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Renewable energy expansion in the MENA region: A review of concepts and indicators for a transition towards sustainable energy supply.

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Abstract

In the light of the tremendous challenges facing the energy systems of the Middle East and North Africa (MENA), a number of concepts, roadmaps and scenario studies have emerged, describing potential transformation pathways towards a more sustainable, renewable-based, energy supply future in the region. Our article uses the scientific approach of 'transition research' to analyze the most pertinent publications and concepts in this field to identify the key drivers and barriers for the transformation of the regional energy systems. The analysis likewise includes an assessment of possible indicators and indexes that can be used to monitor the sustainability of the transformation process of MENA energy systems.

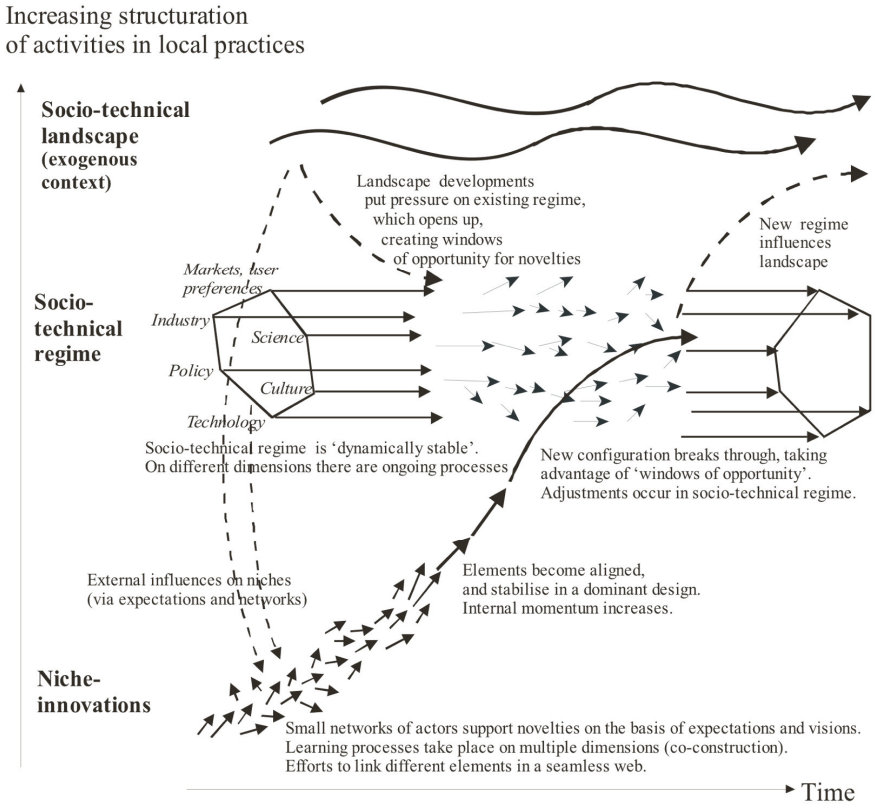
1. Introduction

The energy systems of the MENA region stand at historical crossroads. A multitude of pressures is challenging the incumbent, fossil fuel-based supply structures: soaring demand, increasing energy costs and, especially, the aspirations of the Arab Spring, with its demands for more welfare, participation and sustainable development for the MENA populations. Renewable energies, having experienced tremendous technological progress and cost decreases, are certainly one of the most promising drivers for the imminent energy transition. In the whole MENA region, a constantly growing network of private and institutional actors - today even governments - supports the implementation of renewable energy projects. But, obviously, there are also barriers to a sustainable transformation of the regional energy systems: Political instability, civil wars, mistrust, regulatory barriers and lack of international cooperation could be reasons for stalled sustainability efforts and adherence to the status quo. This paper sets out to provide a deeper understanding of MENA energy transformation processes, as well as their drivers and barriers. In the first part of the article, we present the conceptual framework of 'transition research' as a method to delineate patterns of MENA energy transition. This method is applied to analyze three prominent roadmaps and scenario studies on MENA energy systems. Providing a deeper understanding of the drivers and barriers of transition processes is a very valuable exercise, but it remains merely theoretical if it is not possible to actually 'monitor' or 'measure' the level of sustainability in an energy system. Therefore, in the second part of the paper, we discuss methodologies for (empirically) assessing sustainable transformation in the MENA countries.

