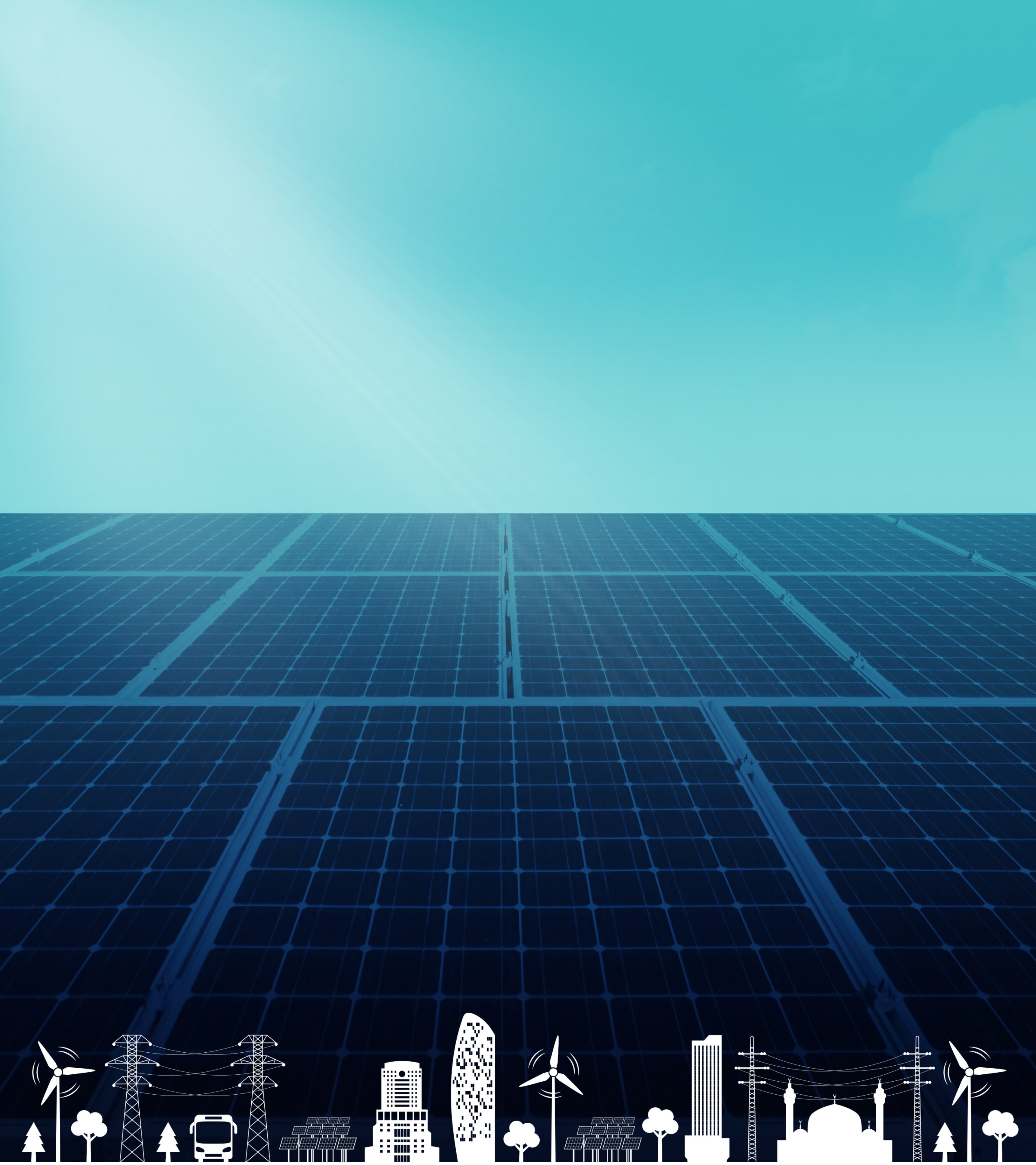

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Energy Transition Phase Model - MENA

Case of Jordan: The Sustainable Transofrmation of Energy Systems

Wuppertal | November 2018 | Report to the Friedrich-Ebert Stiftung

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3.1 Background

The energy systems in the Middle East and North Africa (MENA) region experience considerable pressures from a rapid increase in energy demand according to growing population, changing consumption behaviour and increasing urbanization. Today, almost in all countries of the region fossil fuels are still the dominating energy source, while the dependency from fossil fuel imports in many highly populated countries of the region are a serious risk for the long-term energy security. But also public budgets that are urgently needed for strengthening the socio-economic development of societies are experiencing stronger tensions due to increasing spending for energy subsidization. Interlinkages between basic needs such as energy, water, and food might have furthermore strong adverse impacts on households if energy prices rise. Not least even the missing future perspectives for the young population in several countries of the region strengthen emigration trends to Europe and lead to a brain drain effect, although the region has the opportunity to create powerful renewable energy industries and employment due to its unique solar and wind potential.

Climate change furthermore intensifies adverse living conditions as the region is already today affected by increasing temperatures. This results not only in an increasing number of heat waves and droughts, but also in decreasing precipitation and water availability as well as in deteriorating living conditions in cities and with regard to air quality (e.g. sand storms). At the same time, unprecedented and unexpected floods are experienced in the region, e.g. in Jordan and Morocco, constituting so far unanswered challenges for the affected countries. But also increasing numbers of cars in rapidly growing cities have worsened the air quality significantly in the last decades in many countries of the region.

Driven by these challenges but also by the hopes for the creation of powerful renewable energy industries and substantially decreasing costs of renewable energy technologies at global market scale, ambitious targets for renewable energies have been set in several MENA countries. Furthermore, several MENA countries have already developed successfully renewable energy projects during the last years. That includes especially the development of larges-scale renewable energy power plants.

Nevertheless, despite positive regional and local economic impacts of already developed renewable energy projects, the goal of developing a renewables based energy system is not uncontested in many MENA countries. That currently slows down the development process in some MENA countries, which is particularly related to missing long-term visions, but also missing public awareness and knowledge about benefits from sustainable energy systems as well as the requirements to support the transition process itself. This concerns in particular also decision makers in established organizations and becomes more and more a barrier for the further transformation towards a renewable energy based energy system in the region.

Against this background, the starting point for this report is that an enhanced understanding of transition processes is supportive for constructive dialogue about future energy system developments in the MENA region, and for developing strategies for a transition to a renewables-based energy system. An enhanced understanding of transitions by ministries and public authorities is all the more important as the governance of transitions towards renewables-based energy systems requires innovative approaches and concerted action. Technical innovations and market processes alone are not sufficient for addressing this kind of persistent, complex, systemic challenge (Grin, Rotmans, & Schot, 2010; OECD, 2015). Instead, facilitating targeted fundamental change requires, among others, a clear vision of the goal and direction of the transformation process (Weber & Rohracher, 2012).

3.2 Objectives

The main objective of this report is to develop a phase model for energy transitions in MENA countries. A phase model provides an overall framework which structures the process of the energy transition over time through the differentiation of a set of subsequent phases of the transition process. The phases are described through the main elements and processes shaping each phase, and qualitative differences between phases are highlighted. As such, a phase model provides an overview over a complex transition process. It provides an over-arching guiding vision for the transition and facilitates the early-on development of consistent policy strategies and policy instruments according to needs of the different phases.

The developed phase model will then be applied to the energy system of Jordan as a road test and for purposes of illustration.

3.3 Approach

For developing the phase model for energy transitions in MENA countries, we build on Fischedick et al. (2014) and Henning et al. (2015). They have proposed four phases to describe the transformation of the German energy system towards a decarbonized energy system based on renewable energies ***(see section 4.1)***. Henning et al. (2015) focus on technological developments in each phase, while Fischedick et al. (2014) provide additional insights on interrelated developments in markets, infrastructure and society.

We complement the existing phase models through insights from the field of sustainability transitions research ***(see section 4.2)***. This strand of literature focuses on the dynamics of fundamental long-term change in societal subsystems such as the energy system. Its perspective provides additional insights for the governance of long-term change in energy systems along the four phases.

Furthermore, the phase models of Fischedick et al. (2014) and Henning et al. (2015) have been developed for the German context, and thus require adaptation to the MENA countries. Therefore, we highlight some characteristics that distinguish MENA countries from Germany ***(section 5.1)***, and discuss the relevance of the differences for the transition processes suggested by the phase models of Fischedick et al. (2014) and Henning et al. (2015) ***(section 5.2)***. We aim to develop as a first step a phase model that is broadly applicable to all MENA countries ***(section 5.3)***. Therefore, we need to abstract from some details that are specific for the country level.

