Mainstreaming the water-energy-food security nexus into policies and institutions in the MENA region

Nexus Evidence Base

Critical nexus issues and inter-linkages between natural resources and human securities - opportunities for integrated approaches

Final Draft
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<tr>
<td>ACCWaM</td>
<td>Adaptation to Climate Change in the Water Sector in the MENA Region</td>
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<tr>
<td>AFED</td>
<td>Arab Forum for Environment and Development</td>
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<td>AOAD</td>
<td>Arab Organization for Agricultural Development</td>
</tr>
<tr>
<td>APACC</td>
<td>Arab Plan of Action to deal with Climate Change</td>
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<td>AWC</td>
<td>Arab Water Council</td>
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<tr>
<td>BMZ</td>
<td>Bundesministerium für wirtschaftliche Zusammenarbeit und Entwicklung (German Federal Ministry for Economic Cooperation and Development)</td>
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<tr>
<td>CAADP</td>
<td>Comprehensive Africa Agricultural Development Program</td>
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<tr>
<td>CEDARE</td>
<td>Centre for Environment and Development for the Arab Region and Europe</td>
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<tr>
<td>FAO</td>
<td>Food and Agriculture Organization of the United Nations</td>
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<td>GCC</td>
<td>Cooperation Council for the Arab States of the Gulf</td>
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<tr>
<td>GDP</td>
<td>Gross domestic product</td>
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<td>GEO6</td>
<td>Global Environmental Outlook</td>
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<td>GHG</td>
<td>Greenhouse Gas</td>
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<td>GIZ</td>
<td>Deutsche Gesellschaft für International Zusammenarbeit</td>
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<tr>
<td>ICBA</td>
<td>International Center for Biosaline Agriculture</td>
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<td>IEA</td>
<td>International Energy Agency</td>
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<td>IFPRI</td>
<td>International Food Policy Research Institute</td>
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<td>JD</td>
<td>Jordanian Dinar</td>
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<tr>
<td>LAS</td>
<td>League of Arab States</td>
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<tr>
<td>MEDRC</td>
<td>Middle East Desalination Research Center</td>
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<td>MEMEE</td>
<td>Moroccan Ministry of Energy, Mines, Water and Environment</td>
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<td>MENA</td>
<td>Middle East and North Africa</td>
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<td>MWI</td>
<td>Minister of Water and Irrigation</td>
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<td>NDC</td>
<td>Nationally Determined Contributions</td>
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<td>RCREEE</td>
<td>Regional Center for Renewable Energy and Energy Efficiency</td>
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<td>SDG</td>
<td>Sustainable Development Goals</td>
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<td>UAE</td>
<td>United Arab Emirates</td>
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<td>UN</td>
<td>United Nations</td>
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<td>UNEP</td>
<td>United Nations Environment Programme</td>
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<td>UNESCWA</td>
<td>United Nations Economic and Social Commission for Western Asia</td>
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<td>WEF</td>
<td>Water, Energy and Food Security Nexus</td>
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<td>WWAP</td>
<td>World Water Assessment Programme</td>
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Executive summary

Pressures on water, land, energy and other natural resources and the environment are rapidly growing in the MENA region. This entails an intensification of their interdependencies and nexus risk and leads to threats to water, energy and food security. Conventional sectoral (or “silo”) governance and management approaches and incremental improvements are no longer able to meet these growing challenges.

The water-energy-food (WEF) security nexus approach means a change from business as usual and current mindsets, linking and adding value to existing sectoral approaches and expertise, that way reducing tradeoffs and promoting synergies.

The GIZ Programme “Adaptation to Climate Change in the Water Sector in the MENA Region” (ACCWaM) supports regional and national mainstreaming of the WEF nexus approach into policies and institutions.

This report provides an evidence base in support of a nexus approach and nexus mainstreaming into, and value adding to, regional and national policies and institutions in the MENA region. With that, it also promotes integrated SDG implementation and the integration of climate adaptation and mitigation. This evidence base has been developed in a participatory and iterative process with partners from all relevant sectors. Data and information have been synthesized from regional and national data bases, policies, strategies and action plans, interviews and meetings, and other forms of information exchange.

The main conclusions that can be drawn at this stage include:

- In general (cross-)resource use efficiencies in the MENA region are low. This is despite the extreme natural resources scarcity in large parts of the region, which should normally stimulate improvements in resource use efficiency. To a large extent, this situation is a result of very high (“blanket”) subsidies on resource use.

- As a result, per-capita resource use levels in some MENA countries, in particular in the GCC countries, are among the highest in the world. However, the region is strongly divided, with most of the non-GCC countries having per-capita resource uses below global average. Also in terms of human securities, e.g. food security, there are large differences with some MENA countries having high levels of stunting among children, others having equally high levels of obesity.

- There are a number of cross-resource trends that add pressure on water, land, energy and other resources. In particular the shift to non-conventional water resources generally increases energy intensity as well as GHGs emissions of the water sector. Energy transitions (to renewables) can be quite water intensive, while agricultural intensifications are often water and energy intensive.

- Nexus approaches, based on integrated resource governance and management, cascading use and recycling of water, land, energy and other natural resources can increase cross-resource use efficiencies and, as a consequence, improve human securities while reducing resource demand and costs (key elements of a Green Economy), which will eventually also support political stability.

- In addition to the quantitative analysis and identification of entry points for a nexus approach, we also provide anecdotal evidence of the benefits of the nexus approach from existing projects on the ground. All across the MENA region, including the three focus countries of this project, Jordan, Egypt, and Morocco, numerous pilot studies are underway which test nexus innovations and solutions and demonstrate nexus benefits. If up-scaled, these solutions may become affordable for all countries in the region, supporting their energy, agricultural and other sustainability transitions.
The nexus approach provides ample opportunities for cross-country sharing and up-scaling the technical, economic and institutional innovations, which are currently tested and implemented in individual countries. With that, the nexus approach also provides good opportunities for regional cooperation.

Given that nexus approaches are more complex than conventional sectoral management, there is a need to reduce and communicate (e.g. graphically) this complexity, and to build individual and institutional capacity accordingly.

We encourage continued further consolidation of this data and information or “evidence” base beyond the duration of this project, by all sectors and stakeholder groups and interested individuals. In particular the last section on “concrete opportunities for implementing the nexus approach” deserves constant amendment in line with the rapid progress on the ground.
1 Introduction

The Arab region is known to be energy rich, water scarce, food deficient, and one of the world’s most economically, socially and environmentally vulnerable regions to climate change. Institutional and policy coordination and coherence across the water, land, agriculture, and energy sectors can be improved with the help of a nexus approach, creating opportunities for better governance and management of these resources and associated human securities.

This report provides evidence in support of a nexus approach in the Arab region. It explores the regional and national situation in terms of natural resources (water, energy and land), human securities\(^1\) (water, energy, food) and critical nexus issues and interlinkages and between these resources and securities (Figure 1). In particular it identifies and quantifies tradeoffs\(^2\) related to conventional sectoral approaches and synergies\(^3\) related to a nexus approach. With that the report makes a case for improved coordination and collaboration among institutions and for improved policy coherence. It builds on the development of the nexus concept and its application since the Bonn nexus conference (Hoff 2011) and on numerous recent nexus publications (e.g., Mohtar et al. 2012; Howells et al. 2013; Flammini et al. 2014; UN-ECE 2015; and Al Zubari W. 2016). All of these publications suggest that a nexus or systemic approach, which is implemented by way of integrated resource management and governance, can improve human securities and development, while reducing pressures on resources and on the environment (i.e., a decoupling as stated in the Green Economy concept – UNEP 2011). Accordingly, a nexus approach which supports the integration across institutions and sectors, scales and borders, is an important contribution to sustainable development and eventually to political stability.

