestone to diversify the energy system. Accordingly, Israel can be classified as being in the first phase of the energy transition model. In some areas it is already in an advanced state; in others additional efforts will be required to move towards phase two according to the applied phase model. The following table (Table 4-2) summarises important energy transition indicators in Israel and compares them across years.

### 4.1.2 Assessment of trends and developments at the niche level

Developments at the niche level during each phase are crucial for reaching the subsequent stages of the energy transition (see Table ↑ 3-1). Israel has already made moderate progress in some aforementioned dimensions: the access to small-scale solar PV utilities, energy efficiency, investigating and testing flexibility options, supporting programmes towards e-mobility, and initiating the R&D sector on hydrogen and power-to-X. The following section describes these developments at the niche level in detail.

**■ E-Mobility**

In order to reduce vehicular pollution, Israel aims at substantially increasing the electric vehicle (EV) share in the country. For instance, the »Fuel Choices and Smart Mobility Initiative« has been launched in 2011 to promote Israel's national programme for fuel alternatives and smart mobility (Fuel Choices Initiative, 2021). It represents a joint effort of ten government ministries and brings together governmental bodies, research institutions and commercial companies to create regulatory stability and an investment horizon for market stakeholders. In 2016, the Ministry of Environmental Protection (MoEP) and Jewish National Fund (JNF) introduced a support scheme to set up car-sharing projects in local communities. For this purpose, 220 million NIS[11] were mobilised. Israel pledges to allow only electric passenger cars to be sold by 2030 (REN21, 2019). In order to promote e-mobility, the Ministry of Energy has elaborated the following targets and steps until 2030:

1. all private vehicles will be 100% electric,
2. vehicles up to 3.5 tons: 20% compressed natural gas (CNG) and 80% electric,
3. trucks over 3.5 tons: 60% CNG and 40% electric, and
4. busses: 25% CNG and 75% electric.

11 Approximately 55.35 million Euro using the currency converter https://www1.oanda.com/lang/de/currency/converter/

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 | –21% | –22% | –36% | N/A | N/A | – | – |
| | $CO_2$ emissions per capita | +21% | +29% | +9% | –4% | N/A | –26% of GHG emission (from 2005) | |
| **Renewable Energy** | Installed and planned capacity (MW) | N/A | 99 | 813 | 1,138 | 1,500 (2019) | 5.4 GW | – |
| | Share in final energy use | 4% | 5% | 2.3% | 2.4% | 2.8 (2019) | N/A | – |
| | Share in electricity mix (existing and planned) | 0.08% | 0.34% | 2% | 3% | 10 | 30% | – |
| **Efficiency (Compared to 1990)** | Total primary energy supply (TPES) (compared to 1990) | +60.9% | +101.7% | +89.6% | +93.9% | N/A | – | – |
| | Energy intensity of primary energy (compared to 1990) | –18.8% | –17.4% | –31% | N/A | N/A | – | – |
| | Total energy supply (TES) per capita (compared to 1990) | +8% | +20% | +4% | 0% | N/A | – | – |
| | Electricity consumption per capita (compared to 1990) | +54.8% | +66.7% | +61.9% | +61.9% | N/A | – | – |
| | Residential final electricity consumption (compared to 2005) | +158.2% | +187.7% | +231.3% | +248.6% | N/A | – | – |
| **Buildings** | Total final energy consumption | +66.9% | +103.4% | +110% | +124% | N/A | – | – |
| **Transport (Compared to 1990)** | $CO_2$ emissions in transport sector | +62.5% | +100% | +112.5% | +125% | N/A | – | – |
| | Number of e-vehicles | N/A | N/A | N/A | less than 1,000 EV, around 100,000 hybrid cars (2009) | | – | – |
| **Industry** | Carbon intensity of industry consumption (compared to 1990) | –70.9% | –33.8% | –30.4% | –34% | N/A | – | – |
| | Value added (share of GDP) | 21.5% | 21.1% | 20.2% | 19.4% | N/A | – | – |
| **Supply Security** | Natural gas imports (compared to 2010) | N/A | 0 | –94.6% | –72.6% | N/A | – | – |
| | Oil products imports (compared to 1990) | +92.3% | +51.4% | +0.9% | +24% | N/A | – | – |
| | Electricity exports (compared to 1990) | +266.7% | +774.4% | +1,046.2% | +1,192.3% | N/A | – | – |
| | Electricity access by urban population proportion | 99.9% | 99.7% | 99.9% | 100% | N/A | – | – |
| | Coal consumption (compared to 2010) | N/A | N/A | –99.7% | –99.8% | N/A | – | – |
| | Gas reserves (compared to 2009) | N/A | N/A | +300% | +400% | N/A | – | – |
| **Investments** | Decarbonisation investments (million USD) | N/A | N/A | 425,806 | 157,206 (2015) | N/A | – | – |
| **Socio-economy** | Population (2019) | | | | 8,882,000 | – | – | |
| | Population growth | 1.7% | 1.8% | 2% | 1.9% | N/A | – | – |
| | Urbanisation rate | 91.5% | 91.8% | 92.1% | 92.3% (2017) | N/A | – | – |
| | GDP growth | 3.9% | 5.6% | 2.3% | 3.5% | N/A | – | – |
| **Water** | Level of water stress (compared to 2005) | 0% | –4.7% | –18.5% | N/A | N/A | – | – |

