ENERGY-WATER-FOOD SECURITY CHALLENGE FOR MIDDLE-EAST AND NORTH AFRICA (*MENA*)

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CERTIFICATE OF AUTHORSHIP/ORIGINALITY

I, Bahareh Berenjforoush Azar declare that this thesis, is submitted in fulfilment of the requirements for the award of Doctor of Philosophy, in the School of Information, Systems and Modelling at the University of Technology Sydney.

This thesis is wholly my own work unless otherwise reference or acknowledged. In addition, I certify that all information sources and literature used are indicated in the thesis. This document has not been submitted for qualifications at any other academic institution. This research is supported by the Australian Government Research Training Program.

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List of Abbreviations

FAO	Food and Agriculture Organization
GCC	Gulf Cooperation Countries
GDP	Gross Domestic Product
GFSI	Global Food Security Index
GHI	Global Hunger Index
GTAP	Global Trade Analysis Project
HKH	Hindu Kush Himalayan
IAEA	International Atomic Energy Agency
IEA	International Energy Agency
ILO	International Labour Organization
IO	Input-output
IOA	Input-output analysis
LCA	Life Cycle Analysis
MDG	Millennium Development Goals
MENA	Middle East and North Africa
MFA	Material flow analysis
MIRO	Multi-Regional Input-Output
OEC	Oil exporting country
OIC	Oil importer countries
SD	System Dynamics
SEI	Stockholm Environment Institute
UAE	United Arab Emirates
UNEP	United Nations Environment Programme
VWT	Virtual water trade
WHO	World Health Organization
WPI	Water Poverty Index
WRI	World Resources Institute

Abstract

In the backdrop of emerging concerns about Energy-Water-Food (EWF) security, this research analyses the impact of alternative developmental policy pathways (Scenarios) on EWF security and economic and social outcomes, for the period 2015-2050, for the Middle East and North Africa (MENA) region – a region typified by highly uneven distribution of energy endowments, acutely scarce resources, rather limited arable land, and high degree of political volatility. These impacts are assessed in terms of seventeen selected attributes, grouped into four areas of interest – energy security, water security, food security, and economic and social outcomes. Five Scenarios considered in this research, namely, Business-as-Usual (BAU), Energy-oriented (ESC), Water-oriented (WSC), Food-oriented (FSC), and EWF Nexus-oriented (NSC) – reflect alternative sets of technological, economic and social developmental trajectories – as relevant for each country included in this research. A specifically designed Input-Output framework – incorporating flexible (nested) production functions, factor substitution possibilities through price mechanism, and with high degrees of sectoral disaggregation – is employed to analyse the medium-to-long term impacts of alternative scenarios. Analysis suggests that while the BAU scenario (representing country policy trends) will lead to highly precipitous water security outcomes for most countries considered, and considerably worsened food security outcomes for some countries. Analysis also suggests that while domain-special scenarios (e.g., ESC) will have a perceptibly positive outcome for the domain (i.e., energy), but detrimental outcomes for other domains (e.g., water, food, economic and social). The research also reveals that improvements in water security will come at the expense of economic and social outcomes. Overall, the NSC scenario provides modest outcomes for most domains, although with sharp contrasts across countries – thus demonstrating the 'value' of nexus-informed policy considerations. The analyses were undertaken in this research – it is contended – provides innately useful insights into the trade-offs that policymakers in various countries can consider while develop resource, economic and social policies. Further, while this research has been undertaken for the MENA region, the analytical framework developed, and the overall 'philosophy' adopted to develop a more nuanced perspective on EWF security challenge should serve as a robust platform for other countries as they endeavour to develop policy prescriptions to redress the EWF security challenges. Therein resides yet another significant feature of this research.

Chapter 1: Introduction

1.1 Background

Of all the resources, energy, water and food are the most vital ones for human life. Over the past century or two, countries around the world have over-exploited natural resources such as energy, land (soil and minerals), water and biodiversity in a fierce competition with each other for faster economic growth. This has posed a serious challenge to the notion of sustainable economic growth. Further, global competition among nations for these natural resources has accelerated the rate of their exploitation and has contributed to raising inequity across continents, regions and countries.

For example, China – which until a few years ago was among the fastest growing economies in the world – has become one of the largest importers of natural resources from resource-exporting countries (e.g., Africa, Latin America, Middle East and North Africa (MENA) and Australia). In addition, many of the exporting countries are among the poorest in the world (Pigato & Tang, 2015). According to the Inclusive Wealth Index (IWI) (2012), from 1990 to 2008, natural resources per-capita decreased by 33% in South Africa, by 25% in Brazil, by 20% in the United States and by 17% in China. The implications of such depletions of the environment are indeed a matter of concern.

There is mounting evidence that suggests that most political conflicts between nations are largely driven by the fierce competition above described for faster growth and, hence, for access to basic resources (i.e., energy, water and food). According to United Nations Environment Programme (UNEP) (2015), access to natural resources have been the first reason behind some 40% to 60% of civil wars over the last 60 years and beyond (UNEP, 2015).

In addition to rapid growth in demand, the distribution of energy, water and food is highly uneven, widening the gap between the living standards of the rich and the poor. On a global scale, over 1.2 billion people are currently without access to electricity and 2.7 billion people are without clean cooking facilities (IEA, 2016); one in nine people on earth do not have enough food to lead a healthy active life (WFP, 2015); and 1.1 billion people have no access to any type of drinking source of water (WHO, 2015). Further, due to the changes in middle-class lifestyles and demand for goods and services, scare resources have been stressed extensively (Hoff, 2011). For instance, by 2050, 70% of population in the world will live in urban areas. As a result, water demand will rise by 55%, and food demand by 70% (Hoff, 2011; Mountford, 2011). By 2040, the demand for energy in the world is expected to have grown by 37% compared to demand in 2014 (IEA, 2014).

Concerns about access to clean and affordable energy, water and food are even more serious for the MENA region (the region focus of this research), where social and political struggles are highly intense. The MENA region includes 21 countries (World Bank, 2019a), including non-Arab Western Asian countries (e.g. Iran), Arab countries from the Arabian Peninsula (Asia) and the north of the African continent (see Figure 1). The region has about 6% of the population of the world but only 1% of global renewable water resources; only 4.3% of the region's land is arable and the region as a whole consists of some of the largest and driest deserts on earth. Economic growth in the region declined sharply from 4.3% in 2016 to 3.1% in 2018. Based on a recent report by the World Bank, unemployment in MENA exceeds 11%, with more than 30% of the youth unemployed (World Bank, 2018). The region is therefore beset with an extreme degree of joblessness (Salam, 2014), while its population is experiencing a rapid increase and rapid changes in lifestyle. According to the UN, the population of the region is expected to grow to 700 million by 2050 (Roudi-Fahimi & Kent, 2007) which is more than twice the population of 2018. Therefore, it is expected that demand for water, energy and food, the most vital resources for human subsistence, will increase rapidly, too. Hence, security of water, food and energy is a critical challenge for the region.

Figure 1.1: Middle East and North Africa (MENA)

MENA is known as an energy-rich and energy-exporting region of the world. However, most of the energy supply is sourced from exhaustible oil and gas resources and domestic demand for oil and gas is growing faster than the world average. For example, the annual demand for electricity in the MENA region from 1990 to 2015 was almost twice the world average (Menichetti et al., 2019). Therefore, it is possible that MENA may not remain an energy-exporting region in the future and may instead become a net importer, which in turn could pose a long-term security threat to it. However, one of the main reasons for the increase in demand for energy in the region is the lack of available freshwater. The region is known as the most

water deficient region in the world (Antonelli & Tamea, 2015; Damerau et al., 2015; World Bank, 2007), with several countries in the region (Bahrain, Qatar, Kuwait, Saudi Arabia, Libya, Yemen, Israel and Jordan) having the highest water stress index among the rest of the countries (Maplecroft, 2011). This situation is expected to deteriorate further by 2050 and the unmet demand to surge from 16% in 2015 to 51% by 2050 (Antonelli & Tamea, 2015). Hence, residents in the MENA would have access to less than 550 m^3 per person per annum by 2050, which is half the required amount of water considered by the World Health Organization (WHO) for the minimum living standard (World Bank, 2009). This would affect the economic development, human health, environment and social and political stability of the region (Engelman et al., 1993; Bigas, 2012; Dubreuil et al., 2013). Besides growth in population and changes in living standards, the main factors for the shortage of water in the region is its extensive use for agriculture. Nearly 85% of water is used by the agriculture sector while most of the countries in the region depend heavily on imported food to meet domestic needs. In addition to the shortage of water in the region, low agricultural productivity in the region (both pre- and post-harvest), limited arable land and considerable loss of produced food due to poor logistics put further pressure on the availability and accessibility of food for citizens. Hence, the energy, water and food (EWF) security challenge is real and substantive for the region and if left unaddressed would be a potential factor in further political instability and human suffering in the region.

Redressing this challenge requires the development of an insightful perspective on the nature of the security challenge in the region. However, this is a complex task as i) EWF securities are multidimensional and dependent on demographic, historic, socio-economic, cultural and political contexts; ii) these securities are interconnected and iii) the nature of EWF securities are dynamic. However, the current public policy discourse, with its focus on one sector cannot provide the insightful perspective to capture the security complexity nature or guidance for developing appropriate policy responses to address the security challenge.

1.2 The EWF security nexus

The basic understanding of the nexus between energy, water and food is that they are interlinked at different levels and scales. Energy is required for water withdrawal, treatment and distribution. Water drives the turbines of hydroelectric power plants and is used for cooling thermal and nuclear plants. Energy and water, both, are applied in agricultural activities to produce and distribute food. Even at the household level, energy-water-food linkages are observed and the

same basic, but important, principles are applied to macro-level projects; for example, the design and operation of hydroelectric dams and drip irrigation systems in agriculture.

The EWF security nexus is a concept that recognises that there are inextricable linkages between energy, water and food security, and due to these interlinkages, the security of one resource is dependent on one or both of the other two resources. The impact of changes made in the management of any one of these resources can be positive (synergies), negative (trade-offs) or neutral. The EWF security nexus relates to two main issues: firstly, it seeks to define the interrelationships between energy, water and food resources and secondly, it seeks to recognise governance and management options across sectors that usually are considered in isolation (Granit et al., 2012).

The consequences of ignoring the concept of EWF nexus at present and in the future have been expressed to some extent in the literature (Bazilian et al., 2011; Hoff, 2011; Smil, 2000; Waughray, 2011; WEF, 2011). However, there is a relatively limited understanding of how to address these complex interrelationships when designing policy frameworks. When it comes to providing specific data, information and examples to support the EWF nexus, many researchers emphasise the challenges in each sector individually or they investigate the relationship within a two-sector nexus, particularly energy-water and water-food. Further, the main focus is recognising the role of each of the elements of the EWF nexus to improve human wellbeing. These researchers address the critical issues, including the lack of access to clean water and modern sources of energy, especially in rapidly growing areas and as a consequence the lack of food security, which leads to hunger (OECD, 2006; Thirlwell, Madramootoo & Heathcote, 2007).

Past initiatives to address EWF security have been sector-specific. Although awareness of the nexus approach has increased (Bizikova et al., 2013), so far there have been only a few studies that discuss the EWF security nexus worldwide (Granit et al., 2012; Jalilov, Amer & Ward, 2013; Rasul, 2014). The study by Granit et al. explored the EWF nexus in Central Asia and the Aral Sea Basin with the objective of seeking regional solutions to trans-boundary issues and commonly experienced resource security challenges. The authors indicated that collaborative management and development of trans-boundary water resources in the region were essential to overcoming future EWF and environmental security needs, given that there is a political will for cooperation among the nations. A similar study by Jalilov, Amer and Ward investigated the EWF security nexus on a regional level, in Central Asia. The nature of this study was more specific to the Amu Darya Basin and trans-boundary issues over water, examining the potential for mutually beneficial water development and allocation of water resources to sustain supply to meet the demand for energy, water and food in the region. By applying economic modelling and basin analysis, the study found that there were many mutual benefits to be gained from addressing the

issues from a nexus point of view. Another study by Rasul, entitled 'Food, water, and energy security in South Asia: A nexus perspective from the Hindu Kush Himalayan region', examined the EWF nexus from a regional dimension while emphasising the role of the Hindu Kush Himalayan ecosystem services in sustaining EWF security in the downstream areas of South Asia. The analysis of the study revealed that the complexity of EWF security requires cross-sectoral integration to manage the resources and the important Hindu Kush Himalayan ecosystem services more effectively.

There is currently no published work on incorporating the nexus approach to address the challenges of resource insecurity in the MENA region. Some studies that do exist review one or two resources simultaneously, such as energy-water or food-water security. For instance, a study was proposed by Siddiqi and Anadón (2011) on energy and water nexus in the MENA region (Siddiqi & Anadón, 2011) to investigate the linkages between energy and water. The analysis of this study highlighted that the energy and water sectors were strongly coupled with the high dependency of energy on water. The authors also indicated that virtual water is essential to respond to increasing demand in the future in this region. Another study by Khan revealed that considering the water-food nexus is essential, and countries in the Gulf Cooperation Countries (GCC) must cooperate to support investment in infrastructure and to establish strategic regional food banks.

Some research has been undertaken on the integration of energy and water security, especially in the Middle East region. In a study by Dubreuil et al. (2012), 'Water modeling in an energy optimization framework–The water-scarce Middle East context', the authors highlighted that references have been made to the nexus of energy and water and how considering the linkages between them could help in the planning of cohesive strategies. The results of this study count energy as the main factor in boosting water accessibility in the region.

Another study undertaken by Lee et al. on water-food-land security investigated the impact of food trade on food security and saving water and land resources in the MENA region (Lee et al., 2019). It also noted that virtual water trade was the primary element for integrity and connectivity among resources. The study showed that the region could reduce water stress and save available water resources through food trade. Therefore, it is essential that policymakers consider available water and land in each country in the region for planning for food security.

Even though a direct approach to addressing the EWF nexus had not been suggested prior to the first mentions at 'The Water, Energy & Food Security Nexus – Solutions for the Green Economy' conference held by the Stockholm Environment Institute (SEI) in Bonn in 2011, numerous studies have emphasised that rather than focusing on the challenges of ensuring EWF security separately

as individual systems, the interconnected nature of energy, water and food must be considered, to produce an integrated approach that crosses all three domains. Often there are overlapping challenges among all three systems: energy processing activities that require large quantities of water (OECD, 2006; Thirlwell, Madramootoo & Heathcote, 2007); irrigation and other agricultural practices that require significant amounts of water for food production (Gerbens-Leenes, Hoekstra & van der Meer, 2009; WEF, 2011) as well as energy required for post-harvest stages (Canning et al., 2010); and other activities which impact the environment negatively such as deforestation, overgrazing and agricultural activities with low productivity and high water intensity to ensure food and energy security (Bizikova et al., 2013). Many authors stress that future challenges will require integrating EWF nexus systems because decisions enhancing one area of security while compromising other areas will prove unsustainable. If the current business-as-usual way of dealing with the security challenges are continued, then the intense competition for resources to fulfil individual sector goals will lead to further unsolicited conflict among sectors and cause unrest in the whole region.

Apart from international dialogue on the EWF security nexus, there are no studies on effective integrated systems models that provide an effective policy framework for EWF security in the MENA region and that enable these challenges to be considered from a nexus point of view. This gap in research is a major loophole in policy making and effective management of these resources. The EWF security nexus approach can potentially become the bridge that closes this gap, by incorporating resource use efficiency, transparent and integrated governance of resources and sustainable practices in energy, water and food processes to provide increased access to and supply of sustainable energy, water and food in the region and to lead to further development.

This study will attempt to close the gap in the research by presenting the EWF security nexus as the bridge to assist with making well-informed policies to address the security challenges that are predominant in the MENA region. Additionally, the research presented here will cover the existing approaches (Chapter 2) to determine where these approaches may have been inadequate in addressing resource insecurity. Further, by developing a policy framework, this research demonstrates the appropriateness of the nexus approach by applying this policy framework to provide recommendations that would make timely contributions to the development of potential solutions to address the security challenges in the region.

1.3 Research objectives

Against this backdrop, the main objective of this research is to develop a comprehensive perspective on the nature of the EWF security nexus for selected countries[1] in the MENA region, with a view to strengthening the capacity of the policymakers to address the security challenge.