Finally, we apply the developed phase model to the case of Jordan. We assess the current state of developments in Jordan and match it to the phase model. This includes a more detailed look that specifies some of the previously defined, more abstract model components. We then propose next steps for the energy transition in Jordan according to the phase model. This application is mostly based on knowledge from previous studies and projects conducted in Jordan by the Wuppertal Institute, while some up to date data was collected during the development of this study.

4.1 The Original Phase Models

The phase models of Fischedick et al. (2014) and Henning et al. (2015) propose four phases to structure the (envisioned) German energy transition towards a renewables-based energy system. Main assumptions underlying these phases are deduced from fundamental characteristics of renewable energy sources, as summarized in the following.

To our best current knowledge, in most countries, including the MENA countries, the bulk of the energy used in a future renewables-based energy system needs to be provided by wind and solar sources, while the contribution of other sources such as biomass cannot be significantly increased due to limitations of potential and competition with other uses of biomass (food crops, animal forage, fibre, forestry products) and nature conservation.[1] In agreement with scenario studies (e.g. BP, 2018; IEA, 2017), a basic assumption of the phase models therefore is that the share of electricity from wind and solar sources in the energy mix will significantly increase. This includes the direct utilization of electricity in end-use sectors that so far have relied on fossil fuels and natural gas, in particular e-mobility in the transport sector and the utilization of heat pumps in the building sector. Emission reduction via direct utilization of electricity is technologically difficult in some sectors, such as aviation and the provision of high temperature heat for industry. Possible substitutes for fossil fuels and natural gas in those sectors are hydrogen and hydrogen-based synthetic fuels and gases (power-to-fuel/power-to-gas). The required hydrogen can then be gained from renewable electricity via electrolysis. Direct and indirect electrification of end-use sectors reflect the fact that direct application of renewable energies (e.g. solar thermal energy, geothermal energy) in the sectors is quite limited and electrification makes it possible to significantly increase the shares of renewable energies in the energy mix, but also contributes to decarbonization of end-use sectors.

The feed-in and extraction of electricity from the grid always needs to be in balance to maintain grid stability. Furthermore, electricity cannot simply be put aside for the later. The volatile nature of solar and wind supply in combination with these facts increases the need for a flexible power system management if wind and sun should provide large shares of electricity. Flexibility can be provided through extending grids over larger areas to balance regional variation in the supply of wind and solar radiation, increasing flexibility of the residual fossils-based power production, through storage, through demand-side management and smart linking of all components in so called virtual power plants. Furthermore, flexibility management requires intensified communication between system components via information and communication technologies (ICT).

The stronger coupling of sectors through direct utilization of electricity in the heat and mobility sectors and through the usage of power-to-fuel/power-to-gas solutions requires an alignment of rules and regulations between those sectors[2] and the buildup of infrastructure (e.g. charging stations for e-mobility and hydrogen infrastructure). Furthermore, the low operational costs and the volatility of

1 Certainly there are some exceptions. For example, countries like Iceland and Ethiopia can make use of geothermal resources while countries like Austria and the Scandinavian countries have huge hydropower potentials.

2 In the past, rules and regulations often have been defined independently per sector, and fees and taxes have been introduced for various reasons, including: refinancing the promotion of particular measures / technologies (e.g. surcharge for renewable energy), refinancing infrastructure costs, steering measures due to environmental considerations, and other economic, political and social considerations (e.g. reduced fees for industry to maintain competitiveness). As a result, fees and taxes partly differ strongly for different energy carriers, even if the energy is used for the same purpose.

supply of wind and solar electricity pose considerable challenges to current market designs[3], and therefore a new market design might be required to accommodate large shares of volatile renewables.

A main pillar of a future renewables-based German energy system is a strong increase in energy efficiency that leads to an overall reduction of primary energy needs to almost half of today's level. The increase of energy efficiency is an on-going endeavour throughout the transition process. Energy scenarios indicate that energy efficiency improvements can be seen as a strong prerequisite for fulfilling the energy transition targets as otherwise the induced electricity demand will be four or five times higher than the current power demand and will exceed the renewable energy potential of the country by a factor of two or even three.

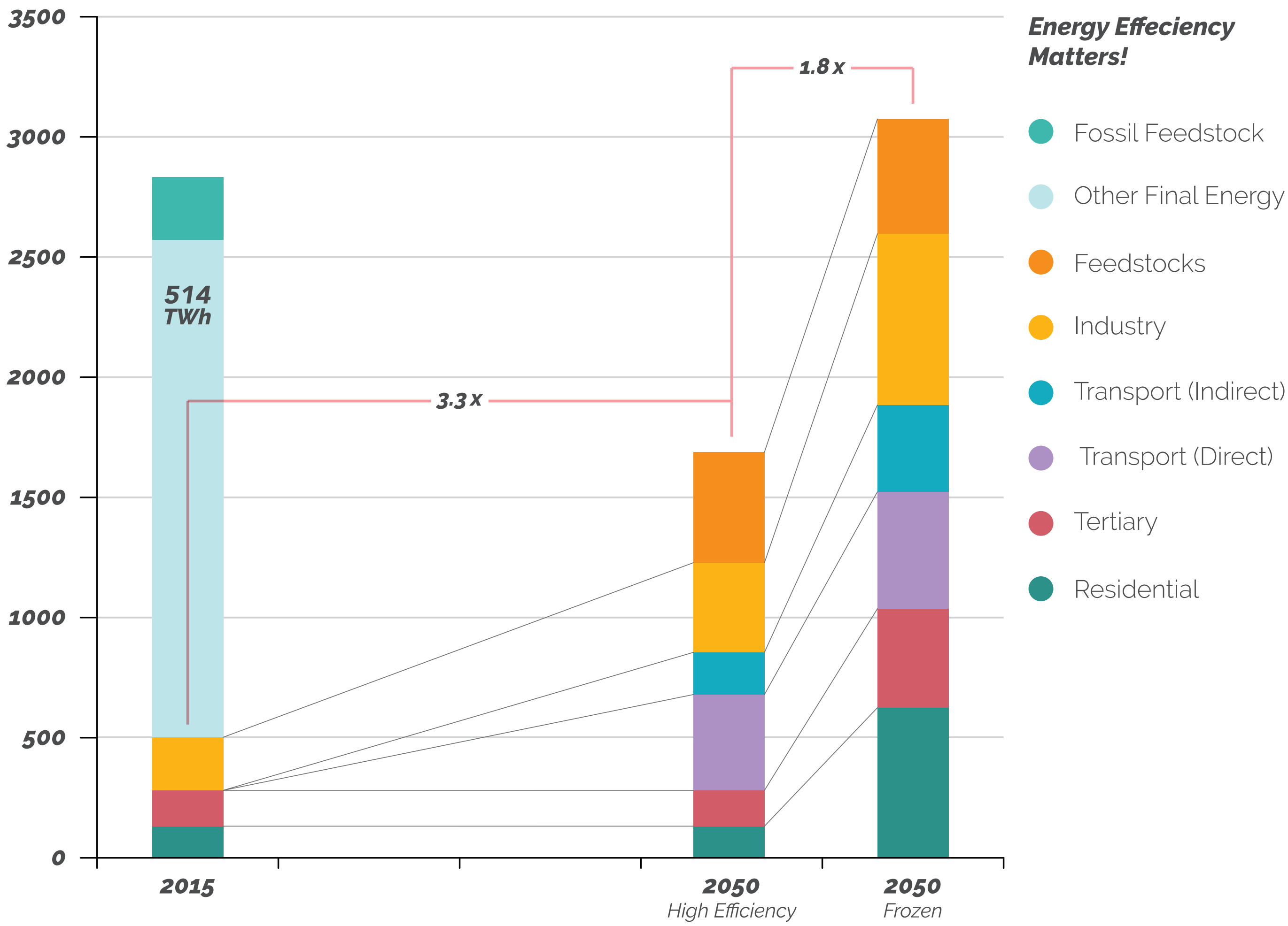

Figure 4-1: Development of the German energy demand until 2050 based on a full decarbonization of the energy system with and without energy efficiency measures | Source: Schneider & Lechtenböhmer (2016)

3 Electricity supply from wind and solar depends on weather conditions. As a consequence, favourable conditions lead to high amounts of feed-in from many plants at the same time, what in combination with low operational costs results in very low market prices. On the other hand, during times of low supply that is barely able to meet basic demand, market prices might become very high.

The outlined socio-technical interdependencies have been condensed into four phases that provide a temporal order of developments that build upon each other. Summarized broadly, the phases follow this sequence:

1. In a first phase, renewable energy technologies (in particular photovoltaic and wind energy plants) are developed and introduced into the market. These developments are triggered by dedicated R&D programs and first market introduction policies. Market introduction has no major effects on the rest of the energy system, yet. Initial strong cost-reductions for the application of those technologies are achieved.