The Nexus Evidence Report is part of a series of studies and policy guides prepared within the project “Mainstreaming the Water-Energy-Food Security (WEF) Nexus into Policies and Institutions in the MENA Region”.\(^4\)

Figure 1: Interlinkages between natural resources and human securities (BMZ 2014)

This evidence base covers the Arab region\(^5\) as a whole, and it zooms in on selected Arab countries (Jordan, Egypt, and Morocco) which have expressed specific interest in mainstreaming a nexus approach into their policies and institutions for improving and adding value to these. Accordingly, the report addresses horizontal (cross-sectoral) and vertical (cross-scale) coordination, collaboration and integration. The evidence base starts from an overview on resource availability, access, quality, use efficiency, and other environmental, social, economic, institutional and policy aspects. In

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1 “Water security” has been defined by the UN as: sustainable access to adequate quantities of acceptable quality water for sustaining livelihoods, human well-being, and socio-economic development, “food security” has been defined by FAO as: availability and access to sufficient, safe and nutritious food to meet the dietary needs and food preferences for an active and healthy life, “energy security” has been defined by the UN as: ‘access to clean, reliable and affordable energy services for cooking and heating, lighting, communications and productive uses’

2 “Tradeoffs” mean that one (resource or security) is losing quality or availability in return for another one gaining

3 “Synergies” means that the total result (of a nexus approach and in terms of resource use efficiencies, availabilities and human securities) is greater than the simple sum of its individual parts (here strictly sectoral approaches)

4 Building upon the identified most critical nexus issues and interlinkages in this evidence base report, the project provides a Regional Policy Guide (Carus and Kramer 2017) and National Guidelines (Mansour et al. 2017) for WEF Nexus mainstreaming into policies and institutions in the MENA region.

5 Arab countries are according to the League of Arab States: Algeria, Bahrain, Comoros, Djibouti, Egypt, United Arab Emirates, Iraq, Jordan, Kuwait, Lebanon, Libya, Mauritania, Morocco, Palestine, Qatar, Syria, Oman, Saudi Arabia, Somalia, Sudan, Tunisia and Yemen
order to systematically make the case for a nexus approach, the following issues are addressed in this report, for the Arab region and for the three selected pilot countries of Jordan, Morocco and Egypt:

| 1. | The status and trends of natural resources scarcities, (in) efficiencies, and human (in)securities |
| 2. | The most critical nexus issues and interlinkages, synergies and tradeoffs (“hard choices”) between and among natural resources and human securities |
| 3. | What are the most important nexus risks and costs associated with conventional sectoral approaches which do not account for cross-sectoral and cross-scale inter-linkages? |
| 4. | Entry points and opportunities for a nexus approach, to promote synergies and co-benefits, and socio-economic and environmental and political gains, eventually also for regional cooperation |

**Identification of most critical interlinkages**

The following sections of this report explore - to the extent possible - these issues quantitatively and geographically: Chapter 2 takes stock of the status and trends of natural resources and human securities, as background for exploring critical interlinkages. Based on this stocktaking, the most critical nexus issues and interlinkages (according to expert opinions), as depicted by the arrows in Figure 1, are explored and quantified and illustrated for the respective regional or national contexts in Chapter 3. Chapter 4 specifies and quantifies risks and costs associated with conventional sectoral approaches that propagate across different resources, environment and human securities and eventually threaten sustainable development as associated with these critical interlinkages. Chapter 5 elaborates on entry points, opportunities and benefits associated with a nexus approach; e.g., in terms of multi-functional production systems, integrated climate adaptation and mitigation, integrated national SDG implementation for sustainable development and, eventually also for political stability.
2 Status, trends and future projections of resources scarcities, (in)efficiencies, and human (in)securities

The situation in terms of natural resources and human securities is further deteriorating in many parts of the region, due to a number of interacting factors, including among others inefficient resource use, lack of coordination and conflicts. This section informs about status, past and current trends of resources and human securities.

The Arab regional context (as a driver for resources consumption): The region is extremely water scarce, but rich in energy, in particular in sustainable renewable energy. Hardly any other region will be hit as hard by climate change as the Arab region, which will further aggravate water scarcity. Resource use efficiencies are mostly below world average and even decreasing (Schaffartzik et al. 2014\textsuperscript{6}). Inequality in terms of natural resources endowment and socio-economic development within countries, as well as between the countries of the region, is among the highest in the world (for spatial patterns and trends see Arab Human Development Report 2016). The Human Development Index ranges from 0.4 for Sudan to 0.85 for UAE. There are considerable human security deficits in parts of the region and LAS member countries.

Population growth rates are higher than in most other world regions (close to 2% per year region wide, even more than 2% in Egypt and Jordan, compared to a global average of 1.2%), causing rapidly growing demand for water, energy, food and other commodities, but also for jobs. The strain on resources in the Arab region is expected to continue due to rapid urbanization (currently 57% of the Arab population live in cities, with an expected increase of up to 75% by 2050) and the large young population (youth between 15 and 29 comprise more than 30% of the population), as well as the anticipated impacts of climate change.

Most of the Arab countries have had a long history of heavily subsidizing energy, water, and food, for a variety of reasons. The current low pricing policies of resources and the lack of incentives for rationalizing resource use promote unsustainable consumption and production patterns, leading to low resource use efficiency, overconsumption and severe resources depletion in most Arab countries.

2.1 Water resources and water security

The Arab region is one of the most water scarce regions in the world, with further growing resource scarcity. Consequently, water resources are severely overused, with eight Arab countries even using more than 100% of their renewable resources, often quickly depleting (fossil) groundwater resources (FAO 2017a). There is hardly any other world region in which water resources and water systems, are projected to be hit as hard by climate change as the MENA region (Waha 2017).

The majority of water resources in the region are being used for agriculture (85%), while the municipal and the industrial sectors consume about 8% and 7% of the total water use, respectively (World Databank 2011, UNDP 2013).

Despite the extreme water scarcity, the region is not using its water resources efficiently. Water use efficiencies are very low compared to global averages. Also irrigation efficiency in the agricultural sector is low, averaging around 45%, resulting also in low crop productivity, particularly for staple cereals, averaging only slightly more than 1 t/ha in the five major cereal producing countries (Algeria, Iraq, Morocco, Sudan, and Syria). The global average productivity is more than 3 times higher than that, and the most productive countries produce up to about 10 t/ha. In terms of agricultural water use, efficiency there is up to a factor of 10 and more difference between for example Germany (0.1 liter of water consumed per kcal produced) and Arab countries such as Iraq, Morocco, Sudan, Tunisia or Yemen (about 1 liter of water consumed per kcal produced (Gerten et al. 2011). It is estimated that if the Arab countries only managed to

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\textsuperscript{6} The global metabolic transition, GEC 26, 87-97
reach global average water use efficiency, they could save up to 50 billion m$^3$ of water annually, an amount sufficient to produce 30 million tons of grain, half of the region’s total grain imports (Sadik 2014). A nexus approach which improves overall resource use efficiency can be helpful to tackle this challenge.

Municipal water efficiency on both the supply-side and the demand-side is also very low. On the supply side, the physical leakage in the municipal networks exceeds 40% in some Arab countries. On the demand side, the per capita water consumption in the domestic sector in several Arab countries, namely the GCC countries, ranks amongst the highest in the world. Recycling and reuse, i.e. reuse of treated wastewater is minimal (with a few exceptions, such as Jordan and Morocco), are examples of yet major lost opportunities for the region under the prevailing water scarcity conditions.

Pricing water has been a contentious issue in most of the Arab countries due to perceived cultural and religious considerations. For example, the average price charged for water in the Arab region is only about 35% of the cost of production, and in the case of desalinated water, the average price charged is only about 10% of its cost. The availability of inexpensive, heavily subsidized water has led to overuse and waste in the agricultural and municipal sectors, which aggravates further the extreme water scarcity.

Given the high subsidies in the water sector and the low resource use efficiency, the region’s per-capita water use is very high, despite their extreme water scarcity. But there is a clear division of the region into GCC countries, with per-capita water uses amongst the highest in the world, and the rest of the region with much lower water uses. In particular in the GCC countries, but also in other parts of the region, water use in irrigated agriculture has expanded way beyond sustainable water availability, in particular beyond the safe yield of aquifers and beyond environmental flow requirements in rivers, in order to maximize food self-sufficiency (Arab Strategy for Sustainable Consumption 2009). This was made possible through subsidies (e.g., fuel and agricultural subsidies) and incentive programs, and has resulted in a large-scale expansion of farming activities with substantial water requirements, satisfied mainly by mining deep and fossil aquifers (GEO 6, chapter 2). This unsustainable expansion still continues, e.g. in Egypt.