The specific objectives of this research are as follows:

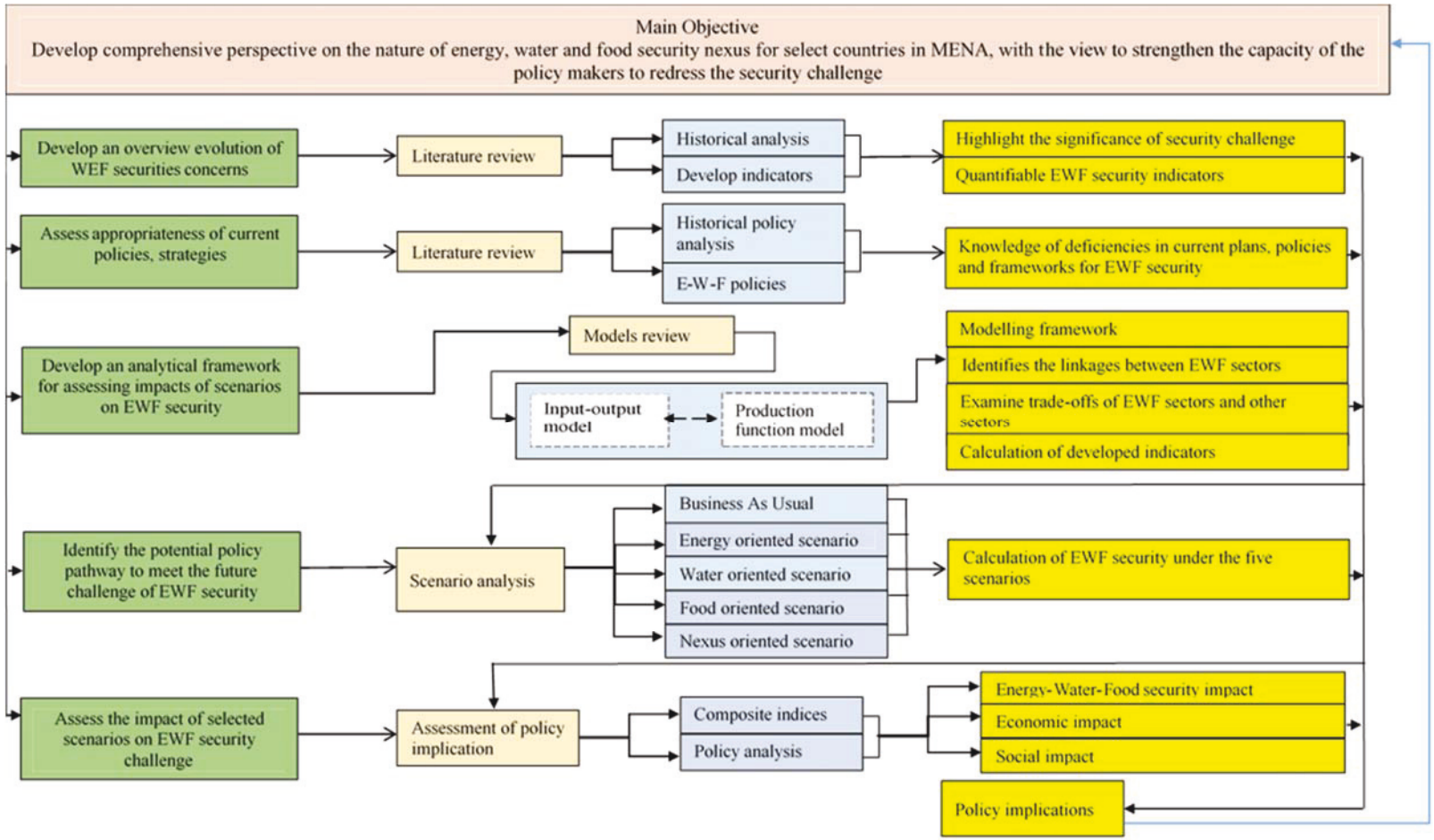
1. To develop an overview of the evolution of EWF security concerns in the MENA region, with a particular focus on the selected countries for this study
2. To assess the appropriateness of current policies and strategies in the MENA region for addressing EWF security threats, with a view to identifying the weakness of existing policies
3. To develop an analytical framework for assessing the impact of alternative resource policy pathways (scenarios) on EWF security
4. To identify the potential policy pathway (scenario) to meet future demand for EWF
5. To assess the impact of selected scenarios[2] on the EWF security challenge in the selected countries and recommend policy options to address those security challenges in the MENA region.

1.4 Research framework

The overall methodological framework for this research is presented in Figure 1.2. The framework combines a set of research methods applied in this research. The methods presented consist of four parts: historical analysis, input-output modelling, scenario analysis and assessment of policy implementation. The methods applied in this research are a combination of qualitative and quantitative approaches, which could develop a broad understanding of the EWF security nexus in the selected countries of the MENA region. More detailed information of the methods in this research is presented in Chapter 5.

[1] The selected countries for this research are Iran, Israel, Saudi Arabia, the UAE, Qatar, Kuwait, Oman, Egypt, Morocco and Tunisia.
[2] Five scenarios will be discussed in this research: Business as Usual (BAU), Energy (ESC), Water (WSC), Food (FSC) and Nexus Scenario (NSC).

Figure 1.2: Overall research framework



1.4.1 Historical analysis

The historical analysis in this research is applied to review the EWF security challenges in the MENA region with particular focus on the countries selected for this research. This analysis will assess the EWF nexus from various dimensions, namely, environmental, economic, technological, social and political, to recognise the security challenges related to the sectors in the region. The EWF security indicators, subsequently developed, are based on the results of the historical analysis. For this purpose, the historical analysis is divided into three time periods, which present significant developments in the economic and demographical structure of the region and their impact on EWF resources. These periods are:

- 1950-1970, which includes decolonisation, socio-economic improvements and state-building processes in the countries in the region
- the 1980s, when countries started structural adjustment, Islamism became widespread and population growth in the region accelerated
- after 1990, which covers the transition towards advanced developments, rights for women, a higher level of education and such conflicts in the region as the Gulf War, the Arab Spring and the Syrian civil war (Yüceşahin & Tulga, 2017).

The aim of the historical analysis is to identify the factors that firstly constructed the nexus of EWF in the past and secondly recognise the nexus security challenges that are predominant today.

1.4.2 Input-output analysis

This research requires a framework that captures inter- and intra-industry linkages and the wider economy and that takes the nexus between energy, water and food into consideration. For this purpose, the conceptual foundation of various methods that could incorporate the nature of the EWF nexus was reviewed. These methods have been categorised based on qualitative and quantitative approaches. The purpose of this task is to review the strengths and weakness of each of the selected methods and select the appropriate framework for this research. Therefore, the selected framework for this research is judged based on the following criteria: the ability to assess the sectors at a disaggregated level while presenting the technology/policy outcomes (spatial scope); the ability to examine the EWF nexus impact over the long term (temporal scope); the ability to consider the technological changes over time (dynamic consideration), the ability to assess the impact of price changes on sectors of the economy (price consideration) and the ability to apply publicly available data (data consideration).

Based on the reviewed methodologies, input-output (IO) analysis with a modified production function was selected for the framework of this study. The framework established based on this

analytical tool consists of five components. In the first component, the core model was extracted from the GTAP[3] 9 database into the form of an IO table in the monetary units. In the second component, the model implemented technological changes based on the alternative scenarios. The third component assessed the impact of changes in sectoral prices (due to technological changes) by using the IO price model. In the fourth component, the substitutional effects in response to the change in EWF were analysed. The last component compared the macroeconomic impact of technological changes with the structure developed in the first component.

1.4.3 Scenario analysis

This research considered five scenarios, namely, BAU, ESC, WSC, FSC and NSC, to examine EWF security for 2030 and 2050. The main focus of the scenarios is to concentrate on one sector as the main factor for enhancing EWF security (ESC, WSC and FSC), while in the NSC scenario all three sectors are considered as the main driver for improving EWF security.

The scenarios are based on the input-output model by considering economic growth, change in the demand for energy, water and food and by considering the new technologies in each sector (energy, water and food). The outcomes of the scenarios could be useful for evaluating EWF security based on the various energy, water and food policies modelled in each scenario.

1.4.4 Assessment of policy implementation

In order to recommend more integrated policies for the energy, water and food sectors, the results of the scenarios developed in this research were applied to assess the impact of the BAU, ESC, WSC, FSC and NSC scenarios on the EWF sectors and the wider economy. The impact of these scenarios is shown in terms of economic and social outcomes, energy security, water security and food security. Specifically, this study examines the trade-offs that may arise between policies that aim to achieve different and oftentimes conflicting objectives (for example, maximising economic prosperity, maximising employment opportunities, and ensuring energy, food and water security) under the three scenarios.

The outcomes of the research provide useful insights into the nature of the EWF nexus and the security challenges that prevail in MENA. The findings are used to put forward comprehensive understanding for more effective policy formulation to address EWF security challenges. The purpose of the policy analysis is to provide timely recommendations that would assist with cross-sectoral integration and strengthen institutional arrangements in the energy, water and food industries, improve the effectiveness of existing frameworks, and help develop additional

[3] GTAP: Global Trade Analysis Project

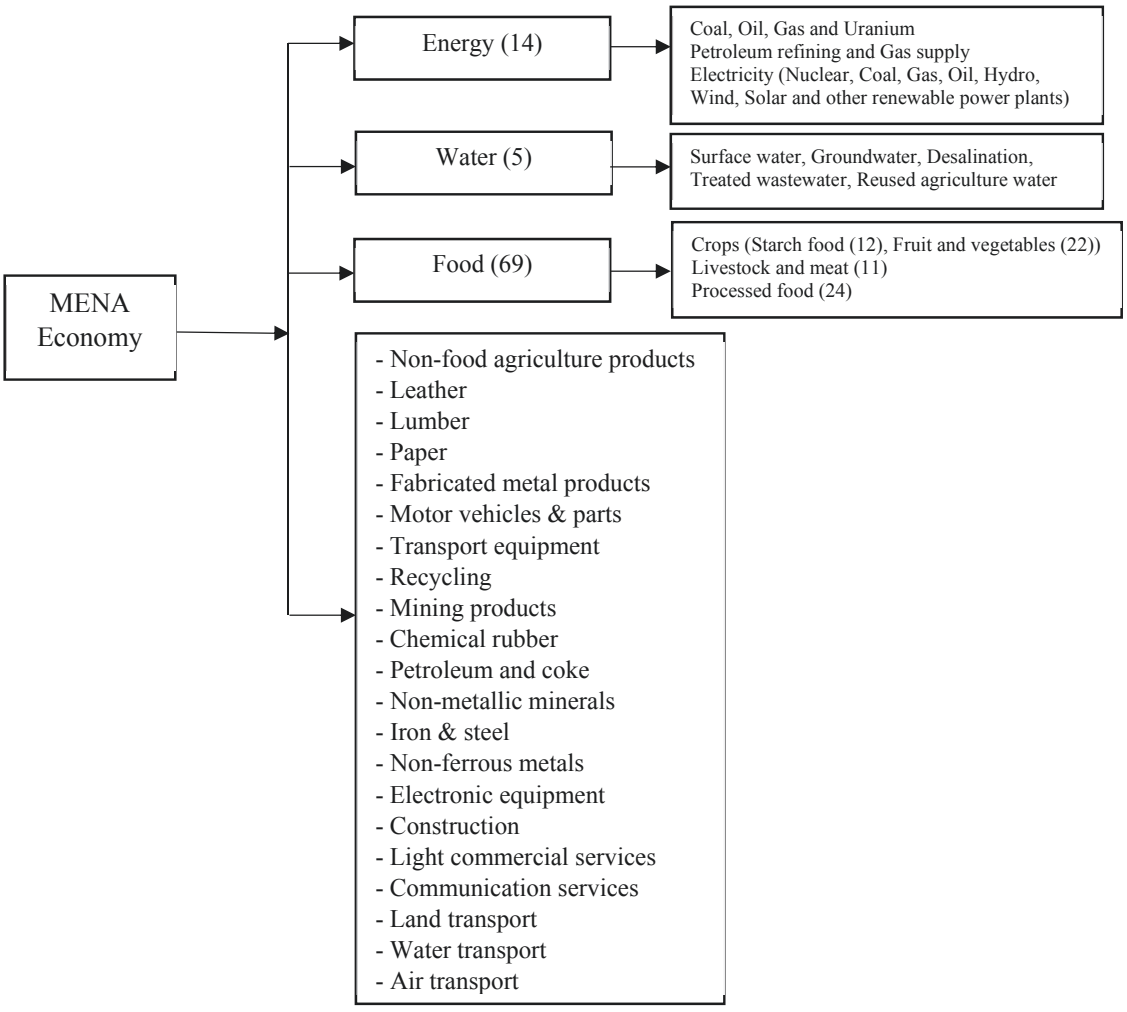
measures that would reduce the potential for trade-offs in the future when considering EWF security in a nexus.

1.5 Scope of this research and data considerations

This research focuses on 10 selected countries (Iran, Israel, Saudi Arabia, the UAE, Qatar, Kuwait, Oman, Egypt, Morocco and Tunisia) in the MENA region which include 65% of the region's population and account for more than 80% of its gross domestic product (GDP). The spatial, temporal and sectoral scope of the analysis is presented based on the data availability. The scope of the sectoral coverage in this research is shown in Figure 1.3.

The structure of the economy in the selected countries in this research is organised based on the available sectors in the GTAP9 database. The energy sector consists of 14 subsectors (primary and secondary energy), the food sector has seven main sectors, there are 21 other economic sectors (excluding energy, water and food sectors) and the water sector. The water sector in the GTAP database is available at an aggregated level, which is further disaggregated into five water supply options, namely, surface water, groundwater, desalination, treated wastewater and reused agricultural drainage. This disaggregation presents existing sources of water used in the selected countries in the region. This disaggregation also accords with the available data published by the Food and Agriculture Organization of the United Nations (FAO). In addition to the water sector, the seven main food sectors presented in the GTAP database have been disaggregated further in detail based on the available data in the food balance sheet presented by the FAO (Figure 1.3).

Figure 1.3: Sectoral coverage for this research



The time period for this research analysis was different for each objective of the study. In the historical analysis, the research covered three periods (1950-1970), (1970-1990) and (1990-2018) based on the important regional and national movements, economic and demographic. For the input-output analysis, the most up-to-date table used was for the year 2011, constructed by the GTAP9 database and published in 2015. The scenario analysis modelled five scenarios for the future of energy, water and food for the 10 countries in this research for the year 2030 (short term) and 2050 (long term). The timeframe was selected based on available strategic plans and consider emerging new technologies which could be available in the long term. For the last objective, the implementation of various scenarios in terms of policy trade-offs and EWF security is discussed mainly for the short- to long-term period.

This research requires four main types of data: energy data, water data, food data and economic data for four general sectors, namely, the energy, water, food and other sectors in the economy.

The data for each type was collected from different published sources. The summary of the data considered for each objective is presented in Table 1.1. Further information about the data applied in the modelling in this research is discussed in Section 5.5.

1.6 Significance of this research

This research is the first attempt to apply a nexus-based approach to policy development and EWF security issues in the selected MENA countries. The research was conducted for one of the most sensitive demographic, economic and political regions in the world, and which is currently facing water and food security challenges. The dominant policies in most of the countries in this research mainly concentrate on mono sectoral (i.e. energy, water or food). The outcome of this research is expected to provide an integrated framework that can be used to develop the insights needed for coherent policies to address the EWF security challenge.

The methodological framework applied in this research could contribute significantly to the available literature related to the EWF nexus as the existing literature is narrowly focused on certain sectors or linkages in the EWF nexus study. The framework could be useful for other regions with similar concerns for their EWF security and need to reform energy, water and food industries.

The research concentrates on 10 countries in the MENA region, which consists of 65% of the region's population and account for more than 80% of its GDP. A national level focus could present trade-offs between the countries in the region. It further could improve the security of the resources for all the citizens in the region. The principle guideline of this research is how such potential trade-offs would lead to efficient policy-making that would increase the cross-sectoral integrations, both at national and regional level. The findings of this research will provide a country-specific outlook on resource security issues and a deeper understanding of the historical, organisational and institutional aspects of EWF security. The conceptual and methodological contributions from this study will make it valuable and provide further direction for multidisciplinary research.