2. The further expansion of renewable electricity supply and usage in the second phase requires measures for the integration of renewable electricity into the energy system, including flexibility of the residual fossil power production, build-up and integration of storage, and activation of demand side flexibility. This already includes some coupling of the power system with the heat and mobility systems (power-to-heat, e-mobility). Cross boarder capacity extensions provide additional flexibility via power exchange with neighbouring countries, and distribution grids need to be retrofitted to accommodate increased decentralized feed-in of electricity.

3. The third phase starts when the further increasing share of renewables creates the need for long-term storage of renewable electricity to balance periods during which supply from volatile sources significantly exceeds demand. For Germany, energy model results indicate that a substantial demand on long-term storage will emerge when exceeding 60% of renewable energies in the electricity generation mix. Another driver for the third phase is an increasing pressure on the end-use sectors to massively reduce the use of fossil fuels, mainly driven by strict sector specific greenhouse gas mitigation targets. Power-to-fuel and power-to-gas technologies become integral parts of the energy system and the associated infrastructure needs to be built up. Imports of renewables-based energy carriers (electricity, hydrogen, synthetic fuels/gases) gain importance. Market structures have to be significantly adapted if marginal costs of the dominant electricity source are nearly (or close to) zero and appropriate incentives have to be created to secure power system stability and a sufficient backup system.

4. In the final phase, the residual fossil fuels become fully replaced in all sectors.

Throughout all phases, the capacities for renewable electricity supply need to be further expanded to meet increasing demands from other sectors and from power-to-fuel/gas applications. Furthermore, as outlined above, energy efficiency needs to be increased considerably throughout.

Certainly, there is no strongly determined switch from one phase to the other, but a more floating switch can be observed with some sub-regions entering the next phase earlier and others later. However, for Germany, phase 1 can be assumed to be completed (Henning et al., 2015; Markard, 2018), and the country entered into the second phase in the first half of the current decade. The developments outlined for phases 3 and 4 are contingent on many technological, political and societal developments, and therefore uncertain from today's perspective.

4.2 Selected Insights from Sustainability Transitions Research

Sustainability transitions research is a research field that aims to increase the understanding of fundamental long-term[4] change in sectors such as energy and transport, and to provide advice for

4 In historical cases, transitions typically took several decades. In envisioned sustainability transitions, change arguably needs to occur faster.

governing these processes towards sustainability targets. The field has emerged at the intersection of innovation studies, science and technology studies, evolutionary economics and history of technology (Markard, Raven, & Truffer, 2012; Smith, Voß, & Grin, 2010). Transition researchers typically apply inter- and transdisciplinary approaches to analyse systemic aspects that arise from the interrelatedness of processes in the dimensions technology, institutions[5], policy, actor networks, infrastructure, and society.

4.2.1 The Multi-level Perspective

The most prominent framework used by transition researchers is the 'multi-level perspective' (MLP) depicted in Figure 2-2 (Geels, 2002, 2011; Geels, Sovacool, Schwanen, & Sorrell, 2017; Rip & Kemp, 1998).

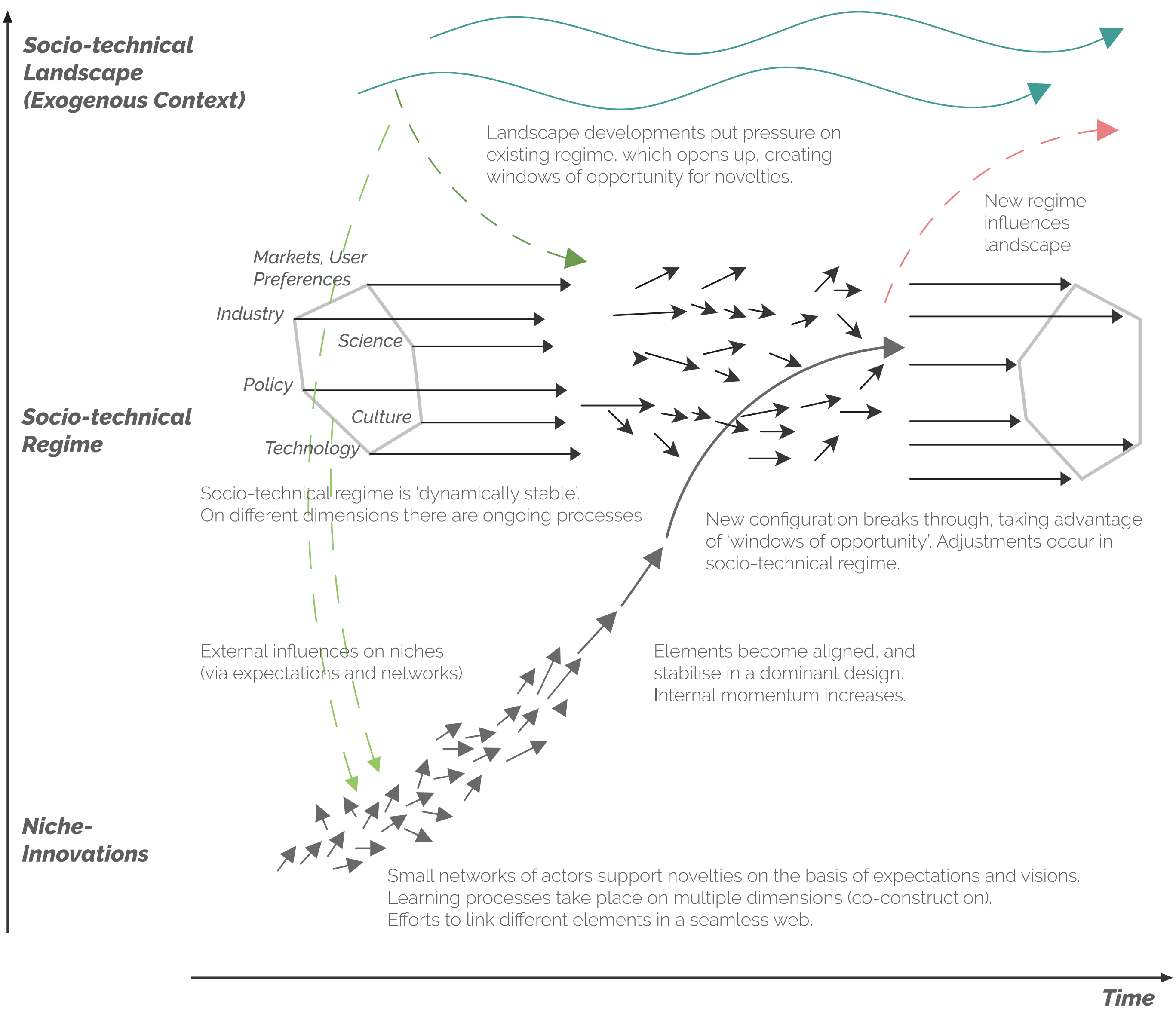

Figure 4-2: The Multi-level Perspective | Source: Geels & Schot (2007)

5 "Institutions" here refers to the sociological meaning of the term, i.e. formal and informal rules and regulations that structure and give meaning to social life (it does hence not refer to the meaning of the term in the sense of organizations).

The MLP suggests that fundamental change is the result of the interplay of developments at three analytical levels. The 'regime' level captures the socio-technical system that dominates the sector of interest (i.e. in our case: the energy sector). The regime is constituted by the application of particular technologies, the existence of (large-scale) infrastructure that facilitates technology application, institutions that regulate the sectoral activities, a broad set of supportive auxiliary technologies and institutions (e.g. insurances), and actors that perform the various roles in the sector's value chain (e.g. technology provider, producer, regulator, intermediary, consumer). The main idea of the regime concept is that the regime is stabilized through various self-reinforcing mechanisms and lock-ins. Those include economies of scale and network effects, long lifetimes of some of the material components, cognitive heuristics that e.g. shape engineers' perspectives and thus technological development, business models that are tailored to the existing value chain, the social significance of the system, regime actors' links to political power, routine everyday behaviour that relies on these systems, and societal expectations and norms of conduct. Moreover, the regime components have co-evolved over long periods of time and have become increasingly intertwined (Unruh, 2000). Due to the interrelatedness, radical change of single components is not feasible without affecting other, connected components. As a consequence, regime change tends to follow incremental development pathways, and fundamental change is hampered.

'Niche innovations' are structurally similar to regimes in that they also provide the same kind of service or function to society, and consist of interrelated components of the same kind as regimes. However, they are radically different from regimes regarding the particular components (e.g. technologies deployed). They are less mature and smaller (e.g. in terms of market size and amount of actors involved), but gain a foothold and evolve in particular geographical areas or market niches, or with the help of targeted policy support.