Figure 2: Water resources in the Arab Region (UNDP, 2013)

![Water resources in the Arab Region](image)


Arab countries rely on both, conventional water resources (including renewable surface and shallow groundwater, and fossil non-renewable groundwater resources) and increasingly energy-intensive non-conventional water resources (including desalinated water from sea water or brackish water, treated municipal wastewater, and agricultural drainage water) to varying degrees (AWC, 2009). While the GCC countries rely mainly on renewable and in particular non-renewable groundwater resources (next to desalinated water), the rest of the region depends on surface water resources in the north and on more or less renewable groundwater in the south. All Arab countries are now beginning to re-use treated wastewater. Desalinated water represents a
progressively larger component in the water budget of the GCC countries and in the future programs of Maghreb countries, initially primarily for drinking water.

More than half of the region’s renewable water resources (about 300 billion m³/year), come from outside the region via rivers such as Euphrates, Tigris and Nile. Quantities of renewable groundwater in the region are quite limited, estimated to be about 45 billion m³, mostly in the form of shallow aquifers recharged from activities dependent on surface water especially during large floods (FAO, 2011). Non-renewable fossil groundwater is available in particularly in the Sahara (in Maghreb countries) and the Arabian Peninsula (in GCC countries) and is primarily used for unsustainable agricultural development and expansion (Al-Zubari, 2008). Since these ground water resources are mostly located in relatively great depth, their utilization (pumping to the surface) is very energy intensive.

To satisfy increasing needs, desalination has become a major non-conventional source of water in the Arab region and in particular in the GCC region. In fact, the region leads the world in the use of desalination technology, possessing over 50% of the world’s desalination capacity. The total desalination capacity for 2010 has been estimated at 12 billion m³ per year. With rapidly escalating demands, and decreasing costs, the desalination capacity in the Arab region was projected to reach 25 billion m³ by 2016 (GWI 2010). Actual figures vary depending on sources, but also come close to 25 billion m³ per year.

**Figure 3:** Cost curve for desalinated water over time

Since the energy demand for desalination per cubic meter is much higher than for conventional water resources (see Figure 3), the energy sector needs to prepare for a major increase in energy demand from the water sector.

Treating and reusing wastewater is another non-conventional water resource that is increasingly used in the region, with the total quantity of treated wastewater in the Arab countries being more than 6 billion m³/year. Wastewater is becoming an important source of water, especially as its generated quantities are expected to further increase over time with increasing water consumption in the domestic sector. Out of about 60% of wastewater that is treated, about 15% are reused in agriculture, landscape irrigation and industrial cooling (World Bank et al. 2011). Wastewater processing and reuse can also generate environmental and ecological co-benefits, thus providing higher returns on investment (Abdrabo 2003). These co-benefits are related e.g. to the recycling of nutrients (and energy savings due to lower demand for mineral fertilizer), co-production of biogas and cleaner water bodies and improved human health.

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Need to raise awareness and highlight the concept of virtual water

In addition to the above mentioned conventional and non-conventional water resources, Arab countries are augmenting water supplies through considerable quantities of ‘virtual water’ in the form of imported agricultural and food commodities. In 1998, the annual quantities of virtual water (i.e. water used in other world regions to produce food for consumption by Arab countries) were estimated to be equivalent to the annual water flow in both the Nile and the Euphrates (Allan 1998). More recently it has been estimated that about 50% of the food calories consumed in Arab countries are imported, and with that also a similar fraction of water for food security is provided as virtual water from other world regions – and saved in the Arab region by not producing that food locally (AFED 2014).

Water security has several definitions. We refer here to the UN Water definition according to which water security is: “The capacity of a population to safeguard sustainable access to adequate quantities of, and acceptable quality of water for sustaining livelihoods, human well-being, and socio-economic development, for ensuring protection against water-borne pollution and water-related disasters, and for preserving ecosystems in a climate of peace and political stability”.

Average per-capita water availability in the Arab region stands at about 800 cubic meters, with 10 countries standing even below 500 cubic meters. Absolute and per-capita water availability continue to decline due to severe climate change, rapid population growth and resource degradation. More intense and more frequent drought further compromise availability and access to water. The resulting extreme and further growing water scarcity in combination with a number of other factors, in particular mismanagement and limited access to water, negatively affects water security and with that human well-being and ecosystem intactness. Consequently, not all of the Arab population is water secure.

About 50 million people in the Arab region are without access to safe drinking water (AFED 2014). UNESCWA (pers comm 2017) states that about 15 per cent of the Arab population does not have access to good drinking water. This water insecurity severely impacts on human well-being and development. Moreover many aquatic ecosystems are threatened, degraded or have disappeared altogether.

Water security is closely intertwined with political stability and conflicts (Water Security Brief, UN Water 2012). Lack of good water governance and management and water security can be a consequence of conflicts, but a lack water security may also fuel conflicts. In some cases there has even been the threat to use water as a weapon, either in terms of refusing access to water, flooding areas or polluting water, all of which has been practiced by the IS (von Lossow 2016).

2.1.1 Water resources, water use, and water security in Jordan

Jordan as pioneer to expand use of non-conventional water resources

Jordan is one of the most water scarce countries in the world with a per-capita water availability below 100 m² per year. Given that extreme and further aggravating water scarcity, Jordan needs to reduce future water allocations in all sectors, including energy and food.

In the past five years, Jordan’s water resources have come under additional pressure from the large influx of Syrian refugees and their water demands.

In response to the pressing water scarcity, Jordan is exploring all supply and demand management options, and is ahead of most Arab countries in terms of adding non-conventional water to its conventional water resources, in particular reusing wastewater. Also it is beginning to desalinate seawater at small scale. Both of these non-conventional water resources are more energy-intensive than conventional resources. At the same time, Jordan has a very progressive “Energy Efficiency and Renewable Energy Policy” for the water sector.

Also in response to the pressing water scarcity, drip irrigation dominates in Jordan. Cereals (which generally have low economic water use efficiency) are hardly grown under irrigation. Irrigation is mostly limited to (relatively high value) fruit and vegetables.

The severe water scarcity also puts water security at risk, in particular among the large refugee population, with knock-on effects for water security of the rest of the population.
2.1.2 Water resources, water use, and water security in Egypt

Egypt is in a very particular situation, in that its water supply depends almost completely on one river (the Nile) with all runoff originating from outside of Egypt.

Water entering Egypt with the Nile flow is used, returned to the river and reused about 3-4 times before most of it is evaporated (primarily in agriculture) or the remainder flowing into the Mediterranean. Water quality decreases with every use cycle and generally along the river course (e.g. through mixed sewage system, inflows of untreated wastewater, industrial wastewater, etc). As a consequence, water quality improvements are a key supply side measure.

Per-capita water availability is also very low with about 600 m³ per year, but still 6 times higher than in Jordan. With rapid population growth (from 90 million now to an expected about 130 million by 2030) per-capita water availability is projected to shrink further.

Reuse of wastewater and drainage water is projected to become a key component in water supply. Currently the amount of wastewater treated / reused (for irrigation) amounts to about 7% / 1% of total water use. Sooner or later also seawater desalination is envisioned to significantly contribute to Egypt’s water supply (currently contributing about 0.2% to total water use. The largest non-conventional water resource at the moment is however virtual water: net import of virtual water with food amounts to more than 30 km³ (Al Saidi et al. 2016), coming close to Egypt’s domestic consumptive water use in agriculture (Al Saidi et al. 2016).

85% of all water goes into agriculture. Egypt has the largest irrigated area of all Arab countries. 90% of it is surface irrigation - which generally has a lower water use efficiency than sprinkler or drip irrigation. Farmers do not pay for water, so there is no incentive for saving. On half of the irrigated area (relatively low value), cereals are grown.

The water provided for agriculture and hence agricultural production contributes about 15% to GDP and employs about 25% of the Egyptian workforce. Due to low water tariffs, cost recovery only stands at about 10% of total costs (Al Saidi et al. 2016).

2.1.3 Water resources, water use, and water security in Morocco

With about 650 m³ per year, per-capita water availability is slightly higher than in Egypt.