The outcome of this research could be beneficial for policymakers at local, national, regional levels involved in developing and implementing energy, water and food policies. Further, this research may contribute to the efforts of the countries in the region and international organisations to identify and address the root causes contributing to poverty, unemployment, resource challenges and sustainable economic development. Further, academic researchers might find the

Table 1.1: Data considerations for each specific objective

Objectives	Data requirement	Data Sources	Data availability	Data gaps	Strategies to overcome the data gaps
1&2	Key historical events and movements; social and development paradigms; historical development of indicators to measure security; institutional arrangements; political orientation	Books, policy papers, journal articles, legislation and personal contact	Scattered	Minor	N/A
3	(a) Input-output table (10 countries) (b) Energy data (c) Water data (d) Food data (e) Constant elasticity of substitution	(a) GTAP9 Database (b) IEA, EIA, GTAP9, national annual reports, unpublished data (C) AQUASTAT, MIRO, national annual reports, journal articles, unpublished data (d) GTAP9, FAO, national annual reports, unpublished data (e) GTAP9, journal articles, unpublished data	Highly scattered	Significant	Use other countries with available data as proxies, access national archives and approach regional researchers and government ministries, Data interpolation
4	(a)Population growth forecasts (b)GDP growth rate for future (c)Data for energy, water and food demand in future (d) Labour productivity for future (e) Energy efficiency improvement (f) Agriculture productivity	(a)UN (b) WB, AFDB, IMF, National strategic plan reports (C) WB, IRENA, IEA, EIA, FAO, OECD, NEA, government reports, journal articles (d) CEIC (e) IRENA, journal articles, regional and global reports (f) WB, FAO, regional and global reports	Highly scattered and partially available	Significant	Data extrapolated from historical trends, assumption

Note: GTAP: Global Trade Analysis Project; IEA: International Energy Agency; EIA: Energy Information Administration; AQUASTAT: FAO's Global Information System on Water and Agriculture; FAO: Food and Agriculture Organization; UN: United Nations; WB: World Bank; AFDB: African Development Bank; IMF: International Monetary Fund; IRENA: International Renewable Energy Agency; OECD: Organization for Economic Co-operation and Development; NEA: Nuclear Energy Agency; CEIC: global economic data, indicators, charts & forecasts.

approach applied in this research a useful point of reference for conducting multi-disciplinary research and development of integrated models.

1.7 Organisation of the thesis

This thesis consists of nine chapters, which are organised as follows:

Chapter 2 comprehensively reviews the existing interdependencies between the energy, water and food sectors to identify the synergies and trade-offs across the sectors and overcome unsustainable patterns. For this purpose, this chapter reviews the existing energy, water and food studies to identify their appropriateness for examining the nature of the nexus and recognise the areas that require further research.

Chapter 3 presents the finding for objective 1 and objective 2. It assesses the historical trends of the EWF nexus for the MENA region with a particular focus on the selected countries in the region. The purpose is to identify the forces that have developed the nexus to gain a deeper understanding of the current security nexus challenges.

Chapter 4 reviews the methods that are used most in evaluating the EWF nexus to determine the interdependencies among sectors and the direct and indirect contributions made by the other sectors of economic activities to EWF nexuses. For this purpose, the relative strengths and weaknesses of the different methods are reviewed in order to select an appropriate methodology for this research. The methodological framework for assessing the EWF nexus is then explained in detail in Chapter 5, which presents objective 3 of this research.

Chapters 6 and 7 relate to objective 4. Chapter 6 is the first part of the empirical analysis of the EWF nexus and it begins by describing the social and economic impacts of the five scenarios considered in this research. This is followed by an investigation of energy security based on the attributes defined in Chapter 5. Chapter 7 forms the second part of the empirical analysis of the EWF nexus, and evaluates water and food security based on the defined attributes in the different scenarios. The outcomes of both chapters for the short term (2030) and the long term (2050) are explained.

Chapter 8 presents the results for objective 5. This chapter evaluates the EWF security for individual countries and by country groupings. The purpose of this chapter is to provide a policy perspective for the EWF security challenge in the countries in this research. Chapter 9 presents the main conclusions of this research and provides some recommendations for future research.

Chapter 2: A review of the EWF security nexus

Energy, water and food are not only the essential resources to sustain life on earth, they are fundamentally interwoven together. However, growing population, globalisation and climate change impact the sustainability of the linkages between and among these resources. This can cause imbalances in the trade-offs between these resources and whether people can overcome these challenges while respecting the interdependency of the resources remains doubtful. Until now, society has gained limited insight into the linkages and how to manage such a system in a sustainable manner in all dimensions. The purpose of this chapter, therefore, is to review the interconnectivity among energy, water and food to identify the synergies and trade-offs across them and overcome unsustainable patterns. To this end, this chapter is broken into six sections. Section 2.1 briefly explores the linkages between energy, water and food. Section 2.2 discusses energy, water and food security in the MENA region. Section 2.3 focuses on understanding the nature of the EWF nexus. Section 2.4 reviews existing studies and compares them in terms of their objectives, methodologies, scope and major findings. Section 2.5 discusses the main limitations of existing studies and then identifies the gaps in the studies. The last section presents a summary of the major findings of this chapter.

2.1 Linkages between energy, water and food

The linkages between energy, water and food are complex and diverse. To assist in understanding the nexus concept, this section discusses briefly the interdependence between and among these sectors.

Energy for water

Energy is consumed in every stage of water supply, such as pumping, transporting and treating. In the Middle East, this consumes 40% of the total electricity generated (Dubreuil et al., 2013). In conventional water sources, pumping groundwater is more energy intensive than pumping surface water. In some countries, more than 40% of total energy is required for pumping groundwater (Hoff, 2011). Another essential use of energy for water is in generating non-conventional water sources, such as reclaimed wastewater and desalinated water, but these need high energy inputs. In Saudi Arabia, half of the oil consumed locally is required to run the

desalination plants (Rambo et al., 2017). It is expected the dependency on desalinated water as a primary source of water will grow by 500% in the MENA region by 2030 (Hoff, 2011). The need for desalinated water will increase the demand for energy significantly in the mid-term in the MENA region.

Water for energy

Water is an essential input for the energy sector. It is needed in the extraction, mining, processing and refining (Hoff, 2011) of oil, gas, coal and uranium and for growing biofuels. It is also required for electricity generation. On the one hand, it is used for cooling power plants and on the other hand, it is used to generate electricity through hydropower. In the United States, half of the fresh water drawn from the ocean is used mainly for cooling thermoelectric power plants (Finley & Seiber, 2014).

Energy and water for food

Energy and water are both inputs for the food sector. Energy is used directly and indirectly in agriculture. The direct usage of energy is for operating farm machinery, and transportation to improve labour productivity and reduce the cost of food production; indirect usage is in producing fertilisers and pesticides to improve yields and land productivity (Schnepf, 2004). Worldwide, food production is one of the main consumers of water resources. An enormous amount of water is needed for food production and processing. In the MENA region, the agriculture sector consumes more than 80% of conventional water resources. The volume of water used directly in the irrigation system is comparable with water for cooling power plants and municipal needs (Finley & Seiber, 2014). It is estimated that one calorie of energy in food requires about one litre of water (Hoff, 2011).

2.2 EWF Security in the MENA region

Access to secure supplies of water, energy and food is a global challenge. However, as noted above, energy, water and food systems are interwoven together and uncertainty in the one impacts the others.

In order to develop a greater understanding, in this section, the nature of the security challenges in the MENA region is discussed. It deals first with each of the three security challenges individually and after that addresses the collective inter-related EWF security challenges.

Energy Security

The MENA region has plentiful oil and gas reserves. The region is the home of seven OPEC members and has two-thirds of the world petroleum reserves, with Saudi Arabia, Iran, Iraq, Kuwait and the UAE the largest proven reserve holders in the world (Abbott & Marsden, 2009). The region also contains more than 40% of the world's natural gas reserves, with Iran and Qatar holding the second and third largest gas deposits in the world. This puts MENA in a crucial position in terms of supplying the energy to meet world demand. In 2017, for example, nearly 30% of global crude oil and 15% of global natural gas were provided from this region alone (IEA, 2019). Hence, political stability in the MENA region is vital for ensuring energy supplies for the world, even more so because the region remains the source of the world's cheapest oil (IEA, 2014). Another critical issue is that most countries in the region rely heavily on oil and gas revenues (Dreger & Rahmani, 2016). For instance, in 2013, 90% of government revenue in Bahrain, Iraq, Libya and Saudi Arabia came from hydrocarbon resources. Between 60% and 80% of government revenue in Algeria, Qatar, Oman, the UAE, Kuwait and Yemen and 50% in Iran also came from hydrocarbon resources (Sowers, 2014). Therefore, income from oil and gas is critical for the political, social and economic stability of most of the MENA nations (Azadi & Yarmohammad, 2011).

As mentioned above, the concept of energy security may differ from country to country. In general, energy security is defined as 'access to clean, reliable and affordable energy services for cooking and heating, lighting, communications and productive uses' (Dreger & Rahmani, 2016). Currently, the region is not only the world's largest oil producer, it has also become an enormous oil consumer due to its rising domestic needs (Woertz, 2015). Energy demand has been gradually escalating over the past decades in response to increases in population, to urbanisation and to improvements in living standards. It has also been impacted by the expansion of desalination capacity in the MENA region (CEBC, 2014), as well as by excessive fuel subsidies. For example, annual demand for electricity in the region was twice the average global electricity demand over the period 1990-2015 (Menichetti et al., 2019). According to British Petroleum (BP), the Middle East, where consumption increased by 4.4%, was the fastest growing region in the world in terms of energy consumption in 2014 (BP, 2015). It is also predicted that the region's energy consumption will increase by 114% over the period 2010-2050.

One of the reasons for the escalation in energy demand in this region is the shortage of potable water. Energy is needed for water purification and desalination, pumping and conveyance, end-user (e.g., heating and cooling in buildings) and wastewater treatment (Al-Zubari, 2014; Siddiqi et al., 2013; Dubreuil et al., 2013). More than 50% of the world's desalination capacity is located in the MENA region and it consumes more than 4% of the total electricity generated there (CEBC, 2014).

Although the region is energy rich, most of its energy resources (oil and gas) are exhaustible. This implies that MENA will sooner or later face long-term energy insecurity, which is thus a key driver for the MENA nations to move towards renewable energies such as solar, wind and nuclear (Abbott& Marsden, 2009). Currently, 3.3% of total electricity in the region is generated by renewables (Bryden et al., 2013). Although the MENA region has massive potential for various types of renewable energy (Fragkos et al., 2013), the water footprint of different types of energy infrastructure (renewables and non-renewables) is a significant challenge for policymakers (Sowers, 2014). One example of the excessive need for water in energy infrastructure is thermal and nuclear-powered plants – for which most countries in the region have expressed ambitions – because they require significant amounts of water for their cooling systems. Nuclear power is already an integral part of the energy mix of Iran and Jordan (Sowers, 2014) while both countries suffer from a lack of enough available water. Wind energy is another option for generating electricity in the region. Between 2008 and 2011, the share of wind energy in producing electricity increased by 27% annually in Egypt, Tunisia and Morocco (Bryden et al., 2013). It is also estimated that solar energy, the generation of which takes up less than 0.3% of the total desert area in the region, could produce enough electricity to meet the entire region's desalination needs (Clemente, 2015). However, solar energy has been largely neglected due to the high subsidies given to hydrocarbon-based fuels, mismanagement and a lack of adequate public awareness about the potential and capacity of renewables. As a result, pro-renewable policies have to a large extent remained unchanged in the region (Fragkos et al., 2013).

In summary, MENA is as an energy-rich and energy-exporting region; most of its energy supply is sourced from exhaustible oil and gas resources; domestic demand for oil and gas is growing faster than the world average. Therefore, it is possible that MENA may not remain an energy-exporting region in the future but may instead become a net importer, which in turn could pose a long-term security threat to the region.

Water Security

Of the three resources in the MENA region under discussion in this thesis, water security is of particular concern. Water security, in the context of the discussion here, is the capacity of a population to safeguard sustainable access to adequate quantities of acceptable quality of water for sustaining livelihoods, human wellbeing and socio-economic development. Such a definition also underscores the importance of protecting a society against water-borne pollution and water-related disasters and for preserving ecosystems in a climate of peace and political stability (Bigas, 2012). The MENA region is known as the most water-deficient region in the world (Antonelli & Tamea, 2015; Damerau et al., 2015; World Bank, 2007). In a global ranking of 186 countries developed by Maplecroft (2011), the top five water-stressed states were Bahrain, Qatar, Kuwait, Saudi Arabia and Libya. This ranking is followed by other countries in the region, such as Yemen, Israel and Jordan (Maplecroft, 2011). According to the World Resources Institute (WRI), by 2040, most of the countries in the MENA region could also become highly water-stressed (Maddocks et al., 2015), while the unmet demand for water in the entire MENA region will rise from 16% in 2014 to 37% between 2020 and 2030 and to 51% between 2040 and 2050 (Antonelli & Tamea, 2015).

According to the World Bank (2007), the availability of renewable water per-capita in MENA declined from 4000 m^3/y in 1950 to 1100 m^3/y in 2007. In terms of physical water scarcity, it is estimated that on average a withdrawal rate of renewable water resources above 20% represents substantial pressure on water resources; a withdrawal rate of more than 40% is considered 'critical'. In 2011, the FAO suggested that the withdrawal of renewable water resources in the region had already gone beyond the threshold limits of 20% and 40% of total renewable water resources (FAO, 2011). It is predicted that by 2050 the availability of water will have dropped to 550 m^3/y per person, which is much lower than the standard of 1000 m^3/y per-capita defined by the World Health Organization (WHO) (World Bank, 2007). It is widely suggested that if water availability falls to less than 1000 m^3/y per person, economic development would be impaired, human health and the environment could be severely challenged, and social and political stability could be affected (Engelman &Leroy, 1993; Bigas, 2012; Dubreuil et al., 2013).

The main reasons for water scarcity in the MENA region include population growth (Roudi-Fahimi & Kent, 2007), rising living standards, increasing industrial activities (Tropp & Jägerskog, 2006) and the impact of climate change on water resources (Bates et al., 2008; Sowers, 2014). In addition to the above, other major reasons for this shortage are the extensive use of water for energy production, energy conversion and food production (Antonelli & Tamea, 2015; Al-Zubari, 2014).

As mentioned earlier, water is needed to extract fossil fuels from the ground, to refine petroleum products and to cool the power plants used for electricity generation (Al-Zubari, 2014; Siddiqi et al., 2013; Dubreuil et al., 2013; Damerau et al., 2015). In 2010, for example, about 15% of total water available worldwide was used to generate energy, an amount that could compete with the water used for food production (FAO, 2015). Water, therefore, plays a critical role in the MENA region, which has the largest reservoirs of fossil fuel-based and renewable energy (Damerau et al., 2015).

Another primary source of water consumption in the region is the water-intensive agriculture sector (Abbott& Marsden, 2009; Al-Zubari, 2014; Sowers, 2014; Antonelli & Tamea, 2015). While water consumption by households and industry is relatively small (Richards & Waterbury, 2008), the agriculture sector accounts for nearly 85% of total water withdrawal in the region (FAO, 2009). An additional negative factor is that water efficiency in the agriculture sector in the region is less than 40% (Al-Zubari, 2014). Besides playing a crucial role in food production and national food security, the agricultural sector also accounts for a large share of the labour force, while making a modest contribution to GDP (Al-Zubari, 2014). For example, based on World Bank data, more than 24% of female employment and 16% of male employment in 2018 was in the agriculture sector.

Irrigation is the primary agricultural challenge in this region (Antonelli & Tamea, 2015) because the irrigation systems in MENA countries are mostly dependent on scarce groundwater resources (FAO, 2011). Cheap (fossil) fuels in some large MENA countries (e.g., Saudi Arabia, Libya and Iran), and the availability of advanced drilling technologies in these countries have contributed to a dependency on underground aquifers that are incredibly precious and scarce – one could say that they are even more valuable than oil resources. As a result, non-renewable water resources have been depleted before they have been given any chance to be naturally

restored by rainfall or surface flows (Sowers, 2014; Antonelli & Tamea, 2015). Some of the springs and wells have already run dry due to aggressive usage by the agricultural sector or local communities in Saudi Arabia, Algeria, Yemen, the West Bank and Gaza and Jordan (Sowers, 2014).