2. Transition research theory in the context of MENA energy systems

Transition research explores processes and strategies of change towards more sustainable lifestyles and production/consumption patterns in our society. This relatively young academic concept first became popular in the Netherlands (Kemp et al. 2007; Loorbach 2007; Grin et al. 2010) but is increasingly being taken up also by scholars of other regions in the world. The central aim of transition research is to understand complex techno-social systems from an integrated, multi-level system perspective (Loorbach and Rotmans, 2010a). A very popular approach to this end has been provided by Geels (2002), who identifies transformation processes as results of interactions between three different transition levels: 'niche innovations', 'socio-technical regime' and the 'socio-technical landscape' (see Fig. 1)

Fig 1. Illustration of the multi-level perspective on transitions. Source: Geels, 2002.



On the micro-level, niche innovations (for instance, new technologies, small networks of actors) play a central role by taking advantage of windows of opportunity for novelties according to internal momentum, learning processes, support measures, and price/performance improvements. Combined with exogenous changes at the macro- or 'landscape level' (e.g., geopolitical and broad economic trends, emigration, environmental problems, …), pressure is exerted on the prevailing regime (the 'socio-technical regime' at the meso-level), thus leading to dynamic transformations of the existing practices and structures in policy making, markets, industry, technology and culture (Geels and Schot, 2007). Geels' multi-level approach can also help to unfold transformation processes in the field of sustainable energy systems - an area where transition research has generally met 'fertile ground' in the last years (Chappin and Ligtvoet, 2013).

Knowledge from different scientific disciplines is essential to understand and describe transitions of real energy systems. This kind of knowledge can be categorized into system, target and transformation knowledge. While 'system knowledge' helps to understand socio-technical systems in their natural environment, 'target knowledge' is needed to define common socio-ecological objectives for achieving sustainability. 'Transformation knowledge', the third and central knowledge pillar, helps to unveil and describe the underlying processes of complex societal transitions.

Our article uses concepts of transition research theory, particularly Geels' multi-level typology, to reveal the most relevant drivers and barriers of sustainable energy system transformation in the MENA region.

3. Review of energy system transformation concepts for the MENA region

In this chapter, we analyze three concepts/publications displaying different views on energy transformations in the MENA region: First, a study published by the private sector initiative Dii promoting the 'Desertec' concept; second, the 'Mediterranean Solar Plan', a political roadmap being proposed by the Union for the Mediterranean (UfM), and, third, a scenario study of researchers from the University of Athens, Greece, who analyzed the impact of different macro-economic frameworks on the transformation pathways of MENA energy systems.

3.1. Desert Power: Getting Started (Dii, 2013)

Drawing its principal motivation from the prominent 'Desertec' concept, this roadmap study by the Desertec Industrial Initiative (Dii) investigates the feasibility of a mainly renewable-based electricity supply scheme for the EU-MENA power systems. By means of a cost-optimizing economic model, it shows that the MENA countries can supply themselves almost entirely with domestic renewable energies (98% renewable share in MENA electricity generation) by 2050 and even export approximately 20% of their generated electricity to the EU. The study identifies a number of drivers sustaining the argument that a transformation towards such an end-state is possible: First, there is the economical attractiveness and technical viability of the concept. In the long run, the continuously falling technology costs render renewable electricity generation cost-competitive with fossil-fuel power, enabling a progressive replacement of conventional mid- and base-load plants by wind, PV and CSP power plants. This process is facilitated by a powerful intercontinental transmission system through which regional heterogeneities of intermittent, renewable power generation can be leveled out more easily. The main driver for MENA electricity exports to Europe is the generally higher renewable energy potential - notably solar energy - in the South. Backed by these 'model-proven' findings, Dii argues - not surprising for a private industry initiative - that the power system transformation can (and should) be market-driven. Nevertheless, the study does not omit to mention non-economic barriers to system transformation, such as legal uncertainty, limited market and land access, and institutional barriers due to the currently widespread state ownership and state control of the electricity markets in the MENA region. This is why Dii's 'Getting Started' study is calling for a progressive adoption of a common legal and regulatory framework for renewable energies as a long-term goal for EU-MENA-wide electricity markets.