Morocco has the fourth largest irrigated area of all Arab countries (after Egypt, Iraq and Sudan), of which more than 80% is surface irrigation.

Treated wastewater is projected to increase to 325 million m³ by 2030 (from 0 in the year 2000, INDC UNFCCC).

Desalination has increased from 7 million m³ in 2000 to 14 million m³ in 2014 and is projected to further increase to 510 million in 2030.

Water security, which is access to improved water resources, stands at about 65% (ESCWA and UNEP 2015).
2.2 Energy resources and energy security

Energy is not a scarce resource in the Arab region. The Arab region has vast fossil energy resources and sustainable renewable energy is available in nearly unlimited quantities. However, it needs improved management and governance.

Energy subsidies are among the highest in the world, almost half of all global energy subsidies are spent in the Arab region. In the oil producing Arab countries, energy subsidies range from 55 to 85% of real costs. The resulting distortion of energy prices has significantly contributed to the rapid increase in energy consumption and greenhouse gas emissions. Over the past decades GHG emissions in the Arab world have been growing several times faster than global average (UNEP, Arab Human Development Report 2016).

Regional primary energy demand grows rapidly, at a rate of 6% annually (Pan-Arab Renewable Energy Strategy 2014), electricity demand at an even higher rate (IEA 2017). These rates are much higher than population growth and economic growth (no decoupling as required in a Green Economy is in sight). In Qatar, for example, domestic energy consumption has tripled between 2000 and 2011. Accordingly, in parts of the region (GCC countries) per-capita energy consumption is now among the highest in the world, while in some other countries of the region it is among the lowest (Arab Strategy on Sustainable Consumption 2009). There is a factor of 100 between Qatar’s and Somalia’s per capita energy consumption (AFED 2015).

Energy efficiencies in the Arab region are below world average, which is largely a consequence of the high “blanket” energy subsidies. For example in the GCC region, the average energy intensity is 0.51 kgoe (kg of oil equivalents) per US$ value generated, almost twice the world average of 0.27 kgoe per US$ (Arab Strategy for Sustainable Consumption 2009). Accordingly, energy use is often wasteful, which, on the other hand, implies large potentials for improvements and energy savings.

At present, 98% of the region’s primary energy demand is still met by oil and gas (Pan-Arab Renewable Energy Strategy 2014), leaving the energy system both carbon intensive and vulnerable to global markets and energy prices. In particular the GCC countries are still rich in fossil fuels, but under the Paris Climate Agreement, the full exploitation of these resources might be constrained.

On the other hand, renewable energy, in particular solar (and wind in countries such as Morocco), begins to spread rapidly across the region, with costs becoming competitive to those for fossil energy (Figures 4 & 5).

Figure 4: Cost curves for solar energy over time
Recently, all Arab countries have set ambitious targets for renewables – see Table 1 from the Regional Center for Renewable Energy and Energy Efficiency (RCREEE 2017 pers comm). The shift to renewables is further accelerated by a rapidly increasing demand for electricity, which will meet an increasingly larger fraction of the overall energy demand and which can already today be more cheaply produced by renewables than by fossil energy.

<table>
<thead>
<tr>
<th>Country</th>
<th>Renewable energy target</th>
</tr>
</thead>
<tbody>
<tr>
<td>Algeria</td>
<td>6% of electricity generation by 2015; 15% by 2020; 40% by 2030</td>
</tr>
<tr>
<td>Bahrain</td>
<td>5% by 2020</td>
</tr>
<tr>
<td>Egypt</td>
<td>20% of electricity generation by 2020, of which 12% is wind</td>
</tr>
<tr>
<td>Iraq</td>
<td>2% of electricity generation by 2016</td>
</tr>
<tr>
<td>Kuwait</td>
<td>5% of electricity generation by 2020; 10% by 2030</td>
</tr>
<tr>
<td>Libya</td>
<td>3% of electricity generation by 2015; 7% by 2020; 10% by 2025</td>
</tr>
<tr>
<td>Oman</td>
<td>10% by 2020</td>
</tr>
<tr>
<td>Qatar</td>
<td>At least 2% of electricity generation from solar by 2020</td>
</tr>
<tr>
<td>Saudi Arabia</td>
<td>24 GW by 2020, 54 GW by 2032</td>
</tr>
<tr>
<td>Sudan</td>
<td>1004 MW by 2031</td>
</tr>
<tr>
<td>UAE</td>
<td>30% of electricity generation by 2030;</td>
</tr>
<tr>
<td>Yemen</td>
<td>15% of electricity by 2025</td>
</tr>
<tr>
<td>Djibouti</td>
<td>30% of rural electrification from solar PV by 2017, 100% renewable energy by 2020</td>
</tr>
<tr>
<td>Jordan</td>
<td>7% of primary energy by 2015; 10% by 2020</td>
</tr>
<tr>
<td>Lebanon</td>
<td>12% of electrical and thermal energy by 2020</td>
</tr>
<tr>
<td>Morocco</td>
<td>42% of installed power capacity by 2020 and 52 % by 2030</td>
</tr>
<tr>
<td>Palestine</td>
<td>25% of energy from renewables by 2020; 10% of electricity generation by 2020</td>
</tr>
<tr>
<td>Tunisia</td>
<td>11% of electricity by 2016; 25% by 2030</td>
</tr>
</tbody>
</table>

It is worthwhile mentioning that the GCC countries, despite their excellent position for piloting and also upscaling technological innovations, except for the UAE, have generally less ambitious renewable energy targets than most of the other MENA countries.

Hydropower, which currently contributes the largest share of all renewables in the region, cannot be expanded much further (Pan Arab Renewable Energy Strategy 2014) and may even suffer reductions in cases where river flows become lower and/or less reliable.
Depending on specific national conditions, renewable energy mixes vary significantly. For the 3 pilot countries, the current situation is depicted in figure 6, 7 and 8.

Figure 6: Shares of the different forms of renewable energy in Jordan, Egypt and Morocco (2016)

![Energy Mix Pie Charts](image)

Note that these shares are changing quickly, as new renewable energy strategies are implemented, e.g. in Morocco where wind and solar energy are expanding rapidly, while hydropower is not.

While the Arab region is very rich in fossil energy and in particular also in renewable energy resources, it is also faced with critical energy issues. These include the inefficient use of resources, overconsumption and wastage and also blackouts in peak times. Rapidly growing energy demands due to population and economic development, but also for the desalination of water or the intensification of agricultural production, threaten energy security for all. Accordingly not all of the Arab population is energy secure.

Energy security is about access to clean, reliable and affordable energy services that respect environmental concerns (Hoff 2011).

In most MENA countries, close to 100% of the population have access to electricity, but still 35 million people in the Arab region are without access to modern energy services, in particular electricity (AFED 2013). In Yemen, for example, half of the population has no access to electricity (World Bank 2017).

### 2.2.1 Energy resources, energy use and energy security in Jordan

Jordan’s energy sector is very import-dependent, with 97% of its fossil fuels being imported from abroad. Accordingly more than 17% of its GDP is spent on energy (2014).

Energy demand has been growing rapidly, electricity consumption by about 25% over 5 years (National Electric Power Company 2013).

In 2012, renewables, which are amply available, provided less than 1% of energy generation (most of which has been hydropower from King Talal dam). Jordan aims achieve a contribution of 10% of renewables to power generation by 2020. Additional hydropower could be generated from the planned Red-Dead Canal project.

Jordan is hosting one of the regions first waste-(gas)-to-energy recovery systems for a landfill in the greater Amman municipality with a capacity of 2000 tons a day (GEO6). By 2020 Jordan plans to have 40-50 MW of waste energy capacity installed.
Energy security, measured in terms of access to electricity, stands at almost 100% of the total population (World Bank 2017).

### 2.2.2 Energy resources, energy use, and energy security in Egypt

About 90% of Egypt's total energy demand is met by fossil fuel (mostly natural gas and oil, but increasingly also coal imports). Almost all renewable energy is currently based on hydropower (from the Aswan Dam), accounting for about 8% of total electricity production. Meanwhile Egypt’s potential for solar energy, which is among the highest in the world, awaits exploitation. Egypt is beginning to invest in solar power production, in particular in Upper Egypt.