Due to persistent water shortages, some MENA countries like Algeria, Saudi Arabia and other GCC states have invested massively in water desalination plants (CEBC, 2014). Desalination processes are, however, extremely energy-intensive (Al-Zubari, 2014). For instance, Saudi Arabia, Kuwait, Algeria, Libya, UAE and Qatar use approximately 10% of their primary energy for desalination (CEBC, 2014). An alternative method that is used by some countries, such as Egypt, Lebanon and Jordan, to alleviate water security is wastewater reuse (World Bank, 2007; CEBC, 2014). However, due to improper maintenance and poor management, water pollution and salinity challenges have increased in these countries (Sowers, 2014). Water pollution alone is estimated to cost 0.5% to 2.5% of GDP annually in the MENA region, with Iran, Morocco, Jordan, Gaza and Lebanon as the most impacted countries (World Bank, 2007).

Therefore, the limited availability of water resources together with rapidly growing water demand in MENA have become a severe water security threat – and hence a significant policy challenge – for the region.

Food Security

The 1996 World Food Summit defined food security as 'when all people at all times have access to sufficient, safe, nutritious food to maintain a healthy and active life' (WHO, 1996). Food security is a complex and multidimensional issue shaped by four factors: availability, access, stability and utilisation (FAO, 2013). In addition, food security is achievable if the link between health via appropriate basic nutrition, water sanitation, development in the economy, environmental conditions and trade situation is taken into account (WHO, 2014). Measuring food security is therefore a challenging task as the concept can be considered from various dimensions.

Regarding food security in MENA, while there is no outward shortage, security concerns become relevant if one considers the water scarcity in the region and its dependency on imports. Current and future levels of food production depend not only on the availability of water but

also on the availability of arable land (Antonelli & Tamea, 2015). Countries such as Qatar, the UAE, Bahrain, Oman and Kuwait have the lowest arable land per person in the world (FAO, 2013). Although most of the countries in the region have placed self-sufficiency in food at the forefront of their policies since the 1970s, current levels of available water mean they are unlikely to be able to meet their future agricultural needs (Woertz, 2011).

Further, due to climate change and population growth, countries in the region face an increasing demand for food, all against the backdrop of rising water shortages and lack of arable land. As a consequence, countries in the region have become net importers of food, especially of cereals, sugar and cooking oils (Ahmed et al., 2013; Antonelli & Tamea, 2015). For example, the Middle East region is the largest wheat importer in the world, importing 138.3 million tons of wheat from 2012 to 2014; wheat accounts for nearly 35% of the total caloric consumption of the population in this region (Nigatu & Motamed, 2015). According to the World Bank, more than half of the food calories consumed in the MENA region are imported and this could rise to 64% in the next two decades (World Bank, 2009). Some MENA countries, such as Morocco and Saudi Arabia, compete against each other when importing food, for example, by removing tariffs for the importers and providing subsidies for consumers (Wright & Cafiero, 2011). In 2007-2008, North African countries imported more than 20% of the world's wheat production, despite the fact that they accommodate only 2% of the world's population (Clemente, 2015). Through food trading, a huge amount of the virtual water that is embedded in foods such as rice, barley and wheat was imported into the region (Woertz, 2015). The amount of virtual water exported from the Nile Basin played a significant role to full fill the availability of enough freshwater in MENA countries (Zeitoun et al., 2010). Although implementing a food-import policy helps MENA countries to procure enough food for their populations, some concerns remain. For example, a by-product of this policy is that policymakers in the region have postponed the implementation of any serious reform to enhance the management of water resources (Alan, 2003; Zeitoun et al., 2010).

Also, the volatility of the world food markets is a significant threat to food security in MENA (Wright & Cafiero, 2011). Some rich countries in the region, such as the Gulf countries, need to spend considerable oil wealth to import the food required by their people. However, in the future they may not be able to afford food imports due to the continuing instability in energy prices (Woertz, 2011). Other countries, such as Iran, Syria, Egypt and Jordan, will require strong economies to enable them to buy food from the USA, the European Union, Russia and Australia (Abbott & Marsden, 2009; Sowers, 2014). Recent uprisings in Morocco (2007),

Yemen (2008) and Egypt have mainly occurred as a result of the increasing cost of food (Abbott& Marsden, 2009).

To address the instability in food prices, some countries in the region have joined China and India to procure agricultural land in countries like Sudan and Ethiopia, which have enough renewable water and arable land (Woertz, 2013). However, few of these projects have been successful in mitigating food insecurity because the populations of sub-Saharan African countries are already suffering from acute malnutrition due to war and drought (Sowers, 2014). Such programs are also fundamentally unfair from a moral standpoint.

It is therefore clear that, as with energy and water security discussed in the previous sections, the MENA countries have limited capacity to secure enough food to meet the rapidly growing demand, both in the short and long term. Hence, food security is an issue of great concern for the region.

EWF Security

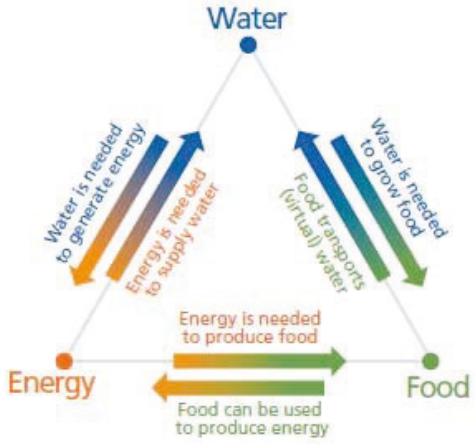
Although significant efforts have been made by the MENA countries to meet their Millennium Development Goals (MDG), particularly their hunger targets (i.e., food security), ongoing conflicts and wars in the region have militated against reaching these targets (FAO, 2015). A significant reason is that food security is highly intertwined with water and energy insecurity. The current status of energy, water and food (as well as climate change) in the MENA region has created massive vulnerability for its population. If the existing trends continue, providing enough energy, water and food will become a significant challenge in the years to come and could potentially create energy, water and food insecurity for the region.

Achieving EWF security is, however, likely to be a complex task. There are several reasons for this complexity. Three potential reasons are discussed below:

i) Above all, the flow of resource-to-use processes of energy, water and food are interconnected in a sophisticated manner and there are a lot of mutual synergies and trade-offs between them. For instance, water is an essential input for producing both energy and food. In Iran, Egypt and Algeria, for example, 92%, 86% and 64% respectively of renewable water resources was used in the agriculture sector in 2013 to secure the food supply chain (Cammett et al., 2015). The remainder of the water supply

was used as input into the cooling systems of thermal power plants, for resource extraction, for transport and for growing bio-fuel plants (Hoff, 2011). In 2010, water used in the energy sector worldwide was 15% of the total world water withdrawn (Clemente, 2015). Energy is a requisite for withdrawing, distributing and treating water (United Nations, 2014). For instance, 14% of total generated electricity in Libya and 5% of total generated electricity in Saudi Arabia is presently needed for pumping water (Siddiqi & Anadón, 2011). Energy is also essential for food-related activities as power is needed for irrigation machinery and for the production and transportation of agricultural foods. In 2013, for example, 5% of energy generated in Egypt and 4.2% of energy generated in Libya was used in the agriculture and forestry sector (IEA, 2016a).

Figure 2.1: The interfaces of water, food and energy



Source: (UNU-FLORES, 2016)

ii) Additionally, EWF security is multidimensional (Rasul & Sharma, 2015). The water, food and energy security trilemma creates a web of several dimensions in a complex structure (see Section 2.3). For example, the security of each of these sectors has technical, economic, social, political and environmental dimensions. The security of each of these sectors could also have a relationship with environmental security, economic security and human health security and so on.

iii) Further, the interactions between energy, water and food are dynamic in nature, varying both in weight and direction (FAO, 2014; Rasul & Sharma, 2015; Allouche et al., 2014). This means that a change over time in one sector could impact one or both of the other sector/s, which could also have direct or indirect implications for the economy, the

environment and society (Allouche et al., 2014; Rasul & Sharma, 2015). Therefore, the security of one sector depends on the security of one or more other sector/s in a dynamic manner (Lele et al., 2012; Ringler et al., 2013).

2.3 Nature of nexus

As explained in the previous section, there are significant synergies and trade-offs among energy, water and food. In other words, there is a complex inter-dependency between the securities/insecurities of these resources/products. This complexity is referred to in the literature as a ***nexus***. Understanding and appreciating the nature and importance of the nexus requires an analytical framework that can capture such interdependencies and provide a useful assessment of the impacts of any potential change in one domain on other domains. Such an evaluation could enable policymakers to compare various policy options and move policy-making into a green economy framework (Hoff, 2011; Waughray, 2011). Such framework could result in optimising the synergies between the three sectors, reducing negative trade-offs and identifying and addressing the social and environmental implications (FAO, 2014; Bazilian et al., 2011; Prasad et al., 2012; Coles & Hall, 2012; Rasul & Sharma, 2015).

From the above discussion, it is concluded that the nexus has three unique specifications: interdependencies, multidimensionality and dynamism. In this research, the multidimensionality feature of the nexus is defined as environmental, economic, technological, social and political. The section below discusses each of the dimensions in detail.

2.3.1 Environmental dimension

Environmental changes impact energy, water and food and the linkages between these resources. As the source of all natural resources, the environment plays a vital role in the nexus approach. In this section, the impact of two dimensions of the environment on energy, namely water and food, are discussed.

Climate change as one dimension of the environment impacts nature and the human system (Holtermann & Nandalal, 2015). The shift in climate incurs significant stress on energy, water and food resources. It affects annual rainfall, the flow of a river, availability of groundwater and water quality. Climate change also impacts energy resources, as available energy infrastructure requires water in order to operate (Dale et al., 2011). Alterations in climate affect

food directly by altering the production of crops and indirectly by influencing the food price (Gregory et al., 2005). However, research shows that human activities are the primary reason for the severity of climate change (Shadman et al., 2016). Due to growth in energy demand, more fossil fuels are being burned, which increases CO_2 emissions in the earth's atmosphere. Fossil fuels alone are responsible for 88% of the world's CO_2 emissions (Dale et al., 2011).

Drought, another dimension of the environment, is considered a significant challenge in many regions of the globe. More than 90% of West Asia and North Africa is arid or semi-arid, which causes severe social and economic issues in these regions (El Kharraz et al., 2012). Drought could be intensified by human behaviour, such as increases in desalination, treated wastewater and exclusive irrigation (Agha Kouchak, 2016). Drought impacts energy, water and food from different aspects. In the water sector, drought reduces the amount of water supply and increases the water temperature, which then affects aquatic species. This results in less electricity generation (Scanlon et al., 2013). In the food sector, drought reduces yield productivity and causes a loss in livestock, which decreases the national harvest and the amount of livestock products. Hence, the decline in food security and the decrease in the share of agriculture in GDP make a country's food security more vulnerable (Devereux, 2007).

2.3.2 Economic dimension

The economic dimension of the EWF nexus is another vital player in the nexus approach. The goal of EWF nexus thinking is to have a 'green economy' and economic growth is not necessarily 'green'. A green economy is 'an economy that results in improved human well-being and social equity, while significantly reducing environmental risks and ecological scarcities' (Hoff, 2011). However, economic growth puts substantial stress on energy, water and food resources and the linkages between them (Boas et al., 2016).

Energy plays a vital role in economic growth while bearing substantial responsibility for polluting the environment (Kais & Ben Mbarek, 2017). In the MENA region, energy is abundant and economic growth is fast, but there is no consideration for the environment and pressure is incurred simultaneously on energy, water and food resources. During periods of economic growth, water usage increases because water is an input into almost everything produced in the energy and agriculture sectors. Over-pumping of groundwater because of the availability of cheap energy to achieve food self-sufficiency is one of the examples of improving economic growth in the MENA region.

Another factor for economic growth is the widespread consumption of water and energy due to low pricing and high subsidisation (Rao et al., 2017). In the MENA region, 22% of government revenue is used to subsidise energy costs, a policy that encourages even more pumping of water out of the ground (IMF, 2014).

2.3.3 Technological dimension

Technology is defined as 'physical mechanisms or processes intended to produce desired results' (Rao et al., 2017), which could optimise the linkages between energy, water and food. The technological dimension is identified as a great support for the environmental and economic dimensions of the EWF nexus to facilitate moves towards sustainable development. It reduces the cost of environmental impacts, which in the end will enhance growth in the green economy (Popp, 2012).

Technological intervention plays a vital role in reducing pollution, especially that caused by CO_2, and it helps keep environmental limitations under control (Camagni et al., 1998). Fewer CO_2 emissions means the economy can produce outputs with less energy use. This means a reduction in energy consumption and improvement in energy efficiency (Chen & Lei, 2018). Through technological innovation, renewable energy can replace conventional fossil fuels, which could reduce the amount of water needed for thermoelectric power plants (Rao et al., 2017). For example, geothermal energy is an established technology that could be used as a source of energy for desalination plants (Rao et al., 2017). In addition to the benefits they bring to energy and water, technological innovations can improve food security. New and current technologies could enhance the productivity of crops and livestock, increase soil fertility and improve water availability, which would result in more food production (UNCTAD, 2017). Although technological innovation creates more and significant potential for accessing more energy, water and food, it requires local and regional policies to simplify the adaptation process. This integration is especially needed in energy and water policies (Rao et al., 2017).

2.3.4 Social dimension

Any function in society requires energy, water and food. Hence, any change in the linkage between these resources impacts the individuals in a society and these impacts can be direct or indirect. A direct effect happens as a result of the strong relationship between the different levels

of income in a community and the resources that they can afford. An example of direct impacts could be the conflict in Syria where lack of water, drought and climate change in 2011 caused the migration of large populations from rural to urban areas, which in turn increased food insecurity and played a direct role for initiation of the Syrian civil war (Gleick, 2014). Society can suffer indirectly through the link between EWF resources and climate change. For example, due to hot weather, lack of rain and the high evaporation rate of fresh water in GCC[4] countries, almost 90% of drinking water is now generated from desalination plants that require excessive amounts of electricity.

Another social dimension of EWF insecurity is a misinterpretation by society of the value of resources. For instance, GCC countries are among the worst food wasters in the world even though their food security is under significant threat. Researchers estimate that around 80% of food purchased weekly in Saudi Arabia is thrown away to make room for new groceries (Baig et al., 2018). This is due to the country's subsidisation policy, indicating that the real value of food is hidden. Another example is water consumption in Qatar, a country with no surface water and limited groundwater. Up to 99% of domestic water is provided through desalination. However, the use of water per-capita is 500 l/day, which is the highest in the world (Baaloush & Ouda, 2017). Over-subsidisation sends the message to consumers that resources are cheap and can be exploited (Rao et al., 2017).

To sum up, at the social level, energy, water and food decisions are always linked to householders' consumption as they seek to meet their demands while ignoring trade-offs between resources (Gyawali, 2015). Therefore, there is a need for educational awareness programs that inform individuals about the consequences of their actions on the environment.

2.3.5 Political dimension

Processing the EWF nexus needs policies that enhance harmonisation and cooperation across sector activities. Such strategies improve collaboration and reduce trade-offs (Carius & Kramer, 2017). These policies can be divided into two parts: regional and national. From a regional perspective, currently the MENA political system is complicated with little integrity between the sectors. Nor do the available strategies reflect the interdependency of the sectors; for

[4] The Gulf Cooperation Council (**GCC**) is a political and economic alliance of six Middle Eastern countries: Saudi Arabia, Kuwait, the United Arab Emirates, Qatar, Bahrain and Oman.

example, policies do not consider the amount of water required for energy generation from fossil fuels and renewable resources. Even if such strategies were available at regional level, there is no obligation to implement them at a national level (Carius & Kramer, 2017). Another regional issue is transboundary issues as the region is highly dependent on outside water resources; more than 60% of surface water resources originate from outside the region, a primary challenge for the region going back 4500 years (Gleick & Society, 2014). Three central basins in this region, the Euphrates and Tigris Basin, the Nile Basin and the Jordan Valley Basin, are surrounded by 11 countries (Syria, Iraq, Israel, Egypt, Jordan, Lebanon, Gaza Strip, West Bank, Turkey, Sudan and Ethiopia) and these basins need to meet the demand of 46% of the MENA region's population. There is no integrated policy among these countries and food security and the stability of energy generation are under threat (Al-Zubari, 2019).