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

As part of the governmental effort, the following targets are planned to promote electric transportation with taxation incentive:

Table 4-3
**Electric transportation targets**

| Year | 2019 | 2020 | 2021 | 2022 | 2023 | 2024 |
|---|---|---|---|---|---|---|
| Full electric | 10% | 10% | 10% | 10% | 20% | 35% |
| Plug-in | 20% | 25% | 30% | 40% | 55% | 83% |
| Hybrid | 30% | 45% | 50% | 83% | 83% | 83% |

*(Source: Israel Government, 2019)*

Owing to low electricity prices, short driving distances and the possibility of self-generating energy, the conditions for promoting EVs are advantageous. Around 29 million ILS[12] in grants have been awarded to around 30 local authorities and over 15 charging and fuel companies and vehicle importers to promote electric mobility (Gutman, 2019; Ministry of Energy, 2019). Financed by the Ministry of Energy, currently 2,500 charging stations are installed within Israel (Ministry of Energy, 2018). However, the implementation is rather slow as a study by the Ministry of Energy reveals. Most citizens are put off by the poor infrastructure of charging stations which mainly hampers the acquisition of EVs (Noel and Sovacool, 2016).

Besides the EV promotion, the government has established a methanol blending standard. According to IRENA (2021), an M15 standard was introduced in 2016. Methanol can reduce emissions (compared to gasoline) and is a biodegradable fuel. Typically produced from natural gas or coal, methanol can also be produced »green« by biomass or when renewable electricity serves as input. The use of methanol as fuel in Israel is however, highly limited (ibid.).

## Demand-side management (DSM)

The use of smart meters, smart appliances that can be operated automatically or remotely, or EV batteries for storage options are currently tested in Israel as a form of demand-side management (Michaels and Parag, 2016). Not being connected to neighbouring electricity networks, Israel's electricity system cannot be backed up through regional electricity imports and exports. Accordingly, the electricity sector in Israel is designed to secure electricity demand at any given moment, today mainly through flexible natural gas power plants. The electricity consumption is characterised by a great amount of volatility either during the day or between seasons, and the peak hours of demand account for only about 3% of the total hours of demand per year. The power system is capable of producing electricity at twice the output of the average annual consumption of electricity. To optimise consumption and reduce the investment in expensive ramping-up production, Israel is experimenting with demand-side management policies. IEC has published a tender to replace the regular meters with smart meters across Israel. Since those DSM technologies are not widely implemented, the public is not familiar with them; hence, misconceptions and mistrust prevail. For instance, it seems odd that remote third parties control household electricity usage in Israel. Also, several health concerns regarding smart meters have been raised (Michaels and Parag, 2016).