Energy security, measured in terms of access to electricity stands at almost 100% of the total population (World Bank 2017).

### 2.2.3 Energy resources, energy use and energy security in Morocco

Electricity demand in Morocco has doubled over the past 10 years and is projected to grow by another 150% until 2030 (MEMEE 2012).

The contribution of renewables in electricity production is projected to increase to more than 40% by 2020; in 2015 about 7% comes from hydropower. The contribution of renewables to the total energy demand is projected to reach 11% by 2020 and about 13% by 2025 (MEMEE 2012), making Morocco’s renewable energy (solar, wind, hydropower) plans the most ambitious in the region.

Energy security, measured in terms of access to electricity stands at almost 100% of the total population (World Bank 2017).

### 2.3 Land resources, agriculture and food security

Arable land is also a scarce resource in most Arab countries (AFED 2014). It stands at about 4% of the total land area in the Arab region (compared to a global average of 11%). Arable land is threatened by further land degradation and desertification (GEO6 West Asia 2016). Non sustainable water management is one of the causes of land degradation in the Arab countries, in particular salinization. Land scarcity and degradation are co-limiting agricultural production together with water scarcity and quality degradation.

Despite land scarcity, the productivity of land - or agriculture - is low. For example cereal productivity is less than half of the global average productivity (World Bank 2017). Agricultural productivity growth rates for the past decades have consistently been lower than global average (AFED 2104).

Land use and land degradation add pressure on terrestrial ecosystems. The resulting loss of ecosystems, their functions and services reduces the resilience also of the societies living on the land, e.g. to droughts and other calamities.

Arab countries increasingly depend on other regions for food security and meeting their food demands. Accordingly, Arab countries increasingly outsource land use via trade and foreign direct investments, to some extent within the region itself (with Sudan being a prime target of foreign direct investment in land). The region’s food self-sufficiency (locally produced food for meeting local demand) stands at less than 50% (in terms of kcal), it imports close to 60% of its grains, 70% of its vegetable oils and more than 70% of its sugar. Self sufficiency levels of some GCC countries are even below 10% (AFED 2014, UNDP 2013). In particular GCC countries use trade, and also foreign direct investment as key elements of their food security strategies – see e.g. Qatar’s food security plan.

Food security has been defined by FAO as “availability and access to sufficient, safe and nutritious food to meet the dietary needs and food preferences for an active and healthy life”. Malnutrition is a continuing severe problem in several Arab countries, not only in terms of a lack of food, but also in terms of the opposite: obesity. Again the
region shows a strong division with some of its countries figuring among those with highest incidence of stunting among children, while others have the highest rates of obesity in the world. Obesity, for example in Egypt stands at 42% (for comparison: US 32%) (World Bank 2012).

With Arab food security increasingly depending on imports, it also gets exposed to the vagaries of global markets, which themselves have come under pressure, not only from a growing and more affluent world population, but also from the increasing competition (for land and water) for biofuels and other biomass, as the many new national bio-economy strategies require additional biomass production.

On the other hand, local food production is limited by the fact that almost 90% of the Arab region is classified as dry lands or desert. The extreme water scarcity and land scarcity of the region compromises local production. “There is no doubt that the increasing scarcity of water and arable land resources threaten to leave the region highly vulnerable to food insecurity” (Arab Strategy for DRR 2010).

So the region’s food security is caught between the vulnerability of local food production to decreasing water availability and climate extremes, on the one hand, and vulnerability of food imports to world market price fluctuations – with food prices being closely coupled to energy prices\(^8\) - on the other hand.

Moreover, food security – like water security – is closely intertwined with political instability and conflicts (e.g. Breisinger 2015, AFED 2014).

2.3.1 Land resources, land use and food security in Jordan

Total rainfed and irrigated cropland only covers about 5% of Jordan’s land area, located mainly in the north highlands.

Arable land in Jordan is less than 3% of the total land area (World Bank 2017) or 0.03 ha per capita (compared to 0.2 ha global average).

Land use efficiency (cereal yields per ha) stands at 37% of the global average (World Bank 2017).

Water scarcity strongly limits the further expansion of agricultural production. In fact irrigated and rainfed areas are projected to shrink by about 30% by 2050 compared to 2010 (Al Bakri 2013).

There are many more pressures on land and food production. For example, urban sprawl occupies more and more valuable cropland, including land that has potential for rainfed agriculture. Rainfall which previously became productive in agriculture now falls over cities. The lack of integrated planning causes a loss of water and land productivity, e.g. rainfed land is furthermore coming under pressure from the large influx of Syrian refugees.

Jordan’s food self-sufficiency level for cereals currently stands at about 5 – 10%.

Jordan’s food security has improved over the past 20 years, with average kcal availability per capita having increased from 2800 to 3300 kcal (FAO 2017b).

2.3.2 Land resources, land use and food security in Egypt

Agricultural land covers less than 3% of Egypt’s land area (World Bank 2017), or 0.03 ha per capita, compared to 0.2 ha global average, the majority of which are located in the Nile valley and delta. Almost all of it (more than 99%) are irrigated (Al Saidi et al. 2016).

Land use efficiency (cereal yields per ha) is very high, almost twice the global average (World Bank 2017).

Food self-sufficiency in Egypt stands at relatively high levels, measured at about 79% in 2011, while its cereal self-sufficiency is at about 56% for the same year. However,

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\(^8\) e.g. Ringler et al. (2013): The nexus across water, energy, land and food, COSUST
based on AOAD data (2007 and 2012), these food self-sufficiency levels represent a drop of their values in 2005 where they were at about 84% and 70%.

**Large new agricultural areas are planned in the desert**, which are less productive than the traditional agricultural land (which is increasingly put out of work because of expanding cities). Agriculture in these new areas is often very energy and water intensive and relies on non-renewable fossil groundwater. There is the risk that new agricultural areas, as well as new settlements and housing projects have to be given up again, once the fossil groundwater is exploited, unless new water resources can be developed. One of these non-conventional water sources can be desalination. However, desalinated water (from seawater) will only be available close to the coast and pumping to distant locations is very energy-intensive. Here again the lack of integrated planning across resources can reduce overall resource use efficiencies.

Sea level rise may add additional pressures to land resources either through flooding or through groundwater salinization due to seawater intrusion.

Agriculture contributes about 15% to GDP and about 25% of total employment. Food security has improved, e.g. the average kcal availability per capita has increased from 3200 to 3500 kcal over the past 20 years (FAO 2017b).

However, the growing population (from currently 90 million to about 130 million by 2030) requires large additional amounts of food. Increasing food imports is difficult given Egypt’s economic and financial situation.

### 2.3.3 Land resources, land use and food security in Morocco

- **Arable land** covers about 18% of total land area (World Bank 2017) or 0.24 ha per capita (compared to 0.2 ha global average).
- **Land use efficiency** (cereal yields per ha) stands at 37% of the global average (World Bank 2017).

Food self-sufficiency stands at about 60-70% for basic food (cereals), Morocco is importing the remaining 30 to 40% (depending on rainfall).

Food security has improved, e.g. average kcal availability per capita has increased from 2700 to 3200 kcal over the past 20 years (FAO 2017b).

### 2.4 Climate change

Climate change with its most severe impacts in the Arab region is acting as a threat multiplier across all of the above resources and human security issues. Climate change adds pressure to ecosystems and natural resources and with that also to human securities, e.g. by reducing water availability and/or, the reliability of water systems (with knock-on effects e.g. for energy systems), increasing risks of droughts and floods (also risks for water and energy infrastructure), land degradation and desertification, loss of agricultural productivity, loss of hydropower production potential, higher temperatures and more heat waves, increasing energy demand for cooling, reduced agricultural yields, etc. (World Bank Group 2014).

The Arab Plan of Action to deal with Climate Change (APACC, 2012) suggests that these climate change impacts “may have social consequences due to the flow and migration of people from the affected areas to others within the same country, neighboring countries or other countries [environmental refugees], which would result in increased pressure [there] on the environment and resources”.