At national level, policies can be reviewed from two major dimensions: economic and environmental. Current economic policies are broadly focused on subsidisation of energy, water and food in most countries of the region. In Arab countries, unfortunately, the subsidies are available to the whole nation and there is no differentiation between poor and rich.

As the countries in this region are growing fast, they expect the demand for energy, water and food to increase, which puts pressure on climate change. Recent sand storms in the Middle East are an example of how segregated policies impact the environment. The primary source of a sand storm in Iraq is a reduction in rainfall, land degradation and desertification (Sissakian et al., 2013). Therefore, there is an urgent need for climate policies that align with the nexus approach and consider the linkages between resources (Al-Zubari, 2019).

2.4 A review of existing studies

In recent years, many studies have focused on the EWF nexus from different perspectives: 1) energy-water, 2) water-food, 3) energy-water-food and studies related to climate (Endo et al., 2017). Out of these four important types of nexus, a review of current studies is classified in this thesis in two major sections: section A in this chapter reviews existing major studies related to the EWF nexus globally and section B presents studies related to all types of nexus studies in the MENA region alone. These studies examine the EWF nexus approach in terms of objectives, method and scope, and Tables 2.1 and 2.2 show their detail. This review helps identify the limitations of the research in this area to date. The selected studies are discussed in detail in the following section.

2.4.1 Section A: EWF studies globally

a) Hellegers et al., 2008: China, Ethiopia, India, Jordan, Pakistan, Sri Lanka and the USA

This study was one of the pioneering research projects into the linkages between energy and water. The primary objective of the paper was to review the connections between the sectors and highlight the major policy issues in the water sector. The authors focused on how the growing demand for energy and food would impact the water sector and how, as a result of these effects, the alteration in water allocation could affect food security, exploring some theoretical views of previous studies along with country- and basin-level case studies.

The result of this discussion suggests that assessing EWF interactions provides deep insights which could help to minimise the negative impacts of such linkages and improve synergy benefits through exploring alternative strategies and policies. The dynamic nature of the EWF linkages could alter the institutional status of the sectors, which could lead to possible policy reform. Alterations in policies may lead to the development and promotion of new technologies that improve efficiency and productivity within and among sectors. This study concludes that any increase in energy price will increase the demand for biofuels which will in turn increase the cost of food production. The need for food will also grow as the population grows, which increases the demand for water-intensive foods.

Table 2.1: Major energy, water and food nexus studies

Author	Objective	Method	Scope	Major finding
a)Hellegers et al. 2008	To review the interactions between energy and water and explore the impact of a change in water allocation on food security.	Meta-analysis & qualitative analysis	China, Ethiopia, India, Jordan, Pakistan, Sri Lanka & the USA	Growing demand for energy and food may impact water price, which increases the possibility of policy reform. This change may introduce new technologies which improve efficiency and productivity. Food security falls as more water is needed for biofuel production by 2030.
b)Bazilian et al. 2011	To provide a rationale for a nexus approach while exploring the linkages between energy, water and food.	Qualitative analysis	Worldwide	A nexus approach improves the current security and economic challenges in EWF sectors. 'Silo thinking' dominates, as each area has different policies and regulations, and it needs to be replaced by 'system thinking'. Describes different frameworks that could apply to nexus.
c) Coles & Hall 2012	To explore the nexus approach framework and consequences of applying this perspective to growing demands.	Qualitative analysis	Worldwide	It is not possible to plan for EWF resources in the long term based on a BAU approach. A nexus perspective is the essential perspective for moving towards a green economy.
d)Hermann et al. 2012	To explore the interactions between climate, land, energy and water.	CLEW 5 model & scenario analysis	Burkina Faso	Isolated sectoral policies are not sufficient to investigate the impacts of sectoral policies on other sectors. A consistent framework like CLEW considers interactions among resources which support policymakers in managing resources sustainably.
e) Rasul, 2014	To explore the EWF nexus approach by concentrating on ecosystem services at a regional level.	Quantitative assessment	Hindu Kush Himalaya	Integrated cross-sectoral management is needed to manage the complex interdependencies within EWF sectors. The nexus approach provides deep insight into linkages among EWF and interdependencies between upstream and downstream countries.

[5] CLEW: Climate, Land, Energy and Water

Author	Objective	Method	Scope	Major finding
f) Finley & Seiber, 2014	To investigate the interlinkages between EWF and count water as the most critical resource.	Quantitative assessment	Worldwide	Water plays a vital role in the nexus approach. Resources must be assessed based on integrated policies. Nexus thinking is critical for managing and analysing the trade-offs between resources.
g) Conway et al., 2015	To consider the role of climate change as the primary driver for the nexus approach.	Hydrological models, coupled model & scenario analysis	Southern Africa	Climate variability causes instability in EWF interactions. The linkages between EWF are strong at the regional level as countries with different levels of political power trade resources with each other. Establishing regional agreements for EWF will move the region towards a green economy.
h) Gain et.al., 2015	To explore the concept of the EWF security nexus in the context of Bangladesh.	Policy integration	Bangladesh	The nexus approach should be recognised in the policy documents of Bangladesh to facilitate it moving towards a green economy.
i)Kurian, 2016	To explore the relationship between poverty and the environment and the role of a nexus approach.	Regression analysis & scenario analysis	Worldwide	To implement the nexus approach, a new institutional framework is needed. A trade-off concept assists in evaluating the relationship between poverty and the environment. Transdisciplinary approaches support sustainable development in planning and managing resource usage.
j)White et al., 2018	To analyse how energy, water and food flow virtually through trade within the region.	Input-Output modelling	East Asia	EWF consumption could be beyond the national and regional boundaries plus ecosystem boundaries. There is a mismatch between regional resource availability and resource flow destinations and a lack of consideration for the environmental impacts of trade policies. There is also a mismatch between regional resource availability, resource flow destinations and consumption and a lack of attention to the environmental effects of trade policies.
k)Dai et.al., 2018	To review the different methods used to study the EWF nexus.	Meta-analysis	Worldwide	None of the current research provides a framework for a nexus study. Most of it focuses on understanding nexus interlinkages that are not applicable to supporting governance actions or to implementing technical interventions.

b) Bazilian et al., 2011: Developing countries

Energy, water and food are interlinked in a sophisticated manner, causing security concerns that range from accessing resources to environmental impacts and instability in the market. On the one hand, populations and demand globally are growing rapidly while, on the other hand, the resources are limited and are functioning in a regulated market. There is, therefore, a big concern about balancing supply and demand in different regions at the same time as EWF resources are vital for each society to operate efficiently. Thus, the purpose of this study is to explore the rationale for a nexus approach while at the same time referring to some of the interdependencies between EWF at an aggregated level.

The study applies a descriptive approach to some examples of interdependencies between these three areas and how each of these resources impacts others, all from the perspective of a developing country. The findings of this study emphasise the necessity of the nexus approach to address concerns about the economy and the security of EWF resources. As each of these areas has different rules and regulations, there is a need for 'system thinking' to avoid 'silo thinking.' Therefore, an institutional framework and modelling tools are needed to reflect the complex interactions and support integrated policies. Such a system will optimise the wellbeing of society in the long term. The authors describe the major frameworks that could be used for the nexus approach, such as life cycle assessment (LCA) and the CLEW modelling framework.

c) Coles & Hall, 2012: Worldwide

This work focuses mainly on the concept of the nexus approach and how nexus thinking could shift society towards a green economy. The authors argue that a long-term plan for EWF security is impossible if the current business-as-usual (BAU) scenario continues. This is especially critical for water resources, as the demand for it will increase significantly. Consuming water with the BAU approach could cause serious transboundary conflicts and environmental deterioration. Therefore, a new way of thinking is needed to manage the dynamic nature of resources while respecting their interconnectivity. A nexus perspective provides a transparent framework that analyses the trade-offs between resources while achieving sustainable development goals. The study concludes that applying nexus thinking to science, technology and policy would improve the management of land and water and hence enhance EWF security.

d) Hermann et al., 2012: Burkina Faso

This study explores the interconnectivity between and among climate, land, energy and water (CLEW) at national level in Burkina Faso. It demonstrates that using an integrated approach between resources could be beneficial even for a country with limited resources and the least economic development in the world. For this purpose, the study applied the CLEW modelling framework, which shows the interdependency between climate, land use, energy and water into one consistent framework. The aim of this framework is to systemise the linkages so as to analyse the resources used while considering the impacts of climate change. This research proved that assessing resources separately without recognising their effects on the other resources is not adequate. Having deep insight into the interrelationships among resources allows decision-makers to create policies that can manage resources in a sustainable manner.

The results of this study show that policies in the agriculture sector seriously impact energy and the environment, especially in countries with limited resources such as Burkina Faso. In this case study, providing extra energy resources for the agriculture sector could enhance yields and reduce the need to expand agricultural land in the future. From an environmental perspective, this approach reduces GHG emissions because it allows the forest area to grow. Another finding was that intensification in the agricultural sector will positively impact the energy sector, which will enhance development and improve food security and land use overall.

e) Rasul, 2014: South Asia: Hindu Kush Himalaya

This study emphasises a nexus approach as the most efficient cross-sectoral framework because it improves resource efficiency while controlling competition among sectors. However, the value of the ecosystem needs more attention in this approach. The main focus of this study is to examine the EWF nexus from a regional perspective while considering the role of the Hindu Kush Himalayan (HKH) ecosystem services in supporting EWF security downstream.

The author identifies some of the critical indicators for agriculture, water and energy and how the indicators might change from 2007 to 2050. While the study recognises population and industrial development as the main factors in there being less agricultural land per-capita in the region, its results show that per-capita income and food production have improved in the region in recent years, while per-capita food consumption has stayed stagnant. This situation could get worse in the future as a result of climate change, while the continuing low consumption of food could cause constant hunger and malnutrition in the region.

This study recognises key environmental and socio-economic challenges in the region: the environmental challenges include land degradation, declining soil fertility, water pollution and water-borne diseases, while the socio-economic challenges include malnutrition, a rise in child mortality, poor human health and a serious lack of energy resources.

This study suggests that there is a need for consistent cross-sectoral policies within EWF security that consider the interrelationship between sectors and the linkages among upstream and downstream countries. Such a framework would enhance awareness of the challenges and improve coordination among countries in the region. Applying this framework requires an integrated model that addresses the trade-offs between sectors to strengthen collaboration within the EWF sectors.

f) Finley & Seiber, 2014

This investigation of the EWF interlinkages claims that water is the most important resource for energy and food production. The study focuses on environmental issues such as global warming, which has been intensifying due to over-usage of carbon fuels for energy production. The authors believe that water is the most limited resource among the other resources. Therefore, it is very urgent to increase water efficiency, improve access to clean water and use wastewater for energy and agriculture.

For this purpose, the nexus approach must be developed to enhance EWF security since the silo treatment of resources will not resolve the current challenges. Further, introducing any new technology for each sector is not the solution until evaluating the impact of this technology on other resources and the environment. Hence, integrated governance and international policies based on a nexus approach must be considered. Such strategies would lead the world towards a green economy to provide sufficient energy, water and food for all humans.

g) Conway et al. 2015: Southern Africa

Future climate change challenges and their connection with EWF create the structure of this study. Its claim is that climate change has a high impact on essential sectors, such as agriculture and energy, and on the socioeconomic condition of vulnerable countries.

In this study a modified version of Hoff's framework was applied, which recognised climate change as the primary source of pressure on the EWF nexus. This framework explores the

relationship between the EWF nexus, climate change and economic activities at a national level. The authors suggest two steps for evaluating the economic dimensions of the framework: the first involves using general equilibrium models to convert the impact of biophysics on economic outcomes and the second focuses on climate and energy policy and identifying the role of GHG emissions in national income and employment. In the next step, the study examined five different climate change scenarios from the global hydrological model over different areas in Southern Africa.

The results conclude that uncertain climate change causes instability among the EWF components in the nexus which then impacts economical activities in Southern Africa. At a regional level, the nexus interdependencies are strong, as countries are sharing several resources, such as river basins, power infrastructure and virtual trading of water through food.

h) Gain et al., 2015: Bangladesh

While Bangladesh has a big population moving fast towards urbanisation, poverty remains a significant threat. Available resources are also in danger for several factors: unplanned economic development, lack of enough energy resources, poor quality drinking water, land use change and fluctuations in climate. The aim of this study was to analyse how the nexus approach could assist in overcoming these current challenges in Bangladesh.

At present, the policies in the country follow silo rather than system thinking. The main focus of available plans is sectoral based and a nexus approach has not yet been recognised by policymakers. Further, the policy system in Bangladesh is complicated: some policies overlap or conflict with each other, which creates unproductive and inefficient solutions and new challenges. The authors argue that in this situation, 'policy integration' could remove existing stress on available resources.

However, integrated policies should meet three criteria: comprehensiveness, aggregation and consistency. Satisfying these criteria could support and lead the country towards a nexus approach. Therefore, this study applied the policy integration framework to a different segment of the policy cycle, namely, agenda setting, policy formulation, decision-making, implementation and evaluation. The policy integration framework includes improvement in current policies and resource management (Albrecht et al., 2018). In this framework, stakeholders play a vital role and the collaboration and contribution of different stakeholders help the system to achieve a higher level of policy integration. The results of this study

demonstrate that ‘policy integration' is the foundation of the nexus approach and it could help Bangladesh to reduce the pressure on its resources while alleviating poverty and moving towards a green economy.

i) Kurian, 2016: Worldwide

The primary objective of this study was to explore the relationship between poverty and the environment from a nexus perspective. This objective was broken down into three subsidiary objectives. The first subsidiary objective was to investigate the institutional aspect and how an institutional framework could assist in implementing a nexus approach. The author believes that the institutional framework needs to identify the role of government in controlling how a nation uses and manages the environment. Therefore, a comprehensive view is needed that not only considers the environmental impacts on the EWF nexus but also recognises the role of the government in the interaction between resources, services and risks.

The second subsidiary objective was to introduce trade-offs and threshold concepts as a means to overcoming challenges in the EWF nexus. These concepts empower people to understand the consequences of policies and technologies on the environment and explore the potential for optimising the use of resource. The study explains how trade-offs assist in evaluating the relationship between poverty and the environment as a complex and nonlinear relationship. Poverty-environment interaction can be examined from two dimensions: 1) cost-benefit analysis for environmental management and 2) revenue and expenditure analysis for delivery of services to the public. The third subsidiary objective of the study was to underline the significant role of transdisciplinary approaches to plan and manage environmental resources and move towards sustainable development.

j) White, 2017: China, Japan and South Korea

Due to urbanisation, energy, water and food demand is increasing rapidly in East Asia, particularly in China. Although China has 20% of the world’s population, is has only 7% of the world’s fresh water. Economic growth in China is increasing water consumption in the urban and industrial sectors. China exports virtual nexus resources to Japan and South Korea to respond to the growing demand of customers. Although Japan and South Korea benefit from importing products, China carries the burden of the environmental issues arising from the production of those exports. From a EWF nexus perspective, the current trend of China's national export strategy focuses on economic growth with low value added which is not sustainable. This is because the intensive sectors in China consume huge amount of EWF

resources for producing low value added to satisfy the demands for customers in Japan and South Korea.

The study shows how energy, water and food flow virtually through trade within the region, using a multi-regional input-output (IO) model to demonstrate the linkages between the three sectors and show how human activity puts pressure on the environment. The results of this study demonstrate the inequality between demand and supply in the region, supporting the argument that final consumption is much higher than the available resources while the environmental impact is ignored in the trade-off policies of the region. If China continues the same economic growth and trade policies, responding to its domestic demand will be a significant challenge in the near future. Therefore, policymakers in the region should consider EWF resources in their strategic plans and to operate trade-off more effectively.

k) Dai et al., 2018

The main objective of this study was to explore the different modelling approaches in existing EWF studies. For this purpose, 35 studies were selected based on their objectives, the geographic area they covered and their nexus scope (any combination of energy, water, food, land and climate). The main purpose of the methods applied in the studies is discussed in detail. The nexus studies are divided into three levels: 'understanding interlinkages', 'governance actions' and 'implementing policies' to achieve a trade-off balance.