Finally, the 'landscape' level includes slowly changing, pervasive trends (such as demographic shifts, climate change) as well as more short-term shocks that affect the regime and niches, such as disasters (e.g. Fukushima), economic crises, and wars. A major defining characteristic of landscape developments is that they cannot be influenced (significantly) by regime or niche actors but constitute some external context that fosters some developments on the regime and niche levels but hampers others.

The interconnected and self-stabilizing character of the regime implies that fundamental change does not happen at the level of single innovations, but (only) through dynamics at the level of competing and mutually influencing systems (regime, niches). According to the MLP, transitions come about if both a) the regime is under pressure from landscape developments, and b) niches exist which put pressure on the regime and provide alternative solutions. Transitions may occur along various pathways of landscape-regime-niche interactions (Geels & Schot, 2007), but the constitutive result of a transition is the substitution of a regime by a former niche, or a fundamentally changed regime.

It is important to note that the MLP 'levels' are not of geographical but of analytical nature, and that the MLP can be applied on different empirical levels (Geels, 2011).

4.2.2 Three Stages of Transitions: Processes and Governance

Transitions cannot be perfectly steered nor completely predicted and controlled. The reasons are the involvement of many actors, the high level of interdependency of regime components, the fundamental uncertainty associated with technological, economic and socio-cultural developments, as well as the unpredictability of landscape events. Therefore, the governance of transitions requires experimentation and learning, continuous monitoring, reflexivity, adaptability of measures, and multi-level policy coordination across different levels of administration and different sectors and policy fields (Hoogma, Weber, & Elzen, 2005; Loorbach, 2007; Voß, Smith, & Grin, 2009; Weber & Rohracher, 2012). Recent literature on the governance of transitions furthermore emphasizes the role of policy mixes, i.e. the insufficiency of single policy instruments to orchestrate multiple developments that jointly drive the transition. The innovation policy approach followed by OECD countries has long been based on the systems of innovations approach (OECD, 2005), which is blind to the direction of induced innovations (Weber & Rohracher, 2012). Facilitating targeted fundamental change (towards a renewables-based sustainable energy system) therefore requires additional measures, among others, and the development of a clear vision of the goal and direction of the transition (Weber & Rohracher, 2012). Furthermore, besides policies that support innovation, the relevance of the flip-coin – i.e. policies for 'creative destruction' (Kivimaa & Kern, 2016) or 'exnovation' (David, 2017) of persisting regime components – is emphasized, in particular for later stages of the transition process when niche innovations have gained some momentum. It is far beyond the scope of this report to discuss the governance of transitions at length. In the following, we therefore synthesize some broad insights from this strand of literature into a process-based framework that then is used to enrich the phase model to be developed in section 3.

We distinguish three stages of transitions and associated policy approaches based on (Kivimaa & Kern, 2016; Rotmans, Kemp, & Van Asselt, 2001; Weber & Rohracher, 2012): 'niche formation', 'break-through' and 'market-based growth'. During 'niche formation', a niche matures to a degree that it may compete with the regime or provide viable solutions that may be absorbed by the regime. The literature on strategic niche management has identified the processes that are required for niche formation (Schot & Geels, 2008):

1. The articulation of shared expectations and visions provide direction to learning processes, mobilize actors, and legitimate (policy) support for the niche;

2. The involvement of actors and the building of social networks is important to create a value chain related to niche innovations, and to provide the necessary resources (money, people, expertise);

3. Learning processes at multiple dimensions are required to advance the technology, to understand user preferences and develop markets, to probe the cultural and symbolic meaning of the niche innovation, to explore institutional arrangements that work, and to learn about (unintended) societal and environmental effects.

A policy strategy for niche formation should aim to support these different processes. Policyinstruments for achieving this may include foresight exercises, targeted R&D funding schemes, setting up of innovation platforms, demonstration projects, initiating joint learning processes involving producers and users, providing venture capital, relaxing regulation conditions for experimenting, low-interest loans, educational policies and labour-market policies.

With 'break-through' we refer to the stage when niche innovation spreads beyond its initial niche through growing in terms of involved actors and market share, replication in other locations or contexts, linkage with related niche innovations, and transformation of regime level institutions and infrastructure (Naber, Raven, Kouw, & Dassen, 2017). A policy strategy for this stage should in particular aim to improve the price-performance ratio of the niche innovation compared to established regime technologies, provide full access to infrastructure and markets, and remove institutional barriers. This includes amendment of legislation, market rules and technical standards that hamper the deployment of niche innovations, increasing societal awareness and acceptance, and the construction or retrofitting of infrastructure[6]. Policy instruments for supporting niche innovations at this stage may include public procurement, tax exemptions, feed-in tariffs, deployment subsidies, campaigns to spread knowledge and change societal values, and labelling to support the niche innovation. Complementary to that, a policy strategy should also withdraw support for and increase pressure on the energy regime through internalizing the environmental costs of carbon emissions to create an 'extended level playing field' on which niche innovations and the regime may compete (van den Bergh, Faber, Idenburg, & Oosterhuis, 2006). Policy

6 E.g. retrofitting of distribution grid to accommodate increasing shares of renewable electricity.

instruments may consist in the removal of (hidden) subsidies for fossil fuel-based technologies, CO2 pricing, pollution taxes or even banning certain technologies. Furthermore, to reduce the influence of key regime actors on the government, established actor-network structures need to be broken up. This may involve the development of new forums to bypass traditional policy networks, and the balanced involvement of incumbent and niche actors in policy advisory councils.

At the final stage, which we label as 'market-based growth', the niche innovation has become fully price-competitive, and the institutional environment and infrastructures have been adapted to the niche innovation, which now competes with the regime on a level-playing field. Actor networks have restructured and former niche actors have developed close relationships with policy makers and regulators. Note that market shares of (former) niche innovations may still grow considerably at this stage. A policy strategy for this stage should aim to remove or reduce unintended side-effects[7] and to withdraw subsidies and other policy instruments that induce societal costs.

4.3 Additions to the Original Phase Models Regarding Governance

The literature on transition governance discussed in the previous sub-section highlights the relevance of niche formation processes for a successful up-scaling of niche innovations later on. We therefore add another 'layer' of developments to the phase model. We complement system level developments as outlined in the existing phase models with niche formation developments that (need to) occur 'under the surface' during each phase in order to pave the way for the break-through of innovationclusters that shape the subsequent phase.[8]

The system level layer of the model adopted from the original phase models provides clear (intermediate) targets for system development as orienting guidelines for decision-makers. The added niche level layer adds to this a stronger perspective on processes that need to take place in order to achieve those targets, and provides some guidance as to which governance approaches are useful to support those processes *(see section 4.2)*. The two layers therefore provide complementary information to decision-makers.

For niche formation, we focus on the development of visions, the emergence of actor networks (including empowerment of actors), and learning processes (including experience exchange on national and international level) required to integrate globally available technologies into the domestic energy system. The latter includes the exploration of appropriate support schemes, of required institutional changes (e.g. market rules), of business models and of societal acceptance. Experiments are important to achieve the necessary learning.

Furthermore, the existing phase models have a strong focus on the build-up of a renewables-based system. We adopt this perspective on the required development of capacities, infrastructure and markets. We add a complementary perspective on developments that destabilize the existing fossil fuels-based regime, such as control policies and the removal of subsidies. Changes to regulations and market designs are required to open markets for niche innovations, while those changes at the same time may serve to reduce competitiveness of fossils.

7 For example the removal of distributional effects, i.e. the burden should be shared in a fair manner among society.

8 The conceptual underpinning of this addition is as follows: the MLP can be applied to different empirical levels (Geels, 2011). We split-up the overall energy transition into four 'smaller' transitions of innovation clusters that dominate each phase. For phase 1 those are the renewable electricity technologies, for phase 2 the flexibility options, for phase 3 the PtF/G technologies, and four phase 4 technologies for sectors that are difficult to decarbonize such as some industries and aviation. We then apply the MLP to each of these 'smaller' transitions.

We propose that the overall logic of the original phase models presented in section 4.1 also holds for MENA countries, and spell out the four phases for MENA countries in section 5.3. However, before doing so, we highlight differences between Germany and MENA countries (section 5.1) that suggest changes to the model within the four phases and regarding the temporal dimension of the phases (section 5.2). Furthermore, we complement the description of system level developments through a stronger focus on regime destabilization, and by adding developments that need to take place at the niche level during each phase to prepare for the subsequent phase based on the discussion in sections 4.2 and 4.3.

5.1 Specific Characteristics of the MENA Region

Several countries in the MENA region are endowed with large amounts of fossil fuel resources. But especially populated countries such as Morocco, Tunisia, and Jordan are poor in resource endowment, resulting in a high dependency on energy imports. Significant spending on energy imports and highly subsidized energy prices as part of non-liberalized energy markets make many MENA countries vulnerable for fluctuating international energy prices and jeopardize their energy security.