3.2. The Mediterranean Solar Plan (UfM, 2013)

The Mediterranean Solar Plan (MSP), a flagship initiative of the Union for the Mediterranean[1] (UfM), has likewise subscribed to a sustainability vision for the EU-MENA energy systems. According to the MSP roadmap, drivers towards more sustainability are the the incremental creation of markets for renewable energies, the possibility of electricity exports from MENA to Europe, and also increased efforts to improve energy efficiency. For the short run, until 2020, the MSP envisages a target of 20 GW of renewable generation capacity in the southern Mediterranean countries, to be realized by implementing so-called 'MSP pilot projects'. The MSP roadmap also identifies barriers inhibiting the desired change: missing regulatory framework, generally low economic attractiveness for renewable energy projects due to high financial barriers (high upfront costs) and low fossil fuel prices (fossil energy subsidies). Further obstacles are limited institutional capacity and a low number of specialized firms and staff in MENA to carry out renewable power projects. The MSP roadmap proposes several key actions to overcome these barriers: improving and developing policy and regulatory frameworks for energy on a transnational level; strengthening financial support for renewable energy projects; supporting capacity building and industrial development; and developing new electricity infrastructures ('transmission corridors') between Europe and MENA. However, despite a general consensus about its overall goals, the MSP roadmap has not yet succeeded in convincing all UfM members. At the end of 2013, the entire process experienced a serious setback, when Southern European countries overtly opposed the MSP concept of renewable power transmission through their territories, fearing not only high burdens of infrastructure investments in their countries but also low benefits, as the scheme of renewable power from North Africa would consequently turn them into mere energy transit countries. This example clearly demonstrates the dilemma of multilateral approaches: On the one hand, multilateralism is needed for the development of transnational transition frameworks; on the other hand, their complex and protracted consensus-finding processes can also be regarded as a hindrance for the transition of the energy systems.

3.3. Model-based analysis of future strategies for the MENA energy systems (Fragkos et al. , 2012)

The scenario analysis of Fragkos et al. (2012) explores how macro-economic and political high-level trends can influence the transformation of energy supply systems of MENA countries[2]. The authors present four scenarios until 2030, each assuming different framework conditions for the transformation process: the geopolitical situation, international cooperation, investment conditions, or the motivation for climate action to reduce carbon emissions. Other distinguishing assumptions are the different attitudes of MENA countries towards energy price reforms (removal of energy subsidies), electricity exports, renewable energy support policies, energy efficiency standards or Emission Trading Scheme (ETS) with the EU.

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[1] The Union for the Mediterranean is a multi-lateral political partnership created in 2008 between the EU and 16 southern Mediterranean countries.

[2] Fragkos et al., focus on the "MED-9" region comprising Algeria, Morocco, Tunisia, Egypt, Libya, Israel, Syria, Lebanon and Jordan.

The "Reference Scenario", for instance, rests on the assumption that the MENA countries continue their current energy policies of only weak efforts towards international energy cooperation, feeble climate action and low support for renewable energies. Conversely, the "MED-EU Initiatives Scenario" is driven by the outlook for integrated climate and energy policies with the EU and the promotion of renewable electricity through EU-supported feed-in-tariffs. High ETS carbon prices and electricity exports from MENA to Europe are additional features of this scenario. Fragkos' "Global Integration Scenario" assumes less cooperation with the EU but an enhanced integration of the MENA energy systems into a global, multilateral context. In this scenario, renewable energy deployment is seen as a response to price pressures on international energy markets and as a vehicle to decrease import dependence from fossil fuels (for those MENA countries being net importers of energy). The "Global Integration Scenario" also imagines a significantly improved investment climate, price reforms and energy efficiency standards in MENA countries, as well as 'multiple decentralized actions' for renewable energies, often at a small scale local level, as bottom-up attempts for energy system transformation. The most pessimistic scenario, the "Fragmentation Scenario", is characterized by conflicts, instability and policy failures, ultimately worsening the investment climate in the MENA region. Renewable energies suffer from delayed support, whereas fossil fuel subsidies remain in place, consequently leading to an expansion of carbon-intensive power generation.

4. Challenges and drivers for the sustainable transformation of the energy system

With the findings of the previous chapter and by using the concept of a multi-level perspective (MLP), it is possible to identify and classify for each level - niche innovation, regime, landscape - the most relevant drivers and barriers of the transition process for the energy systems in the MENA region.

Niche innovation level

At the niche innovation level, the energy transition process can be proactively driven by stakeholders from industry or society. They can create 'bottom-up' pressure on the incumbent energy regimes by introducing technological innovations, applying new collaboration schemes or by advocating for the cause of renewable energies.