The result of this investigation shows that although many kinds of research have focused on providing a cohesive framework for the EWF nexus, there is no holistic framework available to cover all three of the levels mentioned above. Most of these studies (30 out of 35) focused only on the 'understanding' and 'governance' levels but few explored the nexus at the 'implementing policies' level. The findings also show that comparing the methods applied is difficult as they explored the nexus from different contexts. In addition, most of the studies concentrated only on a single industry or one function of that industry. An added complication is that most of the available studies used water footprint or life cycle (LCA) methods. Some of them looked at the nexus from a systematic approach, such as cost-benefit analysis or an optimisation management model. Only a few of the studies available discussed the EWF nexus at the macro-level with integrated models and on different geographical scales.

These findings demonstrate that current studies cannot assist 'governance actions' or technical implementation for the EWF nexus, as Dai et al. expressed it.

Table 2.2: Major EWF nexus studies in MENA

Author	Objective	Nexus type	Method	Scope	Major finding
l) Siddiqi et al., 2011	Investigate the linkages between water and energy.	EW	Quantitative assessment	MENA	Water and energy coupled together strongly with a high dependency of energy on water. Virtual water is essential for responding to increasing demand in the future.
m) Hassan Khan, 2012	Review the current situation of water and food and how the sectors impact on each other.	WF	Qualitative analysis	GCC	There is need for a water-food nexus. Countries must cooperate to support investment in infrastructure and to establish regional strategic food banks.
n) Dubreuil et al., 2012	Apply energy optimisation model to water allocation challenges to assessing the optimal energy-water mix in the long term.	EW	TIAM-FR, scenario analysis	Middle East	Energy is the main factor in improving water accessibility. 40% of the total electricity demand will be used for water supply by 2050. Energy-water intensity is a suitable tool for assessing the nexus approach from a technological perspective and water management policies.
o) Siddiqi et al., 2013	Establish a systematic framework that bridges a gap between energy and water expert planners and policymakers.	EW	Jordan's framework (stakeholder theory, boundary spanning agents)	Jordan	There is a need for a cohesive strategic plan to overcome the growing inter-linkage challenges in the energy-water nexus.
p) Daher & Mohtar, 2015	Introduce a conceptual framework (WEF Nexus Tool 2.00) which identifies linkages between related systems and achieve quantifiable results.	EWF	WEF Nexus Tool 2.00 (IO and scenario analysis)	Qatar	Offers a WEF Nexus Tool 2.00 platform to recognise resources and estimate scenarios.

Author	Objective	Nexus type	Method	Scope	Major finding
q) Scardigno et al., 2017	Analyse multidimensionality between water resources and food security	WF	correlation analysis	MENA	There is a positive correlation between water and food. Water and food systems must be treated as an integrated system.
r) Rambo et al., 2017	Exploring the linkages between energy and water nexus	EW	Sankey diagram	Saudi Arabia	Energy and water trends are unsustainable in the long term. Considering the nexus approach is critical for the continuity of these resources.
s) Lee et al., 2019	Investigating the impact of food trade on food security and saving water and land resources	EWL	Eigenvector centralities network	MENA	Virtual water trade (VWT) is the primary element for integrity and connectivity among resources. Plans for food security depends on water and land availability. VWT could improve water stress.

2.4.2 Section B: EWF studies in the MENA region

l) Siddiqi et al., 2011: The Middle East and North Africa (MENA)

This was the first research into the nexus approach in the MENA region. This region expects a big population, growing urbanisation and rapid change in lifestyle by 2050. Demand for water will increase by 76% and for energy by 64%. Therefore, the aim of this study was to investigate the linkages between water and energy in this region to enable it to respond to demand more efficiently and effectively.

This paper used quantitative assessment at the country level to show the interdependency between energy and water and the results of the evaluation show a strong relationship between the two resources, with a high dependency on energy for water. The study emphasises that virtual water plays a vital role in the region. Using virtual water and changing the structure of the economy from an agricultural base to a service base will enable the region to respond to the growing demand for some time into the future. Another major issue is the impact that climate change will have on the availability of water in the future, which will in turn influence the linkages between energy and water. This indicates the significant role of EWF linkages for policymakers and how policies could be affected.

m) Hassan Khan, 2012: GCC

The GCC consists of five countries in the Middle East: Saudi Arabia, Bahrain, Kuwait, Oman and the United Arab Emirates. Although these countries are well known for their energy resources, fresh water and food security is a major problem. Khan discusses the current situation of water and food in the GCC countries and shows how these sectors connected and how to affect each other.

The primary drivers for food and water security in the GCC are growth in population, rapid urbanisation, high income per-capita and changing living standards. From the resource side, the availability of conventional water has reached zero, yet per-capita water consumption is among the highest in the world. To supply such a demand, this region has 60% of the world's desalination plants. Although desalination plants could solve the water shortage, they have an extreme impact on the environment. In addition, because the supply of desalinated water is fully subsidised, household consumption levels are high.

Although 85% of fresh water use is for agriculture, food security remains the most severe challenge for the governments in this region. Low production rates, an arid climate, high temperatures and soil salinity are the main contributors to food insecurity in GCC countries.

Khan suggests that the water-food nexus could help the GCC countries manage the current situation more effectively in the future. Further, this study recommends that water and food security should be considered part of the mutual international policies between GCC countries. All countries in the region must cooperate in their investment in infrastructure and consider establishing regional strategic food banks.

n) Dubreuil et al., 2012: Middle East

This study focused on the energy-water nexus in one of the most water-stressed regions in the world, the Middle East. It argues that there is an essential need for a joint long-term plan for both sectors to control the pressure of human activity and climate change on energy and water resources. Exploring the interdependency between energy and water could help in the planning of cohesive strategies. Hence, this study applied an energy optimisation model for water allocation challenges to assess the optimal energy water mix in the long term.

The study analysed results based on a TIAM-FR[6] bottom-up energy optimisation model designed uniquely for water. The model can undertake assessments at regional level and has a unique specification for climate change which enables atmospheric greenhouse gas emissions to be captured in real time from anywhere in the world. Three different scenarios were discussed in this model: the first scenario was a Standard TIAM-FR, which analysed the business-as-usual trend. The second scenario was a 'With WATER' module, which considered the specific changes resulting from a new water model. The third scenario was 'With WATER module and irrigation efficiency', in which water efficiency improved the irrigation system.

The results of the study support the close and complicated relationship between energy and water. It also counts energy as the main factor in boosting water accessibility in the region. The results showed that the 'With WATER module and irrigation efficiency' scenario was the best long-term option in the Middle East. In this scenario, 22% of electricity demand for generating water could be saved, while CO_2 emissions would drop by 60%. From a water perspective, in this scenario, conventional water as the primary source could meet the demand of the region and the use of unconventional water would decrease by 60%. The study considered energy-water intensity as a suitable tool for assessing the nexus approach from the technological and water management perspectives.

[6] TIAM-FR: The TIMES Integrated Assessment Model

o) Siddiqi et al., 2013: Jordan

This study selected Jordan as a case study because the country suffers from lack of water and low energy resources. Currently, Jordan's policies consider energy and water sectors separately and they are run by different organisations. The requirement to improve the efficient use of resources means that the energy and water nexus must also be assessed from institutional and social perspectives. The purpose of this study therefore was to establish a systematic framework that would bridge the gap between energy and water expert planners and policymakers.

The framework developed consists of three components: first, recognising the physical relationship between energy and water; second, identifying key stakeholders and decision-makers in the sectors and, third, using the results from the first two components, to identify the dominant stakeholders who play a central role between energy and water policymakers.

In summary, the study demonstrated that the relationships between the sectors are asymmetric, with a weak dependency on water for energy and a strong reliance on energy for water. The study also put emphasis on integrated strategic planning among the energy and water sectors to enhance the efficiencies of these resources.

p) Daher & Mohtar, 2015: Qatar

Operating a nexus approach needs support from decision makers. However, there is no useful framework for policymakers that presents resource allocation and the trade-offs between different systems. Currently, the available tools do not cover all the features of a nexus approach, such as multi-dimensionality, interconnectivity and implementing cohesive strategies and policies.

The aim of this paper, therefore, was to present a conceptual framework (WEF Nexus Tool 2.00) that identifies linkages between related systems and enables them to obtain quantifiable results. This framework provides a user with different food self-sufficiency scenarios based on food products, types of agricultural practice, source of water, source of energy and countries of import. Users can run scenarios that have been defined by the developers. Qatar was selected as a case study for this study to demonstrate the readiness of this tool.

q) Scardigno et al., 2017: MENA

This study explored the water-food nexus in the MENA region, where water resources and food security are primary concerns. The purpose of the study was to undertake a

multidimensional analysis of two indices of water and food security.

For this purpose, this study applied the five indices (resources, access, use, capacity and environment) of the Water Poverty Index (WPI) and the three indices of the Global Food Security Index (GFSI) (availability, affordability and food quality). All of these indices were calculated and correlated. This study concluded that it is critical to consider the linkages between water and food systems and that undermining such a relationship makes both systems vulnerable and leads to unsuccessful policies.

r) Rambo et al., 2017: Saudi Arabia

In this work, linkages between energy and water were investigated by mapping the consumption of these resources in Saudi Arabia. The Sankey diagram was selected as a tool to illustrate the flow and inter-dependency between sectors and map all the power plants in the kingdom based on their type and size. The results of this flow demonstrated that agriculture was the primary consumer in the water sector and desalination plants and residential users the primary consumers of energy. The study supports the interconnectivity between the sectors and claims that the sustainability of one is entirely dependent on the other. Despite this, the structure of the energy and water sectors in Saudi Arabia is still far from a nexus approach. The results show that if the current trend of consumption continues, Saudi Arabia will become a net importer of oil in the coming years. Therefore, policymakers need to consider the interconnectivity between water and energy in their planning.

s) Lee et al., 2019: MENA

The MENA region has the highest water deficiency in the world and the lowest food self-sufficiency. Due to these shortages, countries in this region import food to improve their water security. Based on this background, the purpose of this study was to explore the impact of food trade on food water and land security in the region. Trade was examined in the four major crops of barley, maize, wheat and rice between 2000 and 2012.

The study analysed the virtual (embedded water in food trade) water trade structure (expansion or reduction) in the region by applying a network-based approach and evaluating degree and eigenvector centralities. The study showed that the MENA region could reduce water stress and save available internal water resources through food trade. Therefore, policymakers should consider virtual water trade as a facilitator to improve water stress and scarcity challenges. Planning for food security depends on the available water and land in

each country. This information should be cross-checked against food imports while trade-offs between food security and food imports should be considered.

Lee et al. stated that the energy sector would benefit from virtual water trade because any increase or decrease in water withdrawal affects electricity consumption in the region. The study calls virtual water trade a significant component for integrity and connectivity between resources. Such a policy could improve resource management and develop a sustainable trend in the region.

2.5 Major limitations in previous studies

This section discusses the major limitations on earlier studies from the perspective of their objective, their methodology, their scope and the EWF nexus.

Objective perspective

The previous studies on the EWF nexus listed in section A (Table 2-1) can be classified into three different groups. The first group, which consists of studies (**b**) and (**c**), focuses on understanding the concept of the nexus approach, on reviewing the linkages between energy, water and food and on how the nexus approach could assist in improving the security of resources. Both studies emphasise the nexus approach as a unified framework that supports integrity between resources and moves us towards a green economy. The second group consists of the majority of the studies reviewed, namely (**d**), (**e**), (**g**), (**h**), (**i**), (**j**) and (**k**). These papers investigated the nexus approach from various dimensions. Studies (**d**), (**e**), (**g**) and (**j**) describe the nexus from the environmental aspect and consider the role of climate in the nexus framework. Study (**h**) reviews the nexus approach from a policy dimension and calls that a vital factor in implementing a nexus framework. Study (**i**) discusses the nexus from a social and environmental perspective and the role of trade-offs in realising the impact of resource interactions on poverty and the environment. Study (**k**) looks at the nexus from a technical point of view by reviewing the different methodologies applied to it. The third group covers studies (**a**) and (**f**). This group of studies assigned more weight to the water sector and considered water resources as a central element in the nexus.

The objective of the studies in section B can be categorised according to the type of nexus considered in each study. Group one comprises studies that focus on linkages between energy and water, namely, studies (**l**), (**n**), (**o**) and (**r**), all of which explore the interconnection between energy and water. Studies (**l**) and (**n**) put more emphasis on the

economic and technological aspects of the nexus approach, while studies (**o**) and (**r**) discuss the policy dimension. The second group investigated the water and food nexus. Studies (**m**), (**q**) and (**s**) describe the interlinkage between water and food and how by treating them separately, sectors could impact each other. Study (**p**) is the only study that concentrates on the EWF nexus from a technical aspect, introducing the WEF Nexus Tool 2.00 framework to implement a nexus approach.

Reviewing the objectives of sections A and B provided deep insights about the nexus concept and possible linkages between energy, water and food. However, these studies examine the EWF nexus approach mainly from a physical perspective and then attempt to identify the interconnectivity among resources either in detail or from one specific dimension. In the context of MENA, no study explores the linkage between energy, water and food jointly or considers the different dimensions of the nexus.

Research methodology

The studies reviewed for this research applied various methods to show the interrelations between energy, water and food. These methods can be broadly broken down into qualitative and quantitative analysis. The quantitative analysis in these studies included statistical analysis, hydrological models, a climate-land-energy-water (CLEW) model, the WEF Nexus Tool 2.0, a times-integrated assessment model (TIAM-FR), an IO framework, Jordan's framework, scenario analysis and a network-based approach.

Studies (**a**), (**b**), (**c**), (**h**) and (**m**) employed qualitative analysis in their work. Studies (**a**), (**b**), (**c**) and (**m**) described the nature of nexus and explored the interdependency between sectors. Study (**h**) used a policy integrated framework, which concentrates mainly on enhancing policy consistency and integration and improving resources.

The rest of the studies applied quantitative analysis. Studies (**e**), (**f**), (**i**), (**k**), (**l**) and (**q**) used statistical tools to gather data from an expert panel and public sources, while studies (**e**), (**f**), (**k**) and (**l**) used simple statistical analysis of selected data to investigate the linkages among sectors or combined data from different studies to review the current status of nexus studies (study (**k**)). Studies (**g**), (**i**) and (**q**) applied more advanced components of statistical modelling. Study (**i**) used regression to estimate the linkages between sources while study (**q**) used correlation analysis to evaluate the strength of the linkages between the water and the food sectors. Scenario analysis was applied in study (**i**) to assess the possible outcome of different socioeconomic indicators in the future that could help policymakers. Similar to the first group of qualitative analyses, these studies provide an in-depth understanding of

overall linkages between sectors but these methods cannot present the nexus concepts in the wider economy to the extent that is needed for evaluation and decision-making. Similar to the qualitative studies, this group of papers is vital for presenting the integrated nexus framework.

Study (**g**) applied hydrological models with scenario drivers. For this purpose, the global hydrological model (Coupled Model Inter-comparison Project Phase 5 (CMIP5)) was applied to forecast the annual precipitation for Southern Africa by 2080. This model provides a standard protocol for understanding climate change in the past, present and future. It identifies the main reasons for climate change, such as natural disasters, unforced variability or radiative forcing, in the form of a multi-modal context (WCRP, 2019). This study was the only one of those examined with an environmental dimension to the nexus.

Study (**d**) used the climate-land-energy-water (CLEW) model, which shows the interconnection between water, energy, land and climate change. This model assists in strategic planning and decision making, is easy and convenient to use and is adaptable and affordable. However, it is aggregated at the global level and it is data intensive (Dai et al., 2018).

Study (**j**) used environmental input-output analysis (EIOA). This model provides the linkages between sectors at national and regional level and reviews the impacts of sectoral interrelations on the environment, on the economy and on social systems (White et al., 2018). The main limitation of the Input-Output model is its fixed technological coefficient with no substitution between factors. This means that changes in physical structure cannot respond automatically to price changes (refer to Section 4.2.7).