The energy demand in MENA countries is strongly increasing due to a range of reasons. Population is growing rapidly while the use of energy is highly inefficient in several application areas, ranging from low insulation quality of buildings to inefficiencies of cooling and heating technologies. Higher demand caused by the increase in population is exacerbated in some regions by high amounts of refugees. In this regard, especially Jordan has been confronted with recurring refugee crises for decades. Furthermore, energy-intensive industries have established in the last decades due to very low energy prices in several countries. This includes especially steel, concrete, and chemical industries for instance in energy import dependent countries such as Morocco and Egypt, but also in resource-rich countries on the Arabian Peninsula. The increase in demand is further intensified as the installation of energyintensive seawater desalination capacities is part of many regional strategies to satisfy the expected increase in demand for water. As a consequence, the total electricity demand for seawater desalination is predicted to triple in MENA by 2030 compared to the 2007 level (IEA-ETSAP & IRENA 2012).

On the other hand, in MENA, the economic potential of solar and wind energy is immense compared to current levels of demand. E.g., Fichter et al. (2013) estimate that Jordan's CSP potential suffices to cover the estimated demand in 2050 more than a hundred times[9]. This potential provides ample opportunity to satisfy growing domestic demand. To reap this potential and to accommodate high shares of renewables, the electricity grid, however, requires considerable extension and investment in almost all countries of the region.

In the longer term, the large economic potential of solar and wind energy also opens opportunities to export renewables-based energy carriers to neighbouring regions such as Europe, where renewable energy potentials are significantly lower. Imports might become an important pillar of Europe's energy strategy, especially in a later stage of Europe's energy transitions. Some resource-rich countries in MENA have already developed infrastructures for gas and oil, and have gained experience regarding the production and handling of gas and liquid fuels. These countries therefore might benefit from

9 The estimated annual electricity generation of solar CSP amounts to 6.000 TWh/a in 2050, as compared to the estimated electricity in 2050, which is expected to attain 50 TWh/a (Fichter et al. 2013).

the creation of synthetic fuel markets in an advanced status of the energy system transformation. Via power to fuels technology, oil producing and exporting countries might be able to organise a proactive switch from fossil fuel based products to renewable energy based products while further using existing infrastructures, i.e. existing assets.

Against that background, it can be concluded that the main drivers for the transformation of the energy systems differ in various aspects between Europe and MENA. In Europe, energy systems are fully in place and in general do not face high growth dynamics. Instead, the installed energy infrastructures need to be replaced and transformed to meet sustainability goals while maintaining high levels of supply security and economic efficiency. In Germany, the energy system transition process is based on a long tradition in terms of thinking in alternative energy system solutions (starting already in the 1970s) and (based on risk assessments) a strong public resistance against nuclear power plants and the associated more centralized system. In contrast, the energy systems in the MENA region are still under development. The vision of a renewables-based energy system might not only be attractive from a sustainability perspective, but rather to meet growing domestic demand, to increase energy security, and to stimulate economic prosperity. There is no similarly broad resistance against nuclear power production as in Germany, yet.

The urgent need for socio-economic development in the region furthermore results in very high expectations of increasing prosperity through the development of renewable energy industries. Socio-economic prospects are often seen as a prerequisite for setting up supportive regulatory frameworks for renewable energy markets. However, the conditions for supporting entrepreneurship and technological innovation are still weak in almost all countries in the region. The socio-political situation in the MENA region, with many local and regional conflicts, poses considerable challenges to long-term projects such as the build-up of a renewables-based energy system, e.g. with regard to reliable planning and investment security.

The energy transition in Germany has been to a large share driven by private actors (households, farmers, cooperatives) who, triggered by a feed-in tariff, have built up small-scale PV and wind plants. Yet, in many MENA countries, state-owned companies have a crucial role, and – compared to Germany – incumbents and large-scale projects can be assumed to play a stronger role for the energy transition in early phases. Furthermore, foreign investors are important to fund renewable energy projects in the MENA region. Mobilization of capital from abroad is of higher relevance in several MENA countries, in particular in those countries that are not rich in fossil fuel resources. This requires dedicated strategies and efforts to provide stable investment conditions.

5.2 Changes to the Model Due to a Shift of Geographical Area

The energy transition in Germany happens in a fully developed energy system that is no longer growing substantially. Therefore, an increase of supply through renewables implies a reduction of supply from fossil-based energy and nuclear energy. In contrast, MENA countries experience strong increases in demand that require corresponding increases in supply. This provides room in phases 1 and 2 to establish renewables and to increase their feeding volume considerably without immediately undermining existing business of fossil fuel and natural gas-based industries.

Renewable energy technology and supportive technologies such as battery storage have been developed and advanced globally. MENA countries can and do already benefit from experiences made and cost reductions achieved during this process. Furthermore, a global network of companies has emerged around those technologies, which can potentially be tapped to provide expertise for the implementation and operation of those technologies in MENA countries. This provides the opportunity to speed-up the stage of niche formation, which, however, is still needed to internalize globally existing knowledge domestically, to develop institutions that support niche innovations but at the same time fit into the countries' institutional structure, and to build up actor networks including domestic and international actors.

While in Germany the initial spread of renewables was largely driven by small-scale private actors, the introduction of renewables in MENA countries is dominated by large-scale projects led by joint ventures of state-owned companies and investors from abroad. The stronger role of the state will likely lead to different dynamics for the introduction of different innovation clusters in each phase.

The grid situation in MENA countries currently limits the ability of the grid to accommodate rising shares of renewables. Therefore, in phase 1, higher emphasis needs to be on grid retrofitting and expansion. Furthermore, phase 2 likely needs to start earlier (in terms of RE shares) compared to Germany, with a stronger focus on solutions for off-grid applications and small isolated grids.

While in the later phases 3 and 4, the phase models for Germany foresee imports of renewables-based energy (electricity, hydrogen, synthetic fuels), the situation in MENA countries is different as there are huge economic potentials for solar and wind energy. Indeed, it is envisaged that MENA countries can become net exporters of renewables-based energy. The existing natural gas and fossil fuel infrastructure might be retrofitted for large-scale transmission and storage of renewables-based synthetic gases and fuels.

5.3 Phases of the Energy Transition in MENA Countries

We adopt the basic logic of the phase models proposed by Fischedick et al. (2014) and Henning et al. (2015) and propose four phases:

- ***Phase 1*** **– Take-off RE:** Introduction of renewable electricity into the electricity system and initial signs of an accelerated diffusion.

- ***Phase 2*** **– System integration:** Flexibility options and sector coupling become important to accommodate further increasing shares of renewable electricity. Renewable electricity starts to substitute fossil fuels and natural gas in other sectors than electricity.

- ***Phase 3*** **– PtF/G:** Power-to-fuel/gas (PtF/G) applications enter the market and absorb increasing shares of 'surplus' renewables during times of high RE supply, but will also start to be linked with dedicated RE supply facilities for international cooperation and the creation of export market structures.

- ***Phase 4*** **– Towards 100% Renewables:** the residual fossil fuels become fully replaced, also in sectors that are difficult to decarbonize. Export market structures will be expanded.

The following chapters discuss the developments in the four phases loosely along the dimensions used by Fischedick et al. (2014): supply, demand, infrastructure, markets, and society. This reflects the multi-dimensional perspective of transitions research ***(see section 4.2)*** that highlights the interrelatedness of these dimensions during transition processes. Table 5-1 and Table 5-2 summarize main developments during the phases.

Phase 1: Take-off RE	***Phase 2***: System Integration	***Phase 3***: PtF/G	***Phase 4***: Towards 100% Renewable
RE share in energy system about 0-20%[10]	RE share in energy system about 20-50%	RE share in energy system about 50-80%	RE share in energy system about 80-100%
Set up regulations and price schemes for RE;	Further grid extension (national and international);	Temporarily high negative residual loads due to high shares of RE;	Full replacement of fossils by RE and RE-based fuels;
Market introduction RE drawing on globally available technology and driven by global price drop of RE;	Adaptation of market design to accommodate flexibility options;	Temporarily high negative residual loads due to high shares of RE;	Phase-out support policies for RE;
Extension and retrofitting of electricity grid;	ICT structures integrated with energy systems;	Extension of long-term storages; Set up regulations and price schemes for PtF/G;	Stabilization of PtF/G business models and production capacities (large-scale investments);
No replacement of fossils due to growing markets	System penetration of flexibility options;	Increasing volumes of PtF/G (transport, substitute for fossil fuels and natural gas);	Consolidation of RE-based export models;
	Alignment of electricity-, mobility-and heat-related regulations;	First PtF/G infrastructure is builtup (satisfying up-coming national/foreign demand);	Phase-out of fossil fuel infrastructures and business models
	Direct electrification of applications in the sectors buildings, mobility and industry, and changing business models in those sectors;	Reduce prices paid for fossilbased electricity;	
		Sales volumes of fossils start to shrink;	
		Existing fossil-based business models start to change	
Continuing improvement of efficiency Expansion of RE capacities throughout all phases			

Table 5-1: Developments During the Transition Phases (System Level)

10 The figures can be seen as indicative since there is no strong crossover from one phase to the other. It is rather a fluent transition.