## Power-to-X and hydrogen

The main driver in the field of power-to-X (PtX) is the private sector, as the government only supports R&D. Several institutions research the field of fuel cells, such as the Israel National Research Center for Electrochemical Propulsion or the Israeli Center for Research Excellence (I-CORE) – Renewable Liquid Fuels. Several startups in this field are also in place, such as Gencell, PO-CellTech, Electriq Global. Others are also dedicated to hydrogen, such as $H_2$Pro, $H_2$ Energy Now, NrgStorEdge, New$CO_2$Fuels or Edrei Bio Hydrogen. Additionally, most of the main Israeli oil companies are exploring hydrogen options. For example, Sonol (Oil Company) plans to set up the first hydrogen refuelling station in the Haifa region within the next three years; Paz (Oil Company) is investing in fuel cell companies; the Bazan Oil Refineries has established an innovation centre and has shares in the hydrogen company $H_2$PRO. The national company Petroleum & Energy Infrastructures Ltd. (PEI), which is responsible for Israel's fuel infrastructure, is working on a strategy for large-scale hydrogen storage. The government has awarded in total 5.7 million ILS[13] to 11 startup projects and 22.3 million ILS[14] to 17 pioneer and demonstration projects in the fields of electricity, storage, renewable energy, fuel substitutes for transportation, energy efficiency, environment etc. Among the projects that were funded in 2019, the following selected projects have been established or are under development: the first hydrogen gas station, a fuel cell-based drone, a natural gas trading scene, a compressed air tank energy storage system, the development of hydrogen fuel carrier and more (Ministry of Energy, 2019).

The PtX sector in Israel is currently being studied, and one study from Bogdanov and Breyer (2015) that analyses the optimal set of technologies according to the available resources in Israel comes to the conclusion that power-to-gas technologies and gas storages are only feasible above a share of 85% renewables. To sum up, the PtX sector is lately receiving more and more attention. However, the PtX market in Israel, as well as worldwide, is still immature.

## Carbon capture and storage

No carbon capture and storage (CCS) technologies are currently in place, but CCS is being studied. As of 2013, Calvo and Brayer Gvirtzman (2013) have studied the saline aquifers within the geological section in the northern Negev region of Israel in order to calculate and map the total $CO_2$

12 Approximately 7.24 million Euro using the currency converter https://www1.oanda.com/lang/de/currency/converter/

13 Approximately 1.4 million Euro using the currency converter https://www1.oanda.com/lang/de/currency/converter/

14 Approximately 5.5 million Euro using the currency converter https://www1.oanda.com/lang/de/currency/converter/

storage capacity. The study concludes that a large capacity for $CO_2$ storage is available that could be sustained economically (ibid.).

**Storage**

When the percentage of renewables increases, Israel should be prepared to balance the supply and demand. Storage solutions play, therefore, a critical role. To reach 30% of renewables by 2030, Israel may require around 8 GWh of energy storage (Colthorpe, 2020). To increase Israel's storage options, a pumped storage quota of 800 MW has been approved that is divided between four projects: Gilboa (already implemented), Nesher, Jordan Star and Menara. Other storage options are represented, for instance, by Augwind, an Israeli air compressor and energy storage company that has set up a pilot system in the Negev desert with a storage capacity of 120 MWh alongside a 5 MW solar energy facility (Willuhn, 2021). Additionally, Chakratec, an Israeli company in the field of smart storage, provides solutions to deploy fast-charging stations by implementing fast-rotating flywheels and facilitating, hence, high power charges for EVs.

**Information and communication technology**

A pilot to use smart electronic meters has been launched by the IEC to manage the grid efficiently. The IEC is in charge of applying information and communication technology (ICT) in the power sector and it has installed advanced control and supervision systems in the transmission and distribution segments of the grid. Measuring the actual consumption, the meters transmit real-time data to the control system to better control and keep the users informed about the consumption. IEC has published a tender to replace regular meters with smart meters country-wide.