Study (**n**) used a TIMES Integrated Assessment model (TIAM-FR) which evaluates the effects of optimisation in energy over the demand for water while considering the impacts of climate change (Dai et al., 2018). This is a bottom-up model that explores the energy sector from a technical dimension. The limitation of TIAM-FR is that it relies only on current consumer demand as the basis on which to analyse future issues. Also, this model cannot evaluate such macroeconomic components as unemployment, which is essential for policymakers (Ackerman et.al, 2009).

Study (**o**) used 'Jordan's framework' as the model; this is the conceptual framework that considers the EW nexus at policy implementation level with three main components. The first component recognises the physical relationship between energy and water; the second component identifies the key stakeholders and decision-makers in the sectors and the third

uses the results from the first two components to identify the dominant stakeholders who play an intermediate role between energy and water policymakers. Further, it assists in defining the role of key actors in the implementation. However, detailed information about the three components of the model and applied software is not available (Siddiqi & Anadón, 2011).

Study (**p**) implements a new model called the WEF Nexus Tool 2.0. This online tool assigns a value to the possible linkages between energy, water and food and allows the user to develop five different scenarios, enabling users to know the number or quantity of resources consumed in each scenario (Mohtar & Daher, 2013). The disadvantages of this tool are that (i) it is limited to the five scenarios defined by the developers and the user cannot introduce any new scenarios and (ii) it has no scenario for energy and/or water.

Study (**r**) visualised the flow between energy and water using the Sankey diagram. This diagram displays the interconnectivity between resources and identifies bottlenecks in the system visually. However, the Sankey diagram is presented at a very aggregated level and requires data collection from several sources (Rambo et al., 2017).

Study (**s**) applied a network-based approach to explore the structure of the virtual water trade and concentrated on trade network links. This approach could be a suitable method for identifying the structure of trade between nations, for assessing major flow and for understanding the degree of vulnerability of a country (Lee et al., 2016). It also helps break down the complexity of the nexus linkages to both their essential and redundant elements (Tsolas et al., 2018). However, the network-based approach cannot evaluate the impacts of such a complex system on the economy, the socio-economy and the environment.

To sum up, methods used in the existing studies attempt mainly to identify the linkages between sectors without extending the results to trade-off analysis, which is fundamental for policymakers. Studies that consider the EWF nexus from the economic dimension are at a very aggregated level while defined problems focus on only one dimension of the nexus.

Scope

Similar to objective and methodology, the scope of the reviewed studies is varied. Scope here is categorised into three levels: global, regional and country. In section A, most studies, that is, studies (b), (c), (f), (i), (k), (e) (g) and (j), applied the nexus approach at global and regional levels. A few studies, namely studies (a), (d) and (h), focused on exploring the nexus at country level. The major focus of studies (l), (m), (n), (q), (s) was on a regional MENA level and considered two types of linkages in nexus: energy-water or water-food.

There are few studies at country level ((o) (p), (r)), and these considered either two types of linkages (studies (o) and (r)) or explored the nexus for a specific feature (study (p)).

2.6 Summary and conclusion

Energy, water and food are profoundly linked. Based on the studies reviewed for this research, one can conclude that awareness about the cross-sectoral connection is increasing due to climate change, drought, growing demand and changes in policies. Despite the growing number of studies into the nexus approach, current studies do not present the analytical framework to assess the linkages from different dimensions. The research in this thesis, however, identifies this gap and explores the nexus approach from environmental, economic, technical, social and political dimensions. Some of the limitations of existing studies are summarised below:

- The objective of some studies was to explore the interconnection between resources at a general level of understanding to capture the main physical linkages between resources, but they did not examine any specific dimension. The objective of some other studies was to examine the EWF nexus from a specific dimension, such as climate change. There were no studies that discussed the linkages comprehensively from all dimensions.

- The existing research methodologies are inherently restrictive. Some methods, such as CLEW and TIAM-FR, concentrate on some specific interactions between resources or are applicable only at a very aggregated level. Some focus on specific segments, such as energy optimisation and water footprint. However, none of the current studies assessed the linkages at a disaggregated level while considering energy, water and food together.

- Current models cannot analyse long-term trends; even models with scenario analysis (WEF Nexus Tool 2.0) do not give users the freedom to explore different predictions.

- Some regions in the world have not been considered in studies of areas such as the MENA region, even though the security of resources (such as energy) in that area plays a significant role in balancing the security of resources for the rest of the world.

- Current studies in the MENA region investigate the linkages between two

combinations, water-energy and water-food. However, none of the studies that explore dual linkages present an analytical framework that explores the multi-dimensional features of the nexus.

While existing studies enhance nexus understanding, they do not capture sufficiently the interdependencies, multidimensionality and dynamism of WEF security in the MENA region. Further, no study presents a platform for assessing the impacts of alternative policy pathways to address the challenges in the future. Such a policy framework will play a key role for policymakers in the region to manage and govern the currently available resources more effectively and with consistent cross-sectoral policies. Through this approach, social equity would improve while the environmental impacts and resource scarcities could reduce significantly.

Chapter 3: Review of the region of study: MENA

Background

The links between energy, water and food rely on how society uses the three resources. As outlined in Chapter 2, the EWF nexus has multidimensional aspects -environmental, economic, technological, social and political- all of which are embedded in history. Therefore, reviewing the historical trends of the EWF nexus assist in understanding the current nexus security challenges.

This chapter aims to review the current situation of the EWF security nexus in MENA countries. In Section 3.1, the background of the MENA region is discussed and the countries selected for this study introduced. In Section 3.2, the current challenges in the EWF nexus are reviewed, based on the multidimensional nature of the nexus. The last section presents a summary of the major findings of this chapter.

3.1 The MENA region

The Middle East and North Africa (MENA) region is a vast area which consists of 21 countries (World Bank, 2019a). It includes countries with different cultures (Arab and non-Arab), different religions (Muslim, Christian and Jewish) and different languages (Arabic, Persian and Hebrew) (Table 3.1). The region has about 5% of the world's population but only around 1% of global renewable water resources (Droogers et al., 2012) and only 4.7% of the world's arable land (World Bank, 2019a). The vast area of MENA consists of some of the driest and largest deserts on earth, such as the Arabian Desert and the Syrian Desert. Hence, the population is settled mainly near coastal areas, such as the Mediterranean Sea, the Red Sea and the Persian Gulf, or along rivers, such as the Nile, the Tigris and the Euphrates.

Figure 3-1: Middle East and North Africa

The MENA region is recognised as one of the most oil-rich areas in the world. It is the home of seven OPEC members which play a significant role in supplying the energy demands of the rest of the world. In 2017, 36% of global crude oil and 20% of global natural gas were supplied by the Middle East (British Petroleum, 2019). However, low economic growth in the oil exporting countries and continued political tension in the region led to a sharp drop of 3.2% in economic growth overall in 2018 (World Bank 2018). In MENA, 65% of the total population is aged between 15 and 65 but the region suffers from an extreme degree of joblessness, with youth unemployment at approximately 30% (World Bank 2017).

Table 3.1: Regional classification for MENA

Middle East		**North Africa**
Countries from the Arabian Peninsula	**Other countries**	
Bahrain	Jordan	Algeria
Kuwait	**Iran**	Djibouti
Oman	Iraq	**Egypt**
Qatar	Lebanon	Libya
Saudi Arabia (KSA)	**Israel**	Malta
United Arab Emirates (UAE)	Syria	**Morocco**
Yemen	West Bank/Gaza	**Tunisia**

Note: Countries selected for this study are shown in bold.

There is considerable diversity among MENA countries in terms of their population, economic size, economic structure, income levels, EWF demand, degree of access to modern services and resource endowments. This study focuses on 10 individual countries (shown in bold in Table 3.1) from the MENA region, seven from the Middle East and three from North Africa. This selection is due to the lack of primary data for the other MENA countries. The selected countries are home to 65% of the region's population and account for more than 80% of its GDP.

Table 3.2: Key characteristics of MENA countries considered in this research

Country	Region	Income group[7]	Energy resources	Water availability
Tunisia	North Africa	Lower middle	Poor	Extreme scarcity
Egypt	North Africa	Lower middle	Moderate	Scarce
Morocco	North Africa	Lower middle	Poor	Scarce
Oman	Middle East	High	Rich	Extreme scarcity
Qatar	Middle East	High	Rich	Extreme scarcity
Saudi Arabia	Middle East	High	Rich	Extreme scarcity
Kuwait	Middle East	High	Rich	Extreme scarcity
United Arab of Emirate	Middle East	High	Rich	Extreme scarcity
Iran	Middle East	Upper middle	Rich	Scarce
Israel	Middle East	High	Poor	Extreme scarcity

Further, these counties are likely to experience fast population and economic growth in the years to come. Many of these countries have challenges in providing sustainable energy, water and food while having limited arable land for agricultural production, low rates of energy and water productivity and high levels of waste in the food supply chain. This study refines the analysis by grouping the countries into three broad categories of income group, energy resource endowments and the availability of fresh water (Table 3.2).

The table 3.2 shows that all countries in North Africa are much poorer than the Middle East

[7] Note: this study lists countries by income group according to the World Bank (2019). In this classification, countries are divided into four income groups, based on GNI per-capita, namely, low (less than $995 per annum), lower-middle ($996–$3,895 per annum), upper middle ($3,896–$12,055 per annum) and high (more than $12,056 per annum).

countries in terms of income and have fewer fossil fuel resources. All countries in the MENA region are water stressed due to their limited fresh water resources.

The remaining 11 countries in the MENA region have been combined into two groups: the rest of the Middle East and the rest of North Africa. This allows analysis of individual countries in MENA while assessing the regional implications of strategies to address EWF security challenges. All other countries are grouped into one region, called the Rest of the World.

3.2 EWF security nexus challenges in MENA

The demand for water, energy and food as the most vital resources for human subsistence is expected to increase rapidly in the MENA region by 2050. The security of these resources is therefore a critical challenge for it. This section discusses the current security challenges in the selected MENA countries from various perspectives: population, urbanisation, climate change, economic growth, the current situation of resources (energy, water and food) and political situation.

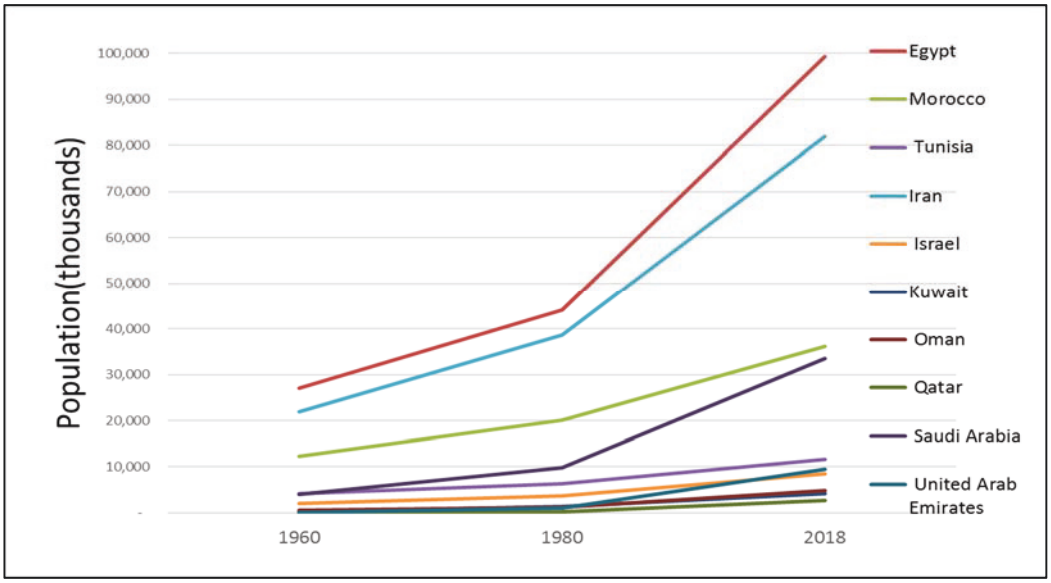
3.2.1 Population

The MENA region experienced the fastest population growth in the world in the last century (Roudi-Fahimi, 2001). This population growth had three key transformation periods. The first period was after the 1960s when the Middle East was faced with a rapid rate of migration and movement towards decolonisation (McKee et al., 2017). In this period, the UAE showed the highest population growth rate while Tunisia showed the lowest (Figure 3.2). Also in this period, modern health care services such as antibiotics, immunisation and sanitation led to a surplus in births over deaths (Roudi-Fahimi, 2001). The second period covers the 1980s, when MENA countries started a structural adjustment and the population growth rate was 1.5% higher than the world's growth rate (Roudi-Fahimi, 2001). The third period was from the 1990s to the present, which encompassed transformations towards urbanisation, political changes (moving towards both radical and democratic changes), rights for women and higher levels of education but also conflicts such as the Gulf War, the Arab Spring and the Syrian civil war (Yüceşahin & Tulga, 2017). After the 1990s, population growth in MENA reached 2.1%, one of the fastest in the world (World Bank 2008).

Although the fertility rate dropped sharply from 7 births per woman in 1960 to 3 births per woman in 2016 (World Bank, 2019), studies predict a rapid upsurge in population by 2050.

According to the UN, the population of the region is expected to reach 700 million (Roudi-Fahimi & Kent, 2007), double the 2018 population. Figure 3.2 shows the change in population over the three periods (1960s, 1980s and 2018). The graph below can be classified into two clusters. The first cluster consists of the countries that are home to 48% of the population in the region, namely, Egypt, Iran and Morocco. Egypt, despite being one of the poorest counties in the region, had the biggest population in the 20th century, followed by Iran and Morocco. In this cluster, between 1960 to 2015, the growth rate of Iran's population dropped sharply by 106%, while Egypt's population growth experienced only a slight decline (25%) (Figure 3.3).

Figure 3.2: Population of the selected countries in the MENA in 1960, 1980 and 2018



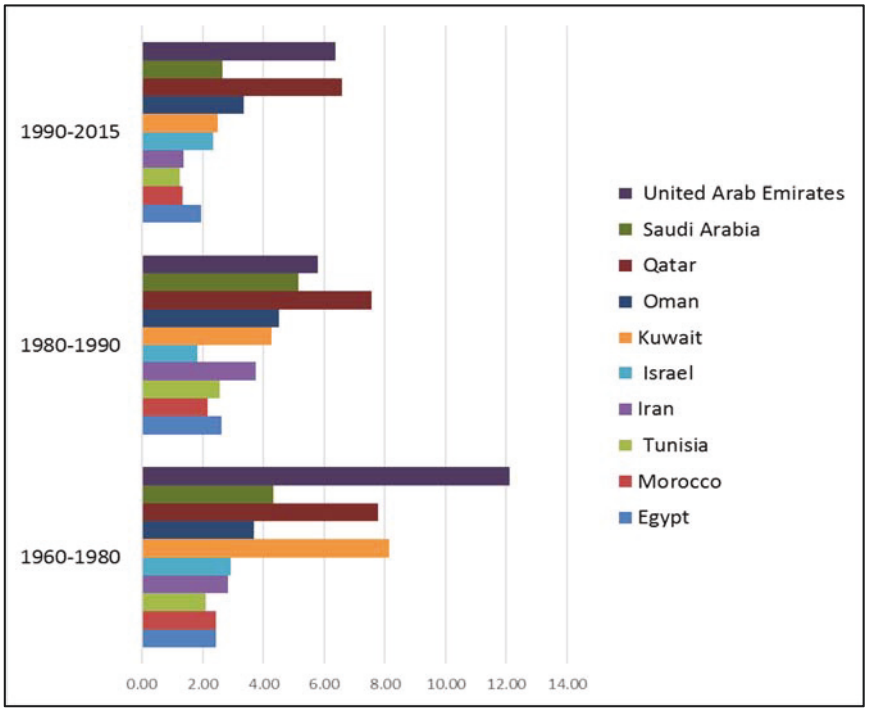
Source: United Nations, 2019a

The second cluster encompasses relatively small countries, namely, Tunisia, Saudi Arabia, the UAE, Qatar, Oman, Kuwait and Israel, all of which are rich, except for Tunisia. Although the second group accounts for only 17% of the MENA population, these countries had much higher population growth rates from 1960. In this cluster, the UAE had the highest population growth rate (12%) in the first period (1960s) as a result of a fundamental change in the structure of the country.