Dii, being such an advocacy organization, underscores in its recent report (Dii, 2013) that renewable technologies have reached in the recent years an unprecedented level of maturity and cost-effectiveness, which can be seen as a pressure exerted from the niche-level to the regime-level of prevailing conventional energy markets and energy policies. The Dii study provides detailed information about the economic attractiveness and technical feasibility of the transformation to an integrated, renewable-based EU-MENA energy system and, furthermore, identifies renewable electricity exports to EU as a potential driver for energy system transformation in the MENA region. Another aspect to mention is real-term experiments in form of pilot projects, such as those proposed by the Mediterranean Solar Plan (UfM, 2013). Pilot projects (e.g., first solar power plants or wind farms in MENA countries) can likewise be understood as drivers of change originating from the niche level: Pilot projects remove barriers by increasing the trust in the technology, prepare the ground for further projects and generally increase the transferability of project experience to other domains through 'learning-by-doing'

processes. Large 'national' renewable power projects (or roadmaps) can trigger a 'competition for prestige' among the MENA countries, which could further accelerate the diffusion of renewable energies in the region. But iconic large-scale renewable energy projects are not the only challenge to the existing market and technology regimes; so can multiple decentralized small-scale projects, like those pointed out by Fragkos et al. (2012) contribute to the transformation of the energy systems as well

Obviously, the success of the transition towards renewable-based energy systems is also challenged by barriers. On the niche level, these barriers could be, for example, the competition of fossil or nuclear energy technologies. As mentioned by Fragkos et al., the recent innovations in the exploration of shale gas/oil have triggered deliberations as to whether the MENA region should also apply these technologies and set up pilot shale gas/oil exploration or extraction projects. The nuclear option is also - despite the Fukushima disaster - still frequently discussed in MENA countries and receives strong support by nuclear industry initiatives worldwide.

Landscape level

Drivers and barriers at the landscape level are external or unexpected developments, which usually cannot be influenced by stakeholders from policy, industry and society.

Examples are demographic change, increasing/decreasing fossil fuel prices, external shocks or climate change. Dii (2013), and Fragkos et al. (2012) take account of such external pressures in their scenario assumptions for MENA energy system transformation. Demographic growth is seen an important exogenous parameter driving the energy demand: Fossil fuel prices are directly linked to questions of energy security in many energy-importing MENA countries. Fragkos' "Fragmentation Scenario" is very instructive in this regard. It describes how increasing energy demand and fossil fuel imports can endanger the energy security of MENA countries. 'External shocks' can additionally impair the prospects for sustainable energy systems, because instability and political conflicts generally lead to higher risk premiums and a generalized capital shortage. Consequently, countries could become constrained to maintain their existing conventional energy supply strategies. The recent developments in Jordan after the 'Arab Spring' are an instructive example for this pattern: Before the year 2011, Jordan had operated most of its electric power plants with natural gas from Egypt. After terrorist attacks on pipelines in Egypt, Jordan's gas supply has become almost totally interrupted, and this amid a phase of skyrocketing electricity demand caused by hundreds of thousands Syrian civil war refugees currently settling in the country. The precarious energy situation has already constrained Jordan to fall back on imported liquid fuels (diesel and fuel oil) for electricity generation. It remains to be seen whether these external pressures also incentivize the exploration of domestic fossil fuel reserves in the country or even lead to a more vigorous pursuit of nuclear power projects. On the other hand, shortages or dramatically increasing prices for fossil fuels can also be seen as drivers for a transformation towards more renewable energies - at least in MENA countries that depend on energy imports.

Regime level

As described above and illustrated in Fig. 1, pressures from the niche innovation level (micro level) or the landscape level (macro level) can trigger dynamic adjustments at the level of the existing energy regime (meso level). A precondition for these

adjustments to occur is that upcoming trends - macro trends and niche innovations - are actually recognized and picked up by the stakeholders. On the regime level, the most relevant group of stakeholders includes players from the political arena. This is quite obvious, because the MENA energy markets are still mainly state-controlled. Consequently, it is, at the current stage, mainly the national governments who can implement renewable support mechanisms, enact new regulatory frameworks, or decide upon energy price reforms and energy efficiency standards. Nevertheless, changes at the regime level could also be catalyzed by transnational governance. Dii (2013) and the roadmap for the Mediterranean Solar Plan (UfM, 2013) point to the importance of multilateralism and trans-governmental institutions, such the Union for the Mediterranean (UfM) and the Arab League, as well as transnational organizations like the Association of Mediterranean Electricity Regulators (MED-REG), or the Mediterranean Network of Transmission System Operators (MED-TSO). Interactions between these institutions are seen as an important driver for a sustainable energy system transformation - if they successfully find arrangements for cooperation, like the establishment of common regulatory frameworks or infrastructure roadmaps for large transcontinental electricity transmission systems across the EU-MENA region.