**Agrivoltaics**

Given the limited land availability and growing energy demand in Israel, the possibility of combining PV and agriculture represents a potential solution. The Ministry of Energy and the Ministry of Agriculture have launched a pilot research programme to assess the feasibility of agrivoltaic projects (Bellini, 2021b). As around 20% of the territory is arable land, agricultural practices, such as open fields and greenhouses, are being tested to integrate solar power generation. The ministries have awarded around 3.5 million ILS[15] to six different studies to explore various combinations of agriculture and solar power generation to avoid potential conflicts.

### 4.1.3 Necessary steps to move on to the next phase

Israel's power sector is considered to be a conventional power system where the supply-side assets are used as the primary source of flexibility. With the planned growing share of renewables in Israel's energy system, Israel should be prepared to balance the supply and demand side. To achieve this, flexibility options have to be harnessed in all parts of the energy system, such as the generation, transmission and distribution sectors, and adequate storage systems.

A smooth transition requires sector coupling between all end-user sectors. However, most of the current energy transition debates in Israel have so far been limited mainly to the power sector. The heating, cooling, transportation, and industrial sectors« energy transition does not yet receive sufficient attention. Implementing sector-specific targets that are updated on a regular basis according to their development can facilitate the integration of variable renewable energies in all sectors. Next to specific targets, policies that regulate the decarbonisation of the different sectors and not just the power sector could further support between power and end-use sectors.

Equally important is the step to turn consumers into energy producers, so-called prosumers, which can support grid resilience. The exploration of new business models along »prosuming« services to the grid, such as micro-generation, smart-metering, demand reduction, load shifting, EVs with a vehicle-to-grid connection and energy storage, offer promising solutions to engage consumers in balancing the grid (Michaels and Parag, 2016). The development of smart grids could eventually enable prosumers to sell their excess electricity to other consumers across the grid. This can improve energy security and make it easier to integrate renewable energies into the energy system.

The upgrade of the grid infrastructure is critical to enable the integration of a large volume of renewables and to guarantee a reliable energy supply over the long-term. Israel's most significant solar potential is in the south, while the major load centres are located in the north and coastal area. The connection with a robust transmission network and interconnections is of utmost importance to allow optimal electricity generation and dispatch. The expansion of transmission capacities is also a signal that can strengthen the confidence of investors in renewable energies. Although regional instability plays a crucial role in increasing renewables in the electricity sector, the latest Abraham Accords may open new partnership options to export renewable electricity or »green« energy carriers, such as green hydrogen.

The current tax framework needs to be reconsidered, as it supports polluting fuels. Industrial companies that use fossil fuels can write off the costs as expenses and thus reduce their tax liability (Grossman, 2016). As a result, solar energy is less attractive, and fossil fuels continue to be used instead. The tax regimes should be revised, introducing tax incentives for the use of renewables rather than fossil fuels.

A successful energy transition also requires the participation of citizens. The energy transition towards 100% renewable energy is a disruptive process, in the energy sector and all other areas of the economy, but also in everyday life. This requires understanding and support from the government,

15 Approximately 0.88 million Euro using the currency converter https://www1.oanda.com/lang/de/currency/converter/

but above all from society. Although the Israeli society is very aware of innovative technologies, there is still a lack of awareness regarding their own energy consumption. Furthermore, it is evident that among local authorities, expertise is at least partly lacking. Developing education and training to minimise skills gaps and to open trust in, for example, DSM-technologies can support the wider implementation of renewables.

A robust institutional and regulatory framework with greater financial viability is key to a more open and competitive power market. The current institutional architecture of the monopolistic electricity market limits the marketability to cope effectively with more complex structures. Today, most decisions concerning the energy sector are made within the IEC and suffer from a lack of interministerial coordination. As IPPs and decentralised power generation become significant, the establishment of independent regulatory bodies could help to better reflect the interests of a broader stakeholder community. The role of the IEC, therefore, needs to be revised. The IEC or a new independent regulatory body should become responsible for the monitoring and evaluation of the sector's performance. Improving the sector's commercial performance can reduce inefficiencies and will help to attract private sector development and growth in Israel's energy market.