The Arab Strategy for Disaster Risk Reduction also highlights that the region is highly vulnerable to extreme events and natural disasters.
3 Critical nexus issues, inter-linkages, tradeoffs ("hard choices") risks, costs and potential synergies between and among natural resources and human securities

Like anywhere in the world, also in the Arab region, resource availability, access and use efficiency are closely interlinked across resources, e.g., water for energy, energy for water, water or energy or land for agriculture, etc. In addition to that, there are also critical interlinkages between these resources and water-, energy- and food-security. Given the extreme scarcity in both water and arable land and the critical human security situation in parts of the Arab region, proactively and comprehensively addressing these inter-linkages is of high importance for sustainable development.

The most critical interlinkages are presented on the following pages.

Water – Energy

The pressing water scarcity requires new solutions, in particular also the use of non-conventional water resources. New non-conventional and marginal water resources (in particular desalinated water, but also deeper groundwater, reuse of wastewater etc.) is often more energy intensive than conventional water resources (see Figure 7).

Desalination is a rapidly growing water source, initially primarily in the GCC region, but increasingly also in other Arab countries. It still almost completely depends on fossil fuels. Saudi Arabia, for example, currently uses 25% of its oil and gas production for desalination. Under BAU that could increase to 50% by 2030 (WWAP 2014). A consequence of this growing energy intensity of the water sector may be a loss of (fossil) energy export capacity, which in turn has negative effects on national fiscal budgets.

Strictly sectoral water and wastewater planning, which does not account for topography and elevation of infrastructure, may cause a significant additional energy demand for pumping water and wastewater across altitudinal gradients.

Low efficiencies in the water sector increases the sector’s demand for energy further (e.g. energy for water pumping, for desalination etc.).

The additional energy demand of the water sector may cause energy insecurity in certain cases. Lack of sufficient and reliable energy supply in turn may impact on water
availability, water security and eventually economic development and human wellbeing (Figure 7).

**Figure 7:** Energy intensity of different water resources (amount of energy required to provide one cubic meter of water safe for human consumption from various water sources) (UN Water 2014)

![Energy Intensity Diagram](image)

**Energy-Water**

The region needs to move to renewable energy sources to meet its commitments under the Paris climate agreement and to reduce its dependency on increasingly expensive fossil fuels. For the non-oil / non-gas countries this is also a matter of reducing their import dependency and import bills. However, some renewables come with additional and sometimes higher water demands compared to conventional systems. In particular **renewables such as hydropower or concentrated solar power are water intensive**. But also some non-renewable non-conventional energy forms such as **fracking or oil shales are also water intensive** (Figure 8). Accordingly and depending on the specific context, renewable energy solutions and energy system transitions may be constrained by water scarcity.

Moreover pumped water storage is used in some Arab countries (such as Morocco) for buffering fluctuations in energy supply and demand, increasing water demand of the energy system further. Also low efficiencies in the use of energy can further increase water demands in the energy sector (e.g. for cooling).

And the **additional water demands from the energy sector could pose risks to water security**.

**Agriculture-water-energy-land**

Agriculture is currently responsible for more than 80% of the total water use (while its contribution to GDP is below 10% in most MENA countries), however this fraction is very likely to drop to 50% or less by 2050, and total allocation to agriculture is also likely to decrease. This is due to an increasing demand from other sectors, especially the municipal sector, while available water resources are mostly already fully exploited. This water constraint is likely to compromise planned agricultural expansions such as in Egypt.
Agricultural development, expansion and intensification, often coupled with more export production, as in the case of the Plan Maroc Vert, also requires additional energy, e.g. for machinery, fertilizer, and irrigation, with potential risks to national energy security. **Given dominant sectoral planning, this additional energy demand from the agricultural sector is not generally accounted for in national energy planning.**

Sectoral land planning (or no land planning at all) may cause the loss of (rainfed) agricultural land and associated water resources due to urban sprawl onto such land.

**Land and ecosystem degradation** compromises ecosystem services, such as water storage, water purification, biomass production, carbon sequestration, buffering of heat waves (e.g. in cities), which in turn leads to increased need and additional costs for hard infrastructure (substituting ecosystems and the “soft infrastructure” that these provide).

Non-sustainable use and overexploitation of land and water (e.g. irreversible depletion of fossil water) and subsequent resource degradation (including desertification) reduce productivities across resources, e.g. lower agricultural yields from degraded land or usability of resources, e.g. limited usability of polluted water. Resource degradation also threatens biomass and food production and poses risks to food security.

Reduced domestic productivity and production, largely caused by a **lack of integrated planning, may cause a drop in food self-sufficiency ratios and higher import dependencies.** This will increase the vulnerability to global shocks and extreme events such as international market price fluctuations and climate extremes. Higher import dependency may also cause more interlinked risks, such as those related to coupled world market prices of several commodities, e.g. food and energy (Figure 9).
Poor and marginalized people and regions are generally more vulnerable to water-, energy- and food-related risks, while in return poverty and human insecurities can increase pressure on natural resources and their non-sustainable use. This can lead to vicious cycles of degradation across resources and across the different human securities (or, if well managed, may lead to virtuous cycles instead).

Not accounting for such externalities and co-risks, while continuing conventional silo approaches, without recycling waste products and by-products across sectors, also increases environmental risks, e.g. related to CO2 emissions or pollution. Accordingly also climate adaptation (e.g. in the water and agricultural sectors) and mitigation (e.g. in the energy sector) need to be better coordinated and integrated.

It should be noted that critical interlinkages may span across different spatial scales; e.g., water resources are generally managed at a local scale, while energy is often managed (and governed) at the national level or even at the level of regional power pools, and food security may draw on global sourcing via trade.

Transboundary shared rivers, which provide most (65%) of the region’s renewable water resources, present a “laboratory” for inter-related (nexus) risks (and opportunities – see below). Upstream changes and intensification of land and water use result in river flow changes and associated co-risks or co-benefits related to these river flows, e.g. food and power production, water supply etc. – there is evidence available from the Euphrates, Tigris and Nile basins, which deliver water from outside to the Arab region; additional transboundary cases are also found within the Arab region. The nexus approach helps to broaden the base of benefits to be shared and may in fact provide incentives for improved cooperation among riparian countries (UN ESCWA Water Development Report 6, 2015).

The critical inter-linkages and risks listed above also need to be translated into costs of inaction or costs of conventional sectoral approaches. Failure to understand and address these critical inter-linkages will lead to missed opportunities (in the best case) or conflicting policies that undermine each other (in the worst case).

A compelling example of the cost of currently dominating approaches are non-sustainable (“blanket”) subsidies for water, energy or food/agriculture, which perpetuate low resource efficiencies, wasteful consumption and have adverse knock-on effects across sectors.

An example of how high subsidies in one sector have repercussions on other sectors (and on the national fiscal budget) are Egypt's energy subsidies, which have the same order of magnitude as the national budget deficit (UNEP, Arab Human Development Report 2012). Egypt’s food subsidies amount to about 1.5% of GDP, total subsidies on fuels and food amount to 13% of GDP. However, Egypt is now beginning to phase out energy and water subsidies, which can support a nexus approach.

In Jordan the water sector is highly subsidized, and so is wheat and barley production and consumption (via consumer prices, including also fodder subsidies). Barley and...
wheat subsidies for example have grown from 70 million JD in 2005 to 220 million in 2008 and 140 million in 2009 (Ministry of Industry and Trade). Food subsidies amount to 2% of GDP.

Food subsidies in Morocco amount to about 1% of GDP. Unless these are linked to comprehensive and integrated sustainability criteria, these subsidies may have negative effects on other sectors, potentially even impeding counteracting measures and financial incentives in these sectors and hence increasing overall costs.

The nexus approach itself, however, also comes with costs: it adds complexity and requires more coordination between sectors, and institutions (e.g. ministries or authorities), which may slow-down decision making and increase transaction costs. Experts are often not trained to take into account the effects their decisions have on other sectors.

It should also be noted that, in addition to strengthening links between sectors, action within sectors is also required for addressing the challenges mentioned above. Major risks and repercussions across sectors as well as costs of inaction are also associated with the enormous implementation gap for many existing strategies and policies.