Potential barriers for the uptake of renewable energy strategies at the regime level are that political (but also industrial) stakeholders either ignore current trends or show no willingness to pick them up. Possible reasons for this could be a lack of information, general mistrust in renewable technologies, or simply strategic behaviour: Particularly in MENA countries, vested interests are very common between the political elite and the oil and gas sector, as well as the electricity utilities. On the international level, a similar pattern of strategic behaviour can be observed if national governments try to enforce their particular interests within multilateral negotiations about transnational support frameworks for renewable energies. That such difficulties can actually occur in practice has been very clearly demonstrated by the recently failed consensus finding for an MSP roadmap at the end of 2013 (see section 3.2). Finally, financial barriers must also be noted. Investors consider renewable energy projects still relatively risky because of the high upfront cost for renewable technologies and the generally insecure market and investment conditions in the MENA region.

Tables 1 and 2 summarize the previously described drivers and barriers for sustainable energy transformation in the MENA region. It must be mentioned that the approach of classifying them according to Geels' multi-level perspective can only give a very simplified understanding of the actually underlying processes of transformation. Barriers and drivers interfere with each other and can mutually reinforce or slow down the dynamics of the transformation process. Moreover, the assessment of only three transformation concepts/studies (Dii, 2013, UfM, 2013, and Fragkos et al., 2012) is certainly not enough to provide a full picture of all drivers and barriers influencing the energy transitions in the MENA countries. More extensive research in this field - possibly by taking account of an enlarged set of scenario studies - would be highly desirable.

Table 1: Drivers for a sustainable transformation of the MENA energy systems

Drivers at "niche innovation level"	Drivers at "regime level"	Drivers at "landscape level"
Innovations and falling cost of renewable energy technologies. Improved knowledge of economic impact of renewable energy supply. Support at small-scale/local level Emergence of renewable energy advocacy organizations in MENA Pilot projects / learning-by-doing	Stakeholders picking up on trends. Willingness of policy makers to support energy system transformation. Implementation of legal and regulatory frameworks Transnational efforts to expand transmission systems . Market liberalization / energy price reforms Capacity building Improved investment conditions	Demographic development (growing energy demand) Increasing fossil fuel prices Difficult fossil fuel supply Climate change The population's welfare and sustainability aspirations Political upheavals

Table 2: Barriers for a sustainable transformation of the MENA energy systems

Barriers at "niche innovation level"	Barriers at "regime level"	Barriers at "landscape level"
Innovations in competing technologies, e.g., shale gas explorations in MENA Nuclear industry initiatives	Policy makers ignore trends and try to keep existing energy system Industry cannot adapt trends in their innovation process Vested interest of stakeholders with conventional energy sector Strategic behavior by governments Difficult finance situation	Low fossil fuel prices Exploration of new fossil fuel deposits

5. Measuring the sustainability of energy systems in the MENA countries

Considering the diversity of the MENA countries and the multitude of drivers and barriers interacting on the different transformation levels, it can be expected that the region's energy systems will transform in a rather nonlinear and heterogeneous manner. How can we monitor the process of the transformation and assess its country-specific differences? Economic science often uses indexes to compare the economic performance of different countries. Indeed, there have been attempts to also develop such indexes for the assessment of the sustainability of energy systems, some even with special focus on the MENA countries. This section presents three indexes and discusses their suitability to mirror energy transformations in the MENA region.