The expansion of renewable energies can make an essential contribution to increasing energy security in Israel. However, although Israel has set a target of 30% renewables in the power sector by 2030 and decision-makers and relevant stakeholders strongly support the energy transition, natural gas is expected to continue to play a crucial role. This support for natural gas has slowed down the development and implementation of renewable energy projects (Willner, 2014). Also, there is no clear implementation plan for renewable energy and the public is not sufficiently informed about the benefits. Therefore, if Israel wants to move towards a renewable energy-based energy system, it would need to develop and implement an overall strategy, including a possible shift away from gas in the more distant future.

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

The analysis carried out provides ample evidence that Israel is on the path towards a renewable energy transition. After undergoing two major energy transitions – the oil crisis in 1973 when Israel replaced the oil with coal as a primary source of electricity generation, and the disruption of natural gas supply from Egypt in the early 2000s – the current transition started with small steps and has so far mainly taken place in the area of solar energy.

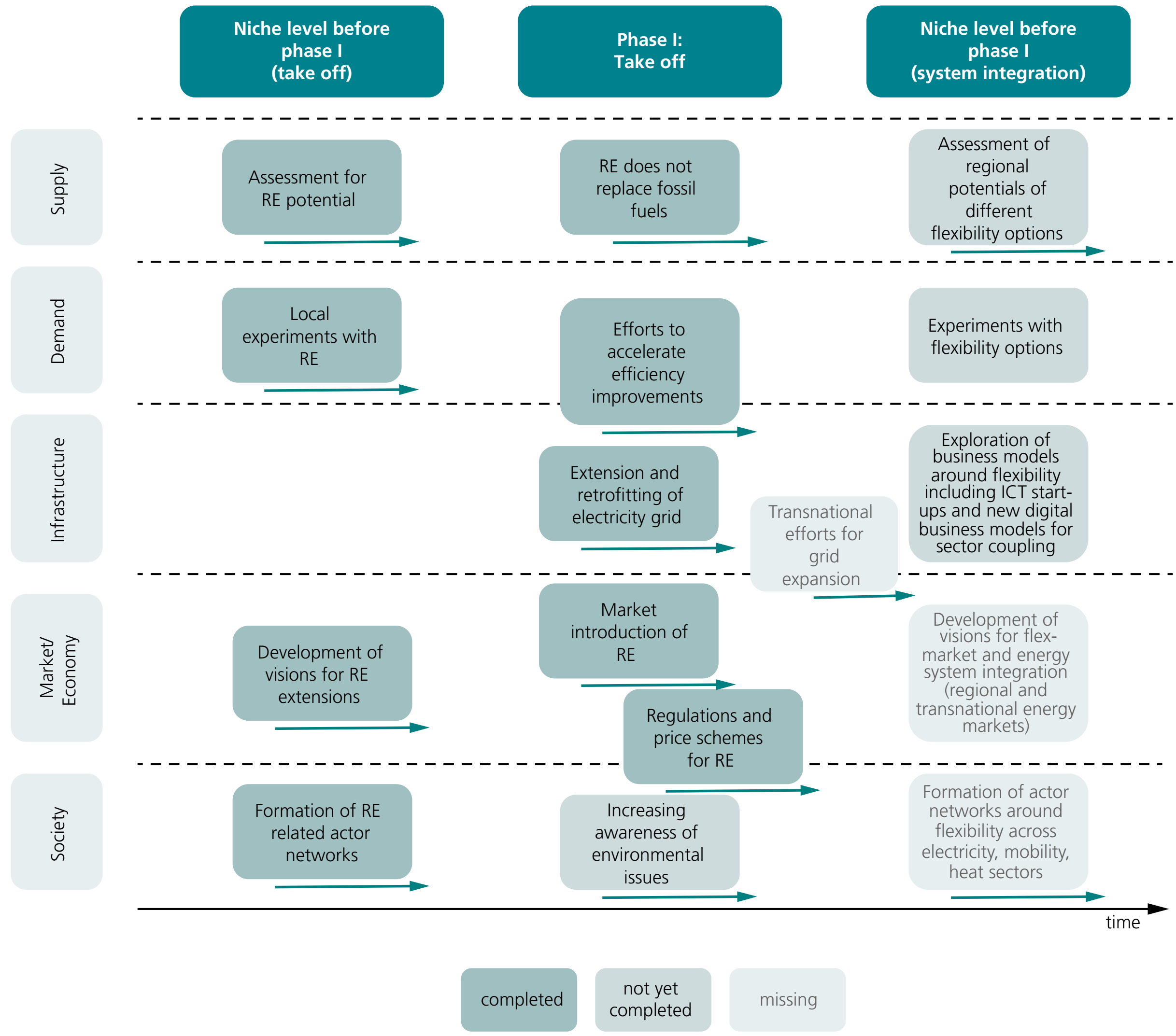
Many laws, regulations, directives, and legal instruments have been established to regulate energy policy in Israel. For the development of the renewable sector, the most prominent law is Article 9 of the Law for Planning and Building (1970), which dictates to utilise solar energy (in the form of solar water heating systems) in the residential sector since 1980. This law has contributed to Israel being a pioneer in the development of solar technology. However, the requirement for solar energy use is so far limited to the residential sector. The use of solar energy in the industrial and commercial sectors is not yet sufficiently regulated. An appropriate framework needs to be created to increase the use of solar energy in these sectors. Especially in a country like Israel, which has such a large solar energy potential, the use of solar energy in industrial processes should be promoted, for example through process heat from renewable energies.