Developments Before Phase 1	***Phase 1***: Take-off RE	***Phase 2***: System Integration	***Phase 3***: PtF/G	***Phase 4***: Towards 100% Renewable
Local experiments with RE;	Assessment of regional potentials of different flexibility options;	Assessment of potentials for different PtF/G conversion routes;	Experiments with PtF/G applications in sectors with difficulties in electrification like industry (steel, concrete and chemical sectors) and special transport (aviation, shipping);	
Formation of RErelated actor networks (joint ventures);	Experiments with flexibility options;	Local experiments with PtF/G generation based on RE hydrogen and carbon capture;	Investments in business models for PtF/G exports;	
Assessment of RE potential and development of visions for RE extensions	Exploration of business models around flexibility including ICT startups and new digital business models for sector coupling;	Formation of PtF/G-related actor network (national and international);	Experiences with synthetic fuel exports;	
	Development of visions for flex-market and energy system integration (regional and transnational energy markets);	Tap global experiences with PtF/G;	Formation of actor networks for creating large-scale synthetic fuel export structures	
	Formation of actor networks around flexibility across electricity, mobility, heat sectors	Development of PtF/G strategy and plans for infrastructure development/ adaptation;		
		Exploration of PtF/G-based business models		

Table 5–2: Developments During the Transition Phases (Niche Level)

5.3.1 ***Phase 1*** – Take-off RE

The introduction of RE into the market is facilitated by developments at the niche level that precedes phase 1: regional potentials for RE are assessed, local experiments with RE conducted, actors connect and form an actor network around RE that includes local and global actors and brings together globally available technology, skills and knowledge about the domestic energy systems, and visions 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, in particular electricity generated by photovoltaic (PV) and wind energy plants. The market introduction of wind and PV energy in MENA countries can draw on globally available technologies and benefit from global price drops of those technologies. Demand is growing overall out of the above-mentioned reasons ***(section 5.1)***, and therefore the comparably small amounts of RE that enter the system do not replace fossil fuels in this phase. The electricity grid is extended and retrofitted to accommodate volatile RE. The integration of RE into the energy system is enabled by regulations that define the specifications for operating RE and that allow renewables-based electricity to be fed into the grid. Price schemes are devised that provide incentives for investors to set up large-scale RE projects and for households to install decentralized PV.

During phase 1, developments take place at the niche level that pave the ground for phase 2. The regional potential of different flexibility options is assessed (e.g. possibilities for pump storage, DSM in industry) and visions are developed that picture through which mix of options the increasing demand for flexibility can best be met in the region. This includes exploration of the role of sector coupling (e-mobility, power-to-heat) and the exploration of business models that are attractive for diverse actors to provide flexibility to the system. Expected flexibility needs and sector coupling provide the ground for ICT start-ups and the exploration of new digital business models.

5.3.2 ***Phase 2*** – System Integration

On the system level, the expansion of RE capacities continues while growing markets still provide ample room for the co-existence of fossil fuel-based energy and renewables. An integrative approach that addresses and relates all energy-relevant activities needs to be developed, including an appropriate consideration of upcoming largescale consumers like water supply systems. The grid is further extended, including cross-border and transnational power lines to balance regional differences in wind and solar supply. Flexibility potentials (DSM, storage) are activated. The electricity market design is adapted to accommodate those options and to create incentives for flexibility provision. This also includes the full integration of ICT infrastructures with the energy systems (digitalization). Regulations in the electricity, mobility and heat sectors are aligned to provide a level-playing field for different energy carriers. This facilitates direct electrification of applications in the mobility, industry and heat sectors. Those applications provide further flexibility to the system.

Developments at the niche level prepare the system for a break-through of PtF/G applications in phase 3. Local experiments are conducted to explore the generation of synthetic fuels and gases under local conditions. RE-based hydrogen and CO_2 from carbon capture are currently envisaged to be the main sources for the required input chemicals. While in the short- and mid-term carbon capture can take place with existing CO_2 intensive industries, long-term strategies have to focus on direct carbon capture from air or bioenergy to guarantee carbon neutrality. Again, an actornetwork needs to be created that brings together local knowledge with global experiences with PtF/G. Based on an assessment of potentials for different PtF/G conversion routes, strategies and plans for infrastructure development are developed, and
business models explored.

5.3.3 ***Phase 3*** – System Integration

On the system level, further increasing shares of RE in the electricity mix lead to intensified competition between renewables and fossil fuels (in some sectors faster than in others), and temporarily high, negative residual loads. Negative residual loads provide cheap electricity for the generation of hydrogen and synthetic fuels and gases. As a consequence, and supported by regulative frameworks that include price schemes, market shares of PtF/G applications increase, in particular in the mobility/transport sector (long distances) and as a replacement of fossil fuels and natural gas. This is facilitated by the development of a hydrogen infrastructure (either in dedicated areas/regions or cross-regional) and by retrofitting existing oil and gas infrastructure for the use of synthetic fuels and gases. Market conditions for fossil fuels-based electricity are worsened on purpose (e.g. through reduction of prices, introduction of fees/taxes) to initiate the phase-out of fossils and to stimulate changes in the business models of incumbent actors. PtF/G solutions also provide long-term storage (several days and seasonal), which becomes more important with high shares of volatile RE and enables the creation of export market structures.

At the niche level, experiments with PtF/G applications are conducted in further sectors, such as industry (concrete, chemicals, steel), heavy transport and shipping. Furthermore, potential arrangements for the export of hydrogen and synthetic fuels and gases are explored and assessed. Actor networks are created, first experiences made, and business models explored.

5.3.4 ***Phase 4*** – Towards 100% Renewables

Residual fossil fuels become replaced step by step by RE-based energy carriers. Fossil fuel-based infrastructures and business models are phased out, while infrastructure for PtF/G solutions is fully developed. Support schemes for RE-based energy are no longer required and phased out. Export schemes for RE-based energy carriers have been consolidated and constitute a vibrant sector of the economy.

As in the original phase models, throughout all phases, the capacities for renewable electricity supply are expanded to meet increasing demands, including demand from other sectors and from power-to-fuel/gas applications. Furthermore, energy efficiency needs to be increased considerably throughout. The developments outlined for phases 3 and 4 are contingent on many technological, political and societal developments, and therefore uncertain from today's perspective.

A Phase Model for the MENA Region: Figure 5-1 depicts the overall transition dynamics across all four phases.