5.1. World Energy Council: Energy Sustainability Index (WEC, 2012)

The 'Energy Sustainability Index', published by the World Energy Council (WEC), regularly evaluates the energy situation of the 91 WEC member countries. WEC calculates the index as a weighted average of different characteristic indicators, most essentially those related to the 'three dimensions of energy sustainability' that WEC defines as energy security, social equity, and environmental impact. Additionally, but

with lower weights, the index also incorporates the general social, political and macro-economic parameters of each scrutinized country. The resulting scores allow a ranking of the 91 countries. In WEC's latest index (2012), the analyzed MENA countries[3] all received relatively poor results, placing them only at ranks between 44 (Qatar) and 88 (Libya). WEC explains the weak performance by a generally feeble energy security in the MENA region (insufficiently diversified electricity production, underinvestment in infrastructure and regulatory barriers), as well as by a poor environmental performance of the energy systems due to high pollution and CO2 emission intensity. On the positive side, WEC acknowledges a relatively good social performance of MENA energy supply, because the high fossil fuel resource endowment enables many MENA countries to provide their populations with cheap and hence affordable energy. This argument, however, conceals that low energy prices are usually backed by oil and gas subsidies, which are generally known as a barriers to the deployment of renewable energy and energy efficiency. A further weakness of the WEC index is that renewable energy deployment, with its potential for job creation and other socio economic benefits, is not considered an indicator for the sustainability of energy supply.

5.2. Arab Future Energy Index (RCREEE, 2013a,b)

In 2013, the Regional Center for Renewable Energy and Energy Efficiency (RCREEE) released the "Arab Future Energy Index" (AFEX), a sustainability index specifically dedicated to the MENA region. Covering a group of 13 MENA countries[4], AFEX provides two sustainability rankings, one for renewable energy (RCREEE, 2013a) and the other for energy efficiency (RCREEE, 2013b). Contrary to the WEC index, AFEX's aim is not to analyze the actual status of the energy systems but, rather, to provide an assessment of the *existing framework conditions* in the MENA countries. Consequently, APEX focuses on indicators assessing the countries' energy policy frameworks, their market structures, energy pricing schemes and institutional capacities (see Table 1 for details). The resulting rankings reveal the highest scores for Morocco (offering the best conditions for renewable energy deployment) and Tunisia (best in terms of energy efficiency), while Libya and Iraq share the lowest ranks. RCREEE's APEX index is a valuable tool for comparing the MENA countries' political and institutional framework conditions for renewable energies and energy efficiency; however, it has the drawback that it doesn't verify whether these framework conditions have actually led to changes in the status of sustainability in the energy systems.

5.3. Energy Transformation Index (ISE, 2013)

The Energy Transformation Index (ETI) of the Fraunhofer-Institut für Solare Energiesysteme (ISE) proposes a very simplified metric to measure the sustainability of a country's energy system. It is just based on two indicators, one measuring the progress of renewable energy deployment, the other quantifying the achievements in terms of energy efficiency. Renewable energy performance is defined as the share of renewable energy use in the total primary energy demand (PED), while energy efficiency is the ratio of the gross domestic product (GDP) and the PED.

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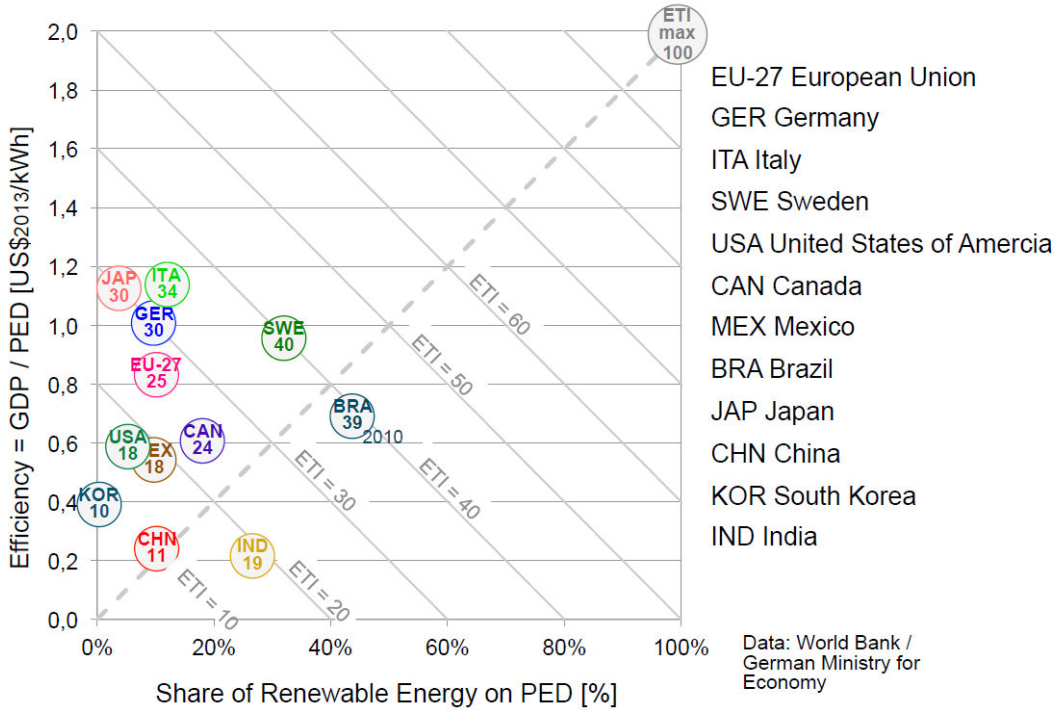
[3] MENA members of the World Energy Council: Algeria, Egypt, Iran, Israel, Jordan, Kuwait, Lebanon, Libya, Morocco, Qatar, Saudi Arabia, Syria, Tunisia, United Arab Emirates