The PIRES plan from 2010 has not been updated yet. But in 2018, Minister of Energy Yuval Steinitz launched a plan to transform the Israeli energy sector by 2030 in order to »rescue Israel from polluting energy« and to cease the use of coal in the electricity generation sector until 2026 (Ministry of Energy, 2021). However, this plan falls short in terms of the concrete implementation of renewable energies and has envisaged a share of 80% natural gas and 20% renewable energies in the electricity sector, which has since been changed to 70% natural gas and 30% renewable energies. These targets signify that natural gas is considered a priority by the Israeli government (Surkes and Staff, 2020). Significant investments are, therefore, directed towards gas infrastructures instead of the renewable energy sector. In light of the global decarbonisation efforts, this bears the risk of technological lock-in effects and stranded investments. On the other hand, diversifying Israel's energy mix would be beneficial in terms of reducing greenhouse gas emissions and increasing energy security.

The transition of the Israeli energy system to a carbon-neutral energy system will require considerable investments in technology development and deployment as well as in infrastructure. In order to make progress in this direction, it is essential to already prepare today for the next steps in the energy transition, which are defined as phases two and three in the applied phase model. This includes, for example, placing a stronger focus on flexibility options, discussing the long-term role of natural gas, increasing participation and awareness among the population and exploring the future role of PtX in the energy system. Furthermore, elaborating a long-term policy vision in combination with a strategic plan can increase the confidence and trust among stakeholders to support and participate in this development.

The phase model analyses could be the starting point for the discussion and development of such a long-term strategy that takes into account the entire energy system and its transition to a fully renewable energy-based system. Fig. 4-11 summarises Israel's status in the energy system transition and provides an outlook for future steps.

Figure 4-11
**Overview of Israel's status in the energy system transition model**




(Source: data based on IEA, 2020a)

# 5

# CONCLUSIONS AND OUTLOOK

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

The model, which includes four phases (»Take-off RE«, »System Integration«, »Power-to-Fuel/Gas«, and »Towards 100% Renewable'), was applied to analyse and determine where Israel stands in terms of its energy transition towards renewables, and to provide a roadmap detailing the steps needed to move forward on this pathway. The insights from the analysis and expert interviews allow for a deeper and more detailed understanding of the Israeli case. With its abundant renewables potential, Israel has excellent preconditions to embark on the pathway towards a 100% renewable energy system, in particular wind and solar. However, Israel is also expanding its natural gas production and investing massively in this infrastructure. While this may seem beneficial in the short-term to meet the country's growing energy demand and generate revenue from potentially exporting natural gas, this pathway could result in technological lock-ins and stranded investments. The world is aiming for carbon neutrality by 2050, which will reduce the demand for fossil fuels, and financing institutions are increasingly considering the climate risks of their investments, which is decreasing the availability of capital for conventional resource exploitations. A stronger emphasis on renewable energy could also help to reduce import dependencies. Moreover, this would help to enhance energy security as the most essential pillar of Israel's energy policy.