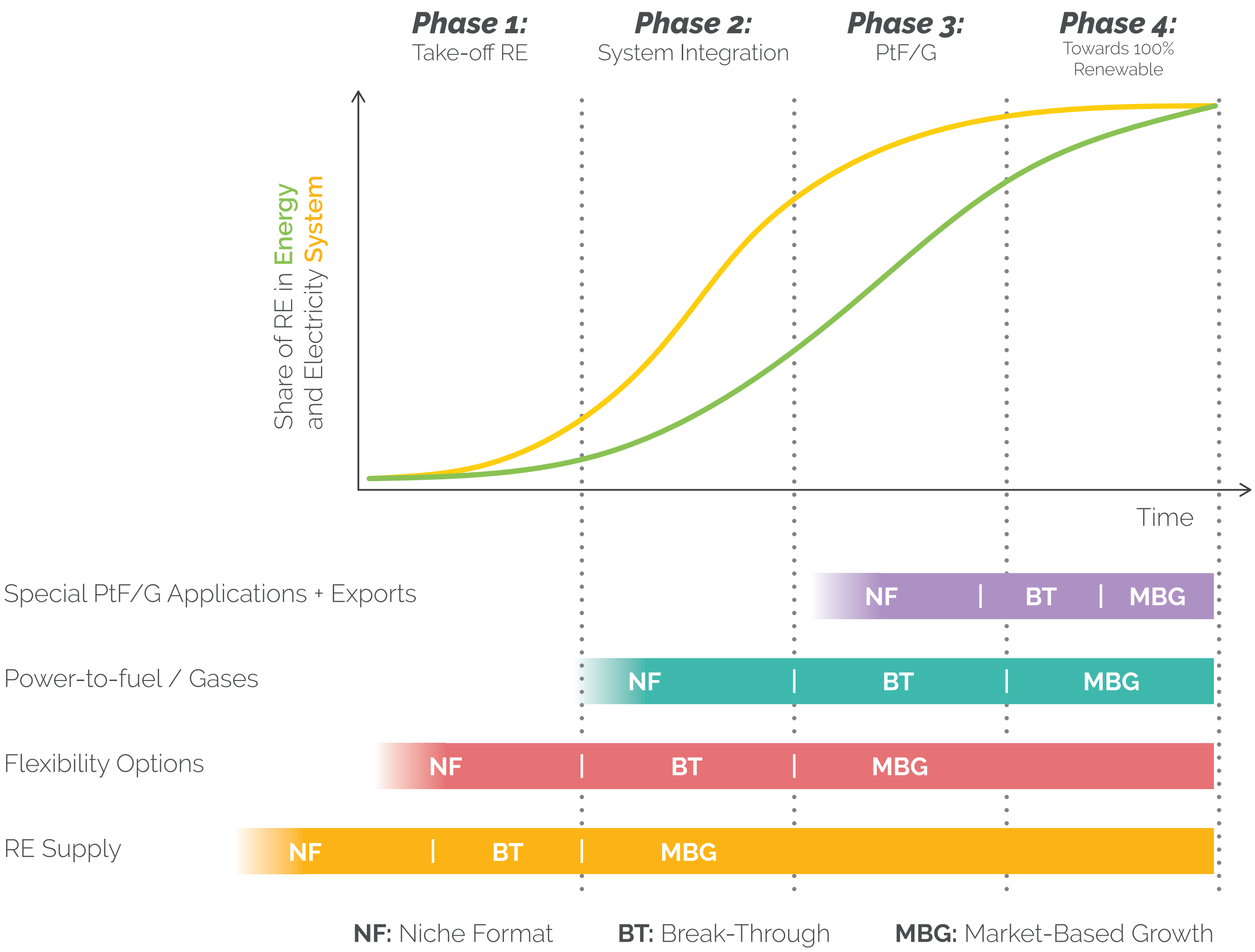

Figure 5-1: Transition Phase Model for the MENA Region

Jordan's energy system is highly dependent on fossil fuel energy imports as the country is poor in fossil fuel deposits. In 2017, the country had to import about 94 % of its primary energy (MEMR, 2018). Jordan displayed a total final energy consumption of 287.55 TJ[11]. Herein, according to the sector distribution, the transport sector is dominating with 49 % in energy consumption, followed by households (23 %), industry (14 %), and others (14 %) (MEMR, 2017a).

Constant increases in the energy demand and energy prices, but also external shocks such as political instability in neighbouring countries, that have resulted for instance in an abrupt interruption of the gas supply and high increases in refugee numbers, increased tensions in Jordan's energy system and finally motivated decision makers to seek alternatives to fossil fuel imports and to strengthen the development of new and locally available energy sources. In consequence, Jordan has become one of the leading countries in the region (albeit far after Morocco) in setting up renewable energy projects in order to benefit from its vast renewable energy potential (RCREEE, 2015). But also the development of non-conventional fossil fuel resources such as shale oil and gas as well as nuclear power forms part of Jordan's political strategies and gains momentum. Against that background, the country currently stands at the crossroads of the development of a future energy system.

In the following, we will assess these developments and the current status of Jordan's energy transition based on the proposed phase model in more detail.

6.1 Categorization of the Energy System Transformation in Jordan According to the Phase Model

6.1.1 Assessment of State and Trends at the System Level

In the following, we discuss the current state and trends of Jordan's energy system along the dimensions supply, demand, infrastructure, actor network and market developments.

Today, the energy mix in the country is still highly dominated by fossil fuels, while renewable energies in total had a share of only 5 % in the energy mix in 2017 (MEMR, 2018). However, the country has successfully implemented a Renewable Energy and Energy Efficiency Law (REEEL) that sets the legal framework for supporting the development of renewable energy power plants and has formulated the National Energy Strategy Plan (2007-2020) that targets a renewable energy share of 10 % in the energy mix by 2020. This was accompanied by reforms in the energy sector such as the reduction of subsidies for electricity and fuel. This strategy has already seen successes. Jordan experienced a strong development of renewable energy projects during the last years. At the end of 2017, the installed power capacity of RE amounted to 736 MW (16% of total installed power generation capacity), while in 2014 the installed capacity of RE was still negligible (Climatescope, 2018). Most of the newly installed RE capacity stems from solar power. Furthermore, after having set a limited feed-in tariff for renewable energy generation already earlier, the country has recently successfully completed three rounds of auctions of licences for wind power (430 MW) and solar power (400 MW) plants that are currently under development and should be commercially operated by 2021 (MEMR, 2017a). In addition, several individual large-scale solar power projects have been allocated to international project consortia for

11 MEMR indicated a final energy consumption of 6,868 toe. We used the IEA unit converter to convert this into TJ (https://www.iea.org/statistics/resources/unitconverter/).

development. Furthermore, the country increasingly supports waste-to-energy projects, and supports the application of renewable energies in water system pumping stations.

Due to the rapid increase in the power demand in Jordan's energy system, driven by high population growth and economic development, currently no real replacement of established fossil fuel capacities takes place. The energy system rather follows an extension of the overall energy system instead of a transformation of existing energy structures.

Concerning Jordan's electricity grid, it currently has a limited capacity of 3,200 MW (with the possibility to manage additional 500 MW). But the country has plans to expand the national grid by 1,000 MW, employing loans and grants from international donors (Abdul Rahim, 2015) . This includes the establishment of the so-called 'Green Corridor', a grid extension aiming at the transport of power generated from renewable energies from the South of the country to the populated Central and Northern regions (Leading Edge, 2018). Yet, further grid investment is needed, going beyond the current statements on future grid extension (Climatescope, 2018). Furthermore, RE projects benefit from preferential grid-access conditions (guaranteed access) for RE projects, though no priority access is granted. Another facilitator for RE projects consists in the adoption of technical guidelines to connect RE systems to the grid (RCREEE, 2015).

Jordan has a public and a private actor network around RE. At the political level, the responsible actor for RE policy is the Renewable Energy Department at the Ministry of Energy and Mineral Resources (MEMR). A key institutional stakeholder in RE research is the National Energy Research Center (NERC) (RCREEE 2015). At the economic/market level, the following organizations are of importance: the state-owned National Electric Power Company (NEPCO) is the only actor responsible for the transmission system and for securing the power supply. NEPCO is the key stakeholder in the power system. However, the spectrum of electricity generating companies has widened, as well as the number of distribution companies, which has amounted to three (JEPCO, IDECO and EDCO) (MEMR, 2017a). So far, the unbundling of the Jordanian power sector has thus succeeded insofar as there are distinct actors for electricity generation, transmission, distribution and retail. However, Jordan still has a single-buyer system (NEPCO), which is a hindrance to the decentralization of the energy system (Climatescope, 2018).

Already in 2014, Jordan introduced net metering (rooftop systems) and wheeling regulations (Climatescope, 2018). Thereby, small scale consumers got the opportunity to produce their own electricity and to sell the potential surplus to the distribution utilities at a fixed tariff (MEMR, 2017b). So far, small-scale renewable energy installations have reached a total of 153 MW (produced by households, universities, commercial and industrial enterprises, government institutions, schools, mosques, churches, telecommunication companies, banks, CBOs, hospitals, farms, etc.) (MEMR, 2017a). But in practice, net-metering is only viable for a small share of consumers paying high tariffs, whilst industry and lower bracket consumers cannot afford it (Greenpeace, 2013). The net metering scheme applies to all RE systems up to 5 MW. However, the policy does not define the day/night/peak capacity tariff structure in detail (RCREEE, 2015).

Nowadays, Jordan is one of the most prominent countries in the MENA region regarding the advancement of e-mobility (El Issa, 2017). This is due to a favourable tax system, favouring electric/hybrid cars over conventional cars by exempting electric cars from registration fees, tax and import tariffs (Jordan Times, 2015a), or by exempting charging devices from customs duties and sales tax (Jordan Times, 2015b), and an important extension of e-mobility infrastructures (charging infrastructure, for example) (Roya News, 2018). However, as of 2017, the country's 3,586 registered electric vehicles can be charged only in 8 stations distributed across the country (El Issa, 2017). With these measures to support e-mobility, Jordan has already taken a first step towards sector coupling activities in the by far dominating transport sector regarding the share of energy consumption in the energy system.