All of the above mentioned consequences of silo approaches and the lack of integrated planning and management, in particular more pressing resource degradation and scarcity and human insecurities are eventually also linked to political (in)stability and conflicts.

3.1 Most critical interlinkages in Jordan - turning challenges and risks into nexus opportunities

The following interlinkages have been identified in stakeholder dialogues as most critical in Jordan:

The agricultural sector uses 65% of total water resources (however increasingly relying on recycled wastewater) but generates only 3% of GDP. Accordingly the economic water use efficiency is very low and there is significant potential for more water-smart food security.

The increasing use of non-conventional water resources and the need for pumping water across large distances and vertical gradients, make the Jordanian water system very energy-intensive. About 15% of Jordan’s total power production goes into pumping water. The energy bill of the Jordanian water sector in 2014 amounted to 301 million JD (of which 163 million were energy subsidies that the government paid). The energy demand of the water sector is projected to increase by more than 50% from 2017 to 2025 (according to MWI), with associated power costs for pumping of more than 600 million JD.

Despite energy efficiency and renewable energy goals in the water sector, total water sector CO2 emissions are projected to increase by almost 30%.

Jordan is introducing energy recovery from wastewater (biogas) in the As Samra treatment plant. Integrated planning of wastewater reuse and energy recovery (and nutrient recovery) can increase overall resource use efficiencies.

Figure 10 shows a selection of nexus projects in Morocco which involve 2 or 3 sectors (water, energy and agriculture/food).
Figure 10: Selection of nexus projects in Jordan which involve 2 or 3 sectors (water, energy, agriculture/food).
3.2 Most critical interlinkages in Egypt - turning challenges and risks into nexus opportunities

The following interlinkages have been identified in stakeholder dialogues as most critical in Egypt: Figure 11 shows a selection of nexus projects in Egypt which involve 2 or 3 sectors (water, energy and agriculture/food).

Given the growing food demand and the (financial) limitations to further increase food imports, more food has to be produced domestically. This can happen either by expanding the agricultural land area (there are plans for a 20% expansion of current agricultural land) or by intensifying production on existing agricultural land. In both cases more water and energy will be required. Already now, 85% of Egypt’s total water withdrawals are for agriculture. Conventional renewable water resources are fully exploited. So agricultural expansions and intensifications are constrained by water availability. Moreover agricultural intensification increases and expansion into new areas requires additional energy (while currently agriculture is responsible for about 5% of total energy consumption (IEA 2017)). However, there is also a large energy potential of more than 400 PJ hidden in agricultural residues (Al Saidi et al. 2016).

Figure 11: Selection of nexus projects in Egypt which involve 2 or 3 sectors (water, energy, agriculture/food)
Sustainable solutions to increasing food production will have to rely on new and renewable water and energy resources. One of the most promising new water resources in the MENA region is desalination of seawater (which is available in unlimited quantities) and brackish water. Seawater desalination, however, is very energy-intensive. Current desalination technologies rely on fossil fuel, which is largely imported and produces additional greenhouse gases.

Besides desalination, another option for adding new water to the national water resources is through wastewater recycling and reuse. In particular for remotely located villages, decentralized wastewater reuse systems can be a sustainable solution. Wastewater reuse does not only increase the amount of water available through recycling, but also recycles nutrients.

**Coupling wastewater reuse with the recovery of energy** from wastewater and sludge (biogas) can improve the productivity of scarce water and land resources further. The recycling of nutrients generates additional co-benefits through savings on industrial fertilizer (and the energy required for its production) and by reducing the pollution of water resources as associated with discharging untreated wastewater. Similarly, energy recovery from agricultural waste via composting and biogas production can also have co-benefits in terms of avoided pollution (as associated with burning of waste).

Hydropower from the Aswan dam still plays an important but shrinking role in Egypt’s electricity supply. While water in Egypt used to be a net source of energy (via hydropower) it has now turned into a net sink of energy, due to the large and further growing energy demands of the water sector, e.g. for pumping and desalination.

**Figure 12: Water flows in Egypt**

Sustainable solutions to food and water and energy security will undoubtedly be based on renewable energy such as solar, wind and also the remaining hydropower (e.g. solar energy for desalination and for water pumping). These renewable energy options each come with specific additional water demands and hence are only feasible if these demands can be met.
Efficiency improvement is another important element of sustainable food-, water- and energy- systems. **Efficiency improvements** in the agricultural sector can enable water savings of up to 60% with knock-on effects for energy savings, e.g. through reduced water pumping. Similarly, **water savings from switching to less water-intensive crops can also lead to energy savings**. Opportunities for Egypt arise through importing crops with low water productivity such as rice or other cereals, while concentrating scarce national water resources on the production of higher value crops (and reallocating water to activities with higher water productivity).

Another **entry point for a nexus approach is the location of new agricultural areas**: very productive agricultural land in the Nile valley and delta is increasingly lost to city/village infrastructure. Less productive desert land, requiring more energy for water pumping than in the Nile valley (Al Saidi et al. 2016), often irrigated with fossil groundwater, only provides a short-term solution. In the long term, **new water resources, including desalination and wastewater reuse will become important pillars of national water supply**. Pumping desalinated and reused water across large distances causes an additional energy demand. Accordingly, **new agricultural land should be as close to the coast as possible** (which is also important for the disposal of the highly saline residues of desalination, the brine. **Solar pumping** of water might be another option to increase the sustainability of new agricultural developments.

**Figure 13: Energy flows in Egypt**

Lastly, a potentially critical interlinkage across the water, energy and food sectors is also oil exploration, which also threatens food security by polluting marine waters and via fisheries. From a nexus perspective and also in view of Egypt’s commitment to “low carbon energy systems” (see the Intended Nationally Determined Contribution under the UNFCCC) renewables provide lower risks and more opportunities for a sustainability transition.

**Given the additional complexity of a nexus approach, compared to strictly sectoral approaches, visualizations are very important means of communication and capacity building.** We present here initial Sankey-type diagrams for illustrating critical interlinkages between sectors and the volumes of cross-sectoral resource flows. We recommend further updating of these diagrams when new data become available. Also, with the appropriate data (time series), these diagrams can also be made dynamic (e.g. as video animations), visualizing future nexus scenarios (Figure 14).
3.3 Most critical interlinkages in Morocco - turning challenges and risks into nexus opportunities

The following interlinkages have been identified in stakeholder dialogues as most critical in Morocco: The national agricultural plan (Plan Maroc Vert) projects a strong increase in productivity which, under a conventional mono-sectoral approach, may increase water and energy requirements.

Morocco has one of the most ambitious renewable energy programs in the region. In particular, concentrated solar power makes this program also water intensive. So it will be important to align Morocco’s energy transition with water availability constraints.

*Figure 14: Selection of nexus projects in Morocco which involve 2 or 3 sectors (water, energy, agriculture/food)*

Morocco is introducing energy recovery from wastewater (biogas) in the treatment plants in Marrakech and Fes. This advanced nexus solution lends itself to up-scaling and transfer through regional cooperation.

Figure 14 shows a selection of nexus projects in Morocco which involve 2 or 3 sectors (water, energy and agriculture/food).
4 Entry points and concrete opportunities for implementing the nexus approach, to promote synergies and co-benefits, and socio-economic and environmental and political gains, also for regional cooperation

We have identified initial examples or good practices, of taking cross-resource or cross-sectoral inter-linkages into account and turning them from risks into opportunities. Examples for integrated management are found in particular in multi-functional production systems. Examples for integrated governance are found in initiatives towards improved policy coherence, e.g. national integrated NDC and SDG implementation. While the examples presented below demonstrate some of the potential benefits of a nexus approach towards integrated management and governance, the exact benefits in terms of improved resource use efficiency, environmental sustainability and human security are yet to be fully quantified.

The nexus approach generally supports the recycling and reuse of waste-products and by-products across sectors, and with that a circular economy. This translates into producing more with less – ensuring more human securities and economic development while using less natural resources and reducing environmental pressure.