[4] Countries are the RCREEE members Morocco, Jordan, Egypt, Palestine, Tunisia, Algeria, Lebanon, Syria, Bahrain, Sudan, Yemen, Libya and Iraq.

Fig 2. Energy Transformation Index. Source: ISE, 2013



Plotting these two indicators on an x-y chart (Fig. 2) enables an easy graphical comparison of the countries' different ETI statuses. Unfortunately, no countries of the MENA region have so far been included into the ETI. It can, nevertheless, be expected that they will also reach a relatively feeble rankings due to their generally low renewable share and relatively weak energy efficiency performance. The main advantage of the ETI index is that is uses a very straightforward and easily applicable method. However, one shortcoming worth mentioning is the too simplified perception that high renewable energy shares are an indicator for high sustainability. For instance, while high shares of biomass or hydro-power can also be ecologically and socially questionable (land use implications, conflict with food production, forced resettlement of populations), they would increase the overall sustainability rating in the ETI.

The three indexes described above all constitute suitable approaches to assess and compare the transformation of MENA countries' energy systems. What is missing at the current stage is a more thorough reflection on the actual link between the indexes' indicators and the goal of sustainability. Under which conditions can low energy prices be an indicator for sustainability? Is a high renewable share equivalent to sustainability of energy systems? These deliberations, of course, require a clearer definition of the term 'sustainability' in the context of the indexes. In our view, the social aspects of energy system transformation are also underrepresented in the index designs. This impairs the indexes' significance, particularly for the MENA region, where social acceptance, jobs, and added value creation for the local industries are also important issues. Further improvements to the current energy sustainability indexes in this direction are strongly encouraged.

Table 3. Key indicators (selection) of the energy sustainability indexes.

WEC Energy Sustainability Index (WEC, 2012)	RCREEE Arab Future Energy Index (RCREEE, 2013a,b)	Energy Transformation Index ETI (ISE, 2013)
Ratio of energy production to consumption	Policy framework	Share of renewable energy in primary energy demand (PED)
Energy consumption per GDP/capita	Market structure	Energy efficiency (GDP/PED)
CO2 emission intensity	Institutional capacity	
Population with access to electricity	Energy pricing	
Diversity of electricity generation	Utility capacity	
Energy affordability	Finance and investment conditions	
Political stability		
Macroeconomic stability		
Rule of law/control of corruption		

6. Conclusion and outlook

This paper intends to contribute to a better understanding of the transformation processes in MENA energy systems working towards more sustainability. We analyzed three key publications/concepts dedicated to scenarios and renewable energy roadmaps in the MENA regions in order to find the most relevant drivers of and barriers to the transformation process. By applying Geels' multi-level perspective, these drivers and barriers were categorized and examined for their relevance in the transformation process. The second part of the article addresses the question of whether the transformation of MENA energy systems can be measured by means of 'indexes'. On the basis of the three examples, it is shown that the so-called 'sustainability indexes' can, indeed, be a suitable tool to quantitatively monitor the dynamics of the transformation process. However, the analysis also revealed that the indicators by which these indexes are calculated do not fully reflect all dimensions of sustainability. Improved methodologies for index building should, therefore, incorporate additional indicators, such as the social aspects of energy supply, an increasingly important issue - especially for the MENA region,

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