To move forward in this direction, renewables must become an integral part of the energy system. This requires the support and implementation of flexibility options, ranging from tariff adaptations and tax revisions to grid upgrades and interconnections. Additionally, it will be critical to increase the participation of the private sector and the general population in the energy transition. To gain broader political support, the energy transition must be recognised by decision-makers as a long-term opportunity to increase energy security and foster economic and social development.

While Israel has made progress in the energy transition, and renewable energy is in a later stage of the take-off phase, increased efforts are required if the country wants to proceed with the transition towards a fully renewables-based system. The results of the analysis along the transition phase model towards 100% renewable energy are intended to stimulate and support the discussion on Israel's future energy system by providing an overarching guiding vision for energy transition and the development of appropriate policies.

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## LIST OF ABBREVIATIONS

| | |
|---|---|
| bn | Billion |
| BOT | Build, operate and transfer scheme |
| CCS | Carbon capture and storage |
| CCU | Carbon capture and use |
| COVID-19 | Coronavirus disease 2019 |
| CSP | Concentrated solar power |
| DSM | Demand-side management |
| EA | Israel Electricity Authority |
| EIB | European Investment Bank |
| EMGF | East Mediterranean Gas Forum |
| EU | European Union |
| EV | Electrical Vehicle |
| FiT | Feed-in tariff |
| GDP | Gross Domestic Product |
| GHG | Greenhouse gas |
| ICT | Information and communication technologies |
| IEA | International Energy Agency |
| IEC | Israel Electric Corporation |
| IPP | Independent Power Producer |
| IRENA | International Renewable Energy Agency |
| JNF | Jewish National Fund |
| LNG | Liquefied natural gas |
| MENA | Middle East and North Africa |
| MLP | Multi-level perspective |
| MoEP | Ministry of Environmental Protection |
| MRV | Monitoring, reporting and verification system |
| NDC | Nationally Determined Contributions |
| NGO | Non-governmental organisation |
| NIS/ILS | New Israeli Shekel |
| OPIC | Overseas Private Investment Corporation |
| PA | Palestinian Authority |
| PAU | Public Authority Utility |
| PIRES | Policy on the integration of renewable energy sources into the Israeli electricity sector |
| PPA | Power Purchase Agreement |
| PtF | Power-to-fuel |
| PtG | Power-to-gas |
| PtX | Power-to-X |
| PV | Photovoltaic |
| R&D | Research and Development |
| RE | Renewable Energy |
| SDG | Sustainable Development Goals |
| USD | US-Dollar |
| VAT | Value Added Tax |
| VRE | Variable Renewable Energy |

## LIST OF UNITS AND SYMBOLS

| | |
|---|---|
| % | Percent |
| $CO_2$ | Carbon dioxide |
| EHV | Extra high voltage |
| GW | Gigawatt |
| GWh | Gigawatt hour |
| HV | High voltage |
| HVDC | High voltage direct current |
| km | Kilometre |
| ktoe | Kilo tonnes of oil equivalent |
| kV | Kilo Volt |
| kW | Kilowatt |
| kWh | Kilowatt hour |
| LV | Low voltage |
| m | Metre |
| $m^3$ | Metre cube |
| m/s | Metre per second |
| Mt | Megatonne |
| Mtoe | Million tonnes of oil equivalent |
| MV | Medium voltage |
| MW | Megawatt |
| MWp | Megawatt peak |
| TWh | Terawatt hour |
| $W/m^2$ | Watts per square metre |

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## ABOUT THIS STUDY

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



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