A key entry point for the nexus approach is the transformation of the energy sector to renewable energy, and the associated shift to renewable energy in all sectors, including the water and agricultural sectors. This shift needs to be water and land smart. Similarly the shift to non-conventional water resources needs to be energy smart. Transitions of the energy, water and other systems need to be assessed and analyzed across the nexus to ensure a holistic management and governance, in order to simultaneously improve water, energy and food security. Policy makers should be mindful of the fact that single sector optimizations may have unwanted side effects, as for example in the case of the promotion of solar pumps which can lead to over-abstraction of groundwater.

Key entry points are transformation of energy sector to renewable energy and shift in the water sector to non-conventional water resources.
The nexus approach and its potential benefits will be illustrated below by three case studies:

- an integrated wastewater and energy system (Waterleau)
- a solar- and seawater-based biomass and food production system (Sahara Forest)
- an energy- and water-smart agricultural system (Reactivate)

**Box 1: Waterleau multi-functional wastewater project in Marrakesh**

Waterleau: multi-functional wastewater treatment in Marrakesh

Marrakesh, a rapidly growing city with over one million people faces resource challenges and environmental difficulties. In response to the growing challenge, the Waterleau multi-functional wastewater project implements nexus principles: while until 2008 untreated wastewater was discharged into the nearby wadis, Waterleau now has a wastewater treatment capacity of 236,000 m³ per day, employing biological wastewater treatment technologies. After a tertiary treatment the water is reused in irrigation, in total 30 million m³ annually. The Waterleau plant also stabilizes the resulting sludge. After the processes of dewatering and drying, the sludge is digested in a solids reactor to produce biogas. About 22,500 m³ of biogas or ca. 135,000 kWh energy are recovered from the sludge per day. The output of the plant totals 1,6 MWe. Moreover a solar drying facility for the sludge is under construction. So the Waterleau plant not only recycles water and nutrients (leading to savings in mineral fertilizer and hence energy required for the production of this mineral fertilizer), but it also generates energy (green electricity and heat), providing up to 45% of the plants energy needs. With that it reduces CO2 emissions by about 60,000 tons per year.

The maximum potential for reuse of urban wastewater in Morocco is estimated to about 700 million m² per year if all wastewater was treated (currently only 25% of the wastewater is treated and only 11% is reused). Assuming similar biogas and energy production rates as in the Waterleau plant, from those 700 million m² about 40 MWe could be generated. This energy recovery can contribute significantly to the country’s renewable energy targets as well as the target of increased resource use efficiency. The solar drying technology moreover taps the region’s almost unlimited solar energy potential (Morocco has an average solar radiation of more than 5 kWh per m² and day).

Given the region’s fast growing municipal water demand, this nexus approach to wastewater, sludge and solar energy can and should be replicated in other countries and contexts, in large cities as well as in a decentralized form in small villages.

Box 2: Sahara Forest Project

Sahara Forest Project

The Sahara Forest Project, which has already been established in Qatar and Jordan (two of the most water scarce countries in the world), and which is projected to be extended to other MENA countries, is a showcase of an integrated multi-functional production system, with recycling and reuse of waste streams. It builds on the two unlimited resources that the region has: seawater and solar energy. It enhances biomass production (in greenhouses) by up to a factor of 1000, while also rehabilitating natural dryland vegetation. Solar power is used for generating electricity, for desalination and also for cooling (via seawater evaporation). Cooling in turn increases the efficiency of power generation and cooling also prevents overheating of greenhouses in summer and accordingly enables crop production all year round.

Saline and nutrient rich (effluent) water can further be used to grow algae, fish or shrimp. And nutrient-rich wastewater from aquaculture can irrigate and fertilize halophyte plants. The Sahara Forest project has been designed for generating as many (qualified and unqualified) jobs as possible.

Desalinated seawater may serve as storage in integrated water-energy systems, bridging fluctuations in renewable energy availability, e.g. day-night fluctuations of PV. Beyond the Sahara Forest project itself, solar desalination plants are operational in all 3 pilot countries of the ACCWaM nexus project (Jordan, Egypt and Morocco), but only at pilot scale. Upscaling of this technology, targeting economies of scale and making the technology economically compatible, opens enormous potential for the region’s transformation of water and energy systems. Preconditions for this to happen are i) eliminating blanket subsidies or replacing them with targeted subsidies for such sustainable solutions, and ii) regional cooperation across MENA countries to share knowledge and technology and for sustainable investments. A promising example of upscaling solar desalination is the Ras Al Khaimah plant in UAE with a projected capacity of 80,000 m³ per day.

If the biomass and food production, which is achieved through the Sahara Forest project in hot arid environments, is upscaled beyond the pilot scale, this technology can reduce or eliminate the need for food imports and with that help to reduce import bills and also the significant energy demand for long distant food transport. In principle also biofuel production and energy generation through anaerobic digestion could be integrated in this nexus project.

A goal of the project is also to transport seawater inland for making it productive. This could be of interest in many other MENA countries, for example in Egypt, where agricultural expansion into the desert currently relies on non-sustainable use of fossil groundwater. Similarly in Jordan, agriculture currently depends strongly on non-sustainable overuse of groundwater. Combining the integrated approach, based on renewable energy of the Sahara Forest project with the Red-Dead Canal could also open opportunities for a sustainability transition in Jordan.
Box 3: Re-activate Project

Re-activate Project: energy smart agriculture

The focus of the Reactive project is on environmentally, economically and socially sustainable energy transition in agriculture (and other sectors). In the Moroccan province Taroudant, where the dominant land use is arboriculture, the project works with the contractor Gie Tazartino. It aims at the (decentralized) use of renewable energy and improvements in energy efficiency. Energy efficiency gains are for example realized through using more efficient water pumps, through improving the geometry of water systems and also through reducing water losses and the associated reduction in energy demand if less water is required. Reductions in water losses are realized e.g. through fixing leakages and through covering water basins, which reduces evaporation by 1-2 cm per day.

The Reactivate project also aims at generating new jobs through labor intensive decentralized and locally sourced renewable energy and energy efficiency improvements. The project also emphasizes labor intensive value generation (and job creation) in agriculture itself.

Among the measures for a labor intensive energy transition in agriculture are improved technical energy and water installations and their maintenance, e.g. PV panels, solar powered water pumping and improved water pumps.

Source: https://www.giz.de/en/worldwide/36137.html

An important institutional pre-condition to make these showcase solutions work is the political will in the respective country to coordinate and cooperate across sectors, ministries and authorities. Only then is there a chance for these solutions to move from pilot to full operational scale and to eventually support sustainability transitions of the MENA countries.

There is significant potential for cross-country sharing of such pilots, technologies, innovations (including also institutional innovations), knowledge and experience. Arab countries can benefit from each other’s experiences in integrated water, energy and land management and the resulting improvements of water, energy and food security. Jointly they can also better exploit their respective complementarities and comparative advantages, e.g. in water availability and other natural resource endowments, technologies and resource use efficiencies, food or energy production potentials etc. While better resource management and governance can foster regional cooperation, the reverse is also true: improved regional coordination and cooperation can promote integrated management and governance, through sharing of best practices and technologies.

Region-wide institutions such as the League of Arab States, UNESCWA (www.unescwa.org), CEDARE (web.cedare.org), RCREEE on renewable energy
(www.rcree.org), MEDRC on desalination (www.medrc.org), and ICBA on saline agriculture (www.biosaline.org), and other regional and national institutes actively facilitate such sharing of knowledge and technologies.

Arab countries can also take a more coordinated (nexus) approach to foreign direct investment (e.g. in land), opening opportunities to integrate these investments with regional and national agricultural strategies, but also with other sectors such as transport and trade (see for example Comprehensive Africa Agricultural Development Program – CAADP). There are a number of imitative in this direction at the governmental and the private sector levels, for example, the King Abdulla Initiative for Abroad Agricultural investment or GCC private sector investment in Sudan.

Trade and infrastructure provide additional opportunities for generating nexus benefits across countries, e.g. food trade enabling sustainable sourcing of food from water-smart production areas or power lines and power pools enabling energy imports from water-smart production areas. In particular transboundary river basins lend themselves to nexus approaches for increasing the basis of benefits to be shared, e.g. through joint planning, locating and managing energy and food production.

We recommend to develop this initial evidence base into a permanent and comprehensive nexus data and information base, to be continuously updated and complemented with new nexus examples and best practices at pilot and at operational scale.
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