The momentum of renewable energy potential is currently high in Jordan. However, Jordan's energy strategy also includes a significant share of non-conventional energy resources such as shale oil as well as nuclear power. The Ministry of Energy and Mineral Resources (MEMR) has already set guidelines for shale oil exploitation, and a share of 12% of shale oil in the energy mix in 2020 is projected (MEMR, 2017a). Furthermore, several companies have already been founded with the focus on shale oil exploitation in Jordan. Also, the development of nuclear power has gained momentum during the last years and is explicitly mentioned in the National Energy Strategy Plan, to address electricity demand and future challenges regarding water desalination. The latter constitutes a special purpose of nuclear power development in strategies, although even renewable energies could be easily applied in that context. For developing and promoting nuclear power, the Jordan Atomic Energy Commission has been founded in 2008.

All in all, with the still dominating focus on fossil fuels in the power sector, the still minor but fast growing importance of renewable energies in the energy system, and regulations for market and grid access of renewables-based electricity being in place, we classify the current status of the Jordanian energy system transformation as being in the first phase of the energy transition model. RE shares are still small and grid expansion and retrofitting has not yet been accomplished, therefore we believe that Jordan will remain in phase 1 for some more years. In deviation from the development suggested by the phase model, Jordan has already partly entered phase 2 regarding the direct electrification of mobility, but the share of e-mobility is still very low and the needed infrastructure hardly exists, yet. Therefore, although first programs already exist, the transformation of the mobility sector is still in a very early stage.

We will have a more detailed look into the niche level in the following to understand whether preparations for entering the second phase of the transition model are made.

6.1.2 Assessment of Trends and Developments at the Niche Level

For successfully achieving the next stage of the energy transition, the phase model suggests that certain developments should take place on the niche level during phase 1 *(see Table 5-2)*:

Jordan so far displays moderate advances in one of the aforementioned dimensions: in the regional potential of flexibility options, represented by battery storage projects and e-mobility.

Concerning battery storage, Jordan's MEMR issued a Request for Submissions of Interest (REOI) in July 2017 for an electricity and energy storage project in the Ma'an Development Area with a capacity of 30 MW to store 60 MWh of electricity. The list of the qualified companies was announced at the end of 2017 and the project is expected to be operational by the end of 2019 (MEMR, 2017a). Also, the solar energy provider Philadelphia Solar has announced plans to develop a battery storage system at a large-scale solar generation plant in the Mid-East region (CNESA, 2018). This illustrates the development of first pilot projects.

The diffusion of electric vehicles in Jordan is a step towards system integration via direct electrification. The timing of charging of batteries of electric cars and the option to use those as storage provide a potential for future flexibility for the electricity sector. According to our knowledge, such storage options as well as the development and testing of smart grid technologies are hardly discussed in Jordan, yet.

6.1.3 Next Steps Needed for Achieving the Second Phase

For reaching the second phase of the energy transition – system integration –, the efforts in the field of flexibility have to be increased, especially with view to exploration of business models and the exploration of flexibility options that have been mostly neglected so far, such as demand side flexibility, and different energy storage options beyond battery storage (e.g. pumped storage or power-to-gas). Furthermore, a strengthening of the transmission and distribution networks, and the improvement of the system operation principles (e.g. improvement of market integration by the expansion of market and control zones) are required (Papaefthymiou et al., 2014). In addition, flexibility options should be an integrated part of energy system development programs and strategies and the respective regulations should be concretized, for example by defining tariffs for different circumstances (peak/night, etc.). Also, visions of a transnational system integration should be developed.

Concerning the digitalization of the energy system, investment, technology, and know-how need to be transferred from the global level to Jordan's energy system. Pilot projects such as for instance virtual power plants or smart grids should be developed and launched. With view to e-mobility and battery storage, the current efforts are already considerable, but should be enhanced. Especially the charging infrastructure is insufficient and needs to be extended.

With view to a market-design for accommodating flexibility options, Jordan should create incentives for the provision of flexibility. These may consist of improving the local market conditions, by removing network constraints in order to increase system size, which would allow a more efficient use of flexibility resources. In this context, it is important to extend the market size to the neighboring markets. The prerequisite is physical access to neighboring markets via grid capacity and the existence of market rules that allow cross-border trading of flexibility (Papaefthymiou et al., 2014). However, there are severe obstacles concerning cross-border and transnational grid extension, as the neighboring countries experience political insecurity or even open conflict. A transnational consortium is needed for neighboring countries to conjunctly agree on a transnational grid development. Also, further investment is needed.

The second phase also comprises the alignment of regulations concerning electricity, mobility and heat. In general, this requires an overall strategy aiming at sector coupling, which does currently not exist in Jordan.[12]

6.2 Outlook to the Next Phases of the Transition Process

As we have analyzed above, Jordan has already made considerable progress in the field of renewable energies, their economic and legal frameworks. With the National Energy Strategy Plan, a useful short- to mid-term concept already exists in Jordan to address challenges in the energy sector. Following the current diversity of technologies, the strategy provides orientation for the most important needs of the country to reduce dependencies from energy imports and the related increasing expenses, but also to satisfy the rapidly increasing demand for energy especially in the power sector. This results in the growing installation of renewable energies, but also in the exploitation of further technological options such as shale oil and nuclear power, which might not only create new path dependencies in the energy system but also potential dependencies from foreign technologies and know-how that can not be adopted properly by the Jordanian industry. This is different to RE technologies as already several examples show how local industries successfully integrated production processes into their business models. The investment in nuclear power and shale oil plants, both with lifetimes up to several decades, constitutes an obstacle to a sustainable energy system transition, which, according to our phase model, would consist in ever increasing shares of renewable energies up to 100 %. This can only be achieved through investment in flexibility options, (trans-national) grid extension, the digitalization of the energy system, the electrification of diverse sectors (transport, industry, buildings), power-to-X solutions, and the development of according business models. In particular, a nuclear power plant with very limited ability to adapt electricity production to volatile electricity feed-in from renewables

12 A more detailed analysis of the respective policy frameworks and regulations cannot be undertaken in this frame and needs further research.

seems to be incompatible with a transition towards a renewables-based energy system already in the mid-term – at the latest in phase 3 when negative residual loads occur frequently.

Against that background, the current National Energy Strategy Plan does not provide an integrated long-term approach considering the entire energy system and the longterm objectives of a transition towards a fully renewables-based energy system. However, according to the proposed phase model, the consideration of the entire energy system over long time periods is necessary to prepare for later phases in a timely manner and to achieve a smooth transition. Therefore, we suggest setting up such a long-term strategy for Jordan. The ground for such a long-term vision needs to laid rather sooner than later.

Table 6-1 summarizes Jordan's current status in the energy system transition and an outlook on the following steps.

Niche Level Before ***Phase 1 (Take-off)***	***Phase 1: Take-off***	Niche Level Before ***Phase 2 (System Integration)***
Local experiments with RE	Regulations and price schemes for RE	Assessment of regional potentials of different flexibility options
Formation of RE related actor networks	Market introduction of RE	Experiments with flexibility options
Assessment of RE potential	Extension and retrofitting of electricity grid	Exploration of business models around flexibility including ICT start-ups and new digital business models for sector coupling
Development of visions for RE extensions	RE does not replace fossil fuels	Development of visions for flex-market and energy system integration (regional and transnational energy markets)
		Formation of actor networks around flexibility across electricity, mobility, heat sectors

Table 6-1: Overview of Jordan's status in the energy system transition model

Starting from the hypothesis that an enhanced understanding and structured vision of a transition towards a fully renewables-based energy system is useful to support energy system transitions in MENA countries, we have developed a phase model for that purpose. To develop the model, we amended phase models that have been developed for Germany, and complemented those by insights from the field of transitions research.

The resulting proposed phase model for energy transitions in MENA countries includes four phases ("take-off RE", "system integration", "PtF/G", "Towards 100% Renewable"), each of which is characterized by a different cluster of innovations that shapes the respective phase. These innovations enter the system via three "stages" of development which describe different levels of maturity and market penetration of the innovations. While the four phases provide a structured overview over the longterm system development and support target setting, the stages complement this perspective through hinting at necessary developments to achieve those targets, and at governance approaches for supporting these developments.

From our explorative application of the model to Jordan, we conclude that the model is useful to structure the many on-going developments in Jordan's energy system, and to provide insights into necessary next steps to transform Jordan's energy system into a renewables-based system. As such, we claim that it fulfils its purpose and can be used to support discussions about strategies and policy-making.

It should be noted, however, that the application of the model to Jordan in the context of the current study was based on prior experiences of the involved research staff and literature research only. An extended application including stakeholders from Jordan would probably allow for deeper and more detailed insights. Furthermore, a future application of the model to other countries would be required to test the flexibility of the model regarding its ability to accommodate the situation in different countries, and the robustness of its main assumptions for larger parts of the MENA region.

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