In 1970, six rulers of the Emirates reached an agreement and the UAE was formally established. From 1980 until 2018, Qatar experienced the fastest growth rate in the region due to immigration. Qatar with 6.65% and Oman with 6.45% ranked as the fastest growing populations in the world between 2010 and 2015 (Brodie, 2018).

The growing population in the MENA region from 1960 impacted energy and water consumption. The per-capita demand for electricity in 2017 was 1000 times higher than in 1970 (World Bank, 2019). Fresh water availability has fallen by more than half per-capita from 3300 m^3 per year in 1970 (Roudi-Fahimi, 2001) to 1076 m^3 per year in 2012 (Droogers et al., 2012). The rapid growth in population will exacerbate the current challenges to EWF security in MENA.

Figure 3.3: Average rate of population change (percentage)



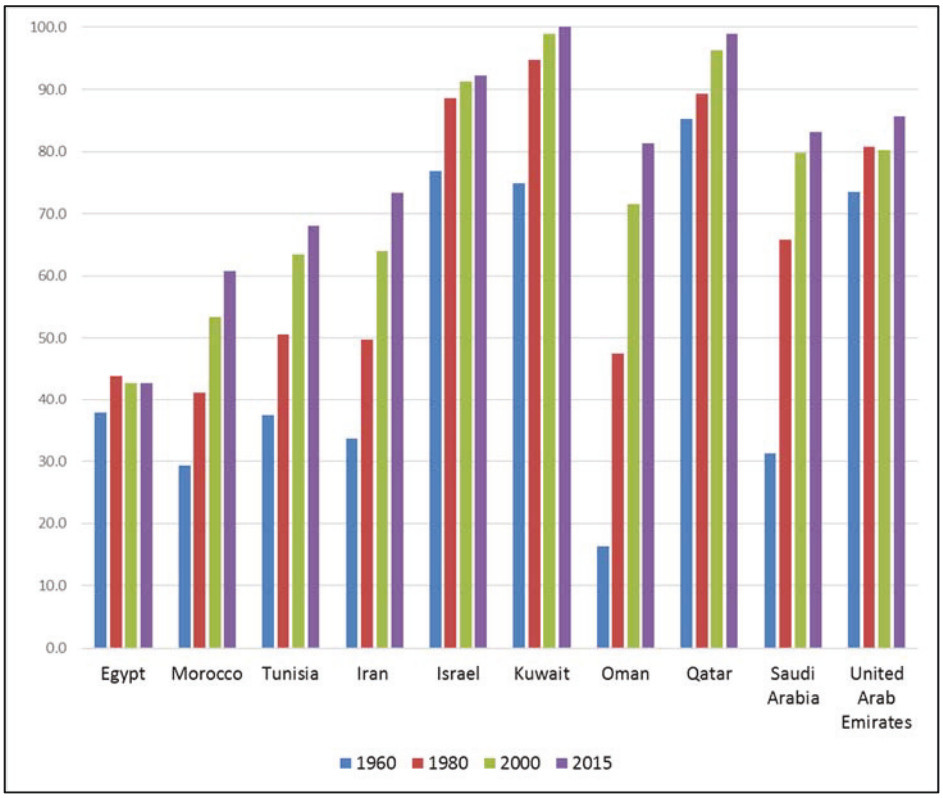
Source: United Nations, 2019a

3.2.2 Urbanisation

At present, 55% of the world's population is settled in urban areas; this figure is estimated to reach 68% by 2050 (United Nations, 2019). The MENA region is not exempt from this trend. In 2015, the urban population accounted for 70% of the total population in MENA and it is expected that urbanisation will reach 90% of the population by 2050 (McKee et al., 2017). However, the urbanisation process varies among countries in the region. Figure 3.4 shows the urbanisation trend from 1960 to 2015 in the selected countries in the region. Among them, Qatar and Kuwait have the highest rate of urbanisation (almost 100%). The North African countries have much lower rates of urbanisation, although the rate of urbanisation in Tunisia and Morocco is expected to accelerate between now and 2050. In Egypt, which has the highest population in the region, urbanisation accounted for only 42% of the population in 2015, the

lowest rate among the countries selected for this study.

Figure 3.4: Percentage of population residing in urban areas, 1960-2015



Source: United Nations, 2019a

Similar to other developed countries, Israel has witnessed and is still witnessing a high rate of urbanisation. In 1995, 8 out of 10 people lived in areas with more than 2000 people, while in 2015 the share increased to 9 out of 10 (Rebhun & Brown, 2015). In Iran, the rate of urbanisation accelerated by almost 50% after the 1979 revolution.

Significant reasons for urbanisation in MENA could be modernisation, land reform, industrialisation (specifically the oil industry) and high incomes. However, no plan has been considered for rapid urbanisation in the area (Al-Mulali & Ozturk, 2015) and that constitutes a severe challenge because it leads to water and land limitations, food insecurity and environmental deterioration (Taravat et al., 2017, McKee et al., 2017).

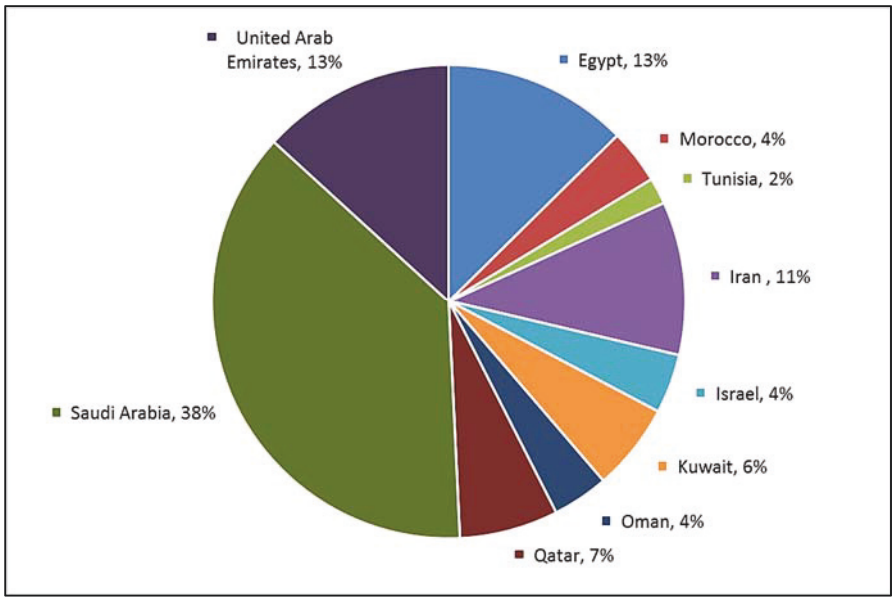
3.2.3 Climate change

MENA as a mostly arid region is particularly under threat from climate change. As the Middle East and North Africa are among the most water-stressed regions in the world, the continuity of available water and hence agriculture is highly dependent on and sensitive to climate change. Lack of water is not the only impact of climate change; it is expected that the region will become hotter in coming years, which will facilitate the occurrence of more drought and put more pressure on available water resources. Also, it is estimated that sea levels will increase by 0.1 to 0.3 metres by 2050, which will affect the coastal areas of all the selected countries in this research (World Bank, 2010). In addition, the region is well known for its oil reserves and many oil-exporting countries are ranked as the highest per-capita emitters of greenhouse gases (GHG) (Nakhooda et al., 2012). In the following sections, the current situation of CO_2 and extreme climate status (drought and aridity) are discussed in detail.

3.2.3.1 CO_2 emissions

Carbon dioxide emissions are the most significant greenhouse gas in the world. The primary sources for CO_2 are fossil fuel combustion, deforestation and cement production (C2ES, 2017). In 2014, fossil fuels accounted for 91% of total CO_2 emissions by humans in the world, of which oil and gas were responsible for more than 50%. MENA produced more than 7% of the world's CO_2 emissions, while the European Union's 28 member countries with a population 1.3 times greater, caused 9% (World Bank, 2019). The primary factors for CO_2 emission production worldwide consist of economic growth, population growth, urbanisation, increase in energy consumption and industrialisation (Qader 2009). These elements are interconnected and growth in one aspect could impact the others. The MENA region currently has all the factors for generating CO_2 emissions: rapid increase in population and urbanisation, substantial economic development and high demand for energy consumption (Hilmi, 2018).

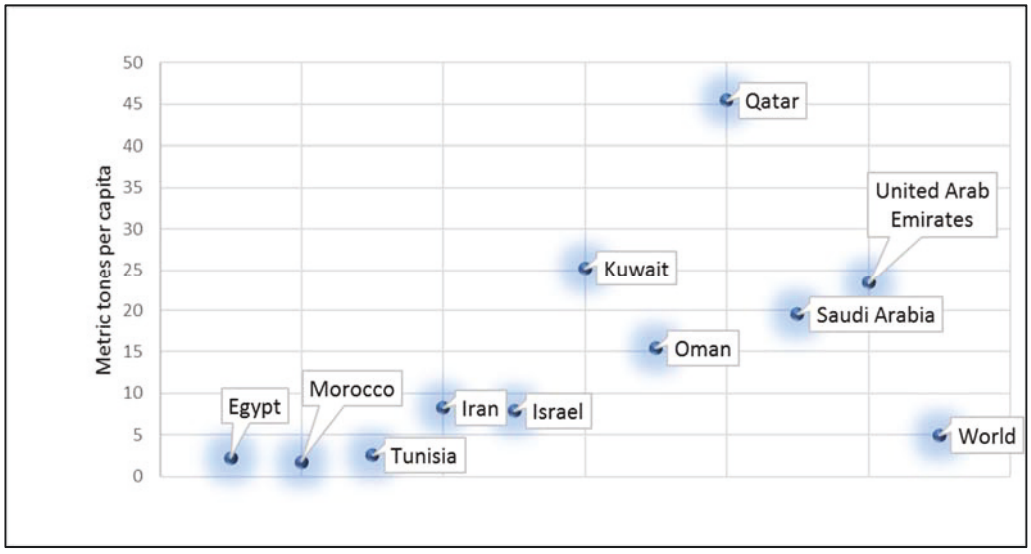
Figure 3.5: Percentage of generating CO2 emissions by country in 2014



Source: Author

Figure 3.5 shows the share of CO_2 produced in each MENA country in 2014. Saudi Arabia produced almost three times more CO_2 than the other oil producer countries of Iran and the UAE. This was due to the massive development projects that were taking place in the kingdom to improve infrastructure and expand different sectors (Qader 2009).

Figure 3.6: CO2 emissions Per-capita in 2014



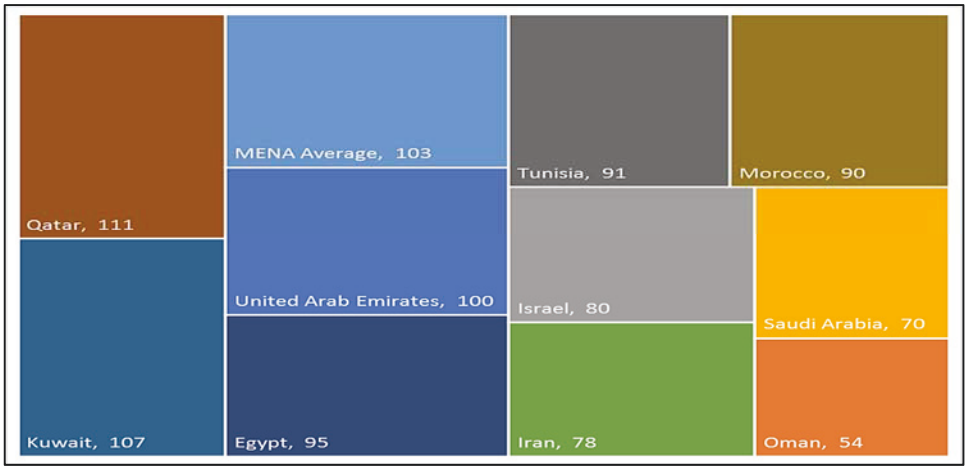
Source: World Bank, 2019

The per-capita CO_2 emissions generated in the Middle East are much higher than the world average (see Figure 3.6). Qatar has the highest emissions in the world, followed by Kuwait and the UAE (Carbon Dioxide Information Analysis Center, 2018). One can explain the main reasons for this behaviour as significant economic growth, geo-climatic conditions and government subsidy policy.

3.2.3.2 Extreme climate: drought and aridity

For the arid and semi-arid MENA region, drought is a familiar natural phenomenon and the third major challenge after floods and earthquakes (World Bank, 2014a). Between 1981 and 2011, drought accounted for around 10% of all disasters in the MENA area. Drought can have significant impact on the social, environmental and economic aspects of the area, where rain-fed farming is essential. Lack of rain results in crop loss, low price for agricultural land and unemployment. As an example, the severe droughts between 1999 and 2001 resulted in crop failures, land and soil degradation, significant death among livestock, population migration and the spread of disease in some Middle East countries (Barlow et al., 2016). However, managing disasters such as drought is one of the most complex tasks for MENA countries. An historical review shows that more than 40 million people were impacted by natural disasters between 1981 and 2010, which had severe effects on the growth and stability of the region (World Bank, 2014b).

Figure 3.7: Average climate risk index score between 2010 -2017



Source: USAID, 2019[8]

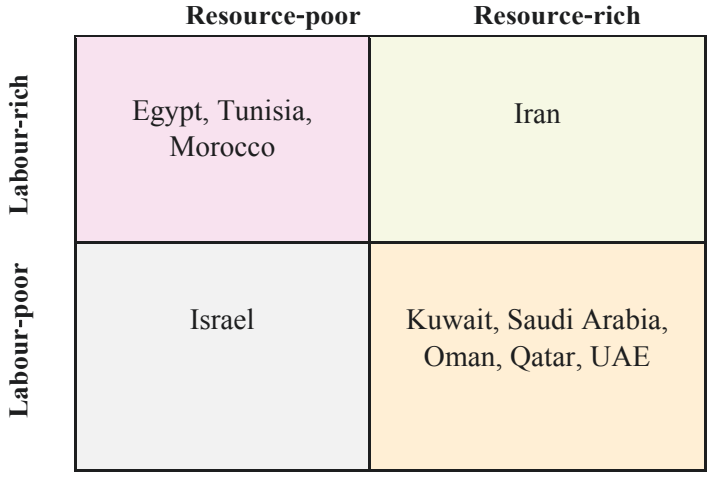
[8] Note: The climate index score is based on four categories: Number of Deaths (weight: 1/6), Deaths per 100,000 inhabitants (weight: 1/3), Absolute losses in PPP (weight: 1/6) and Losses per GDP unit (weight: 1/3).

The agriculture sector in MENA depends heavily on groundwater as a primary source of irrigation which is under pressure due to excessive usage. Receiving enough precipitation could assist to reduce current pressure on groundwater. However, it is expected that the climate will become hotter and precipitation will decrease in coming years. Due to a severe drought in 2001, Iran lost 35%-75% of grain production (mainly wheat and barley). In the same year, 1 million hectare of Morocco's cropland was affected by drought and the government was forced to import more than 5 million tons of wheat (FAO, 2008). Figure 3.7 shows the average climate risk index score from 2010 to 2017 for the selected counties in the region. The lower score represents the countries suffering the highest impact from climate change, with Oman and Iran the most vulnerable to natural disaster.

3.2.4 Economic growth

The MENA region is economically heterogeneous. It consists of both the oil-rich economies (Saudi Arabia, Iran, Kuwait, UAE, Qatar and Oman) and resource-scarce counties (Egypt, Morocco and Tunisia). However, classifying the MENA region in terms of economics is a complex task. Based on the World Bank classification, the MENA region can be categorised into four groups based on resource and labour availability (McKee et al., 2017): 1) resource-poor and labour-rich, 2) resource-poor and labour-poor, 3) resource-rich and labour-rich and 4) resource-rich and labour-poor. Figure 3.8 shows how the countries in this research fit into the World Bank classification.

Figure 3.8: classification of MENA countries in 2017



This classification could change over time if new natural resources are discovered. Based on the current classification, Egypt, Morocco and Tunisia have relatively few hydrocarbon (oil and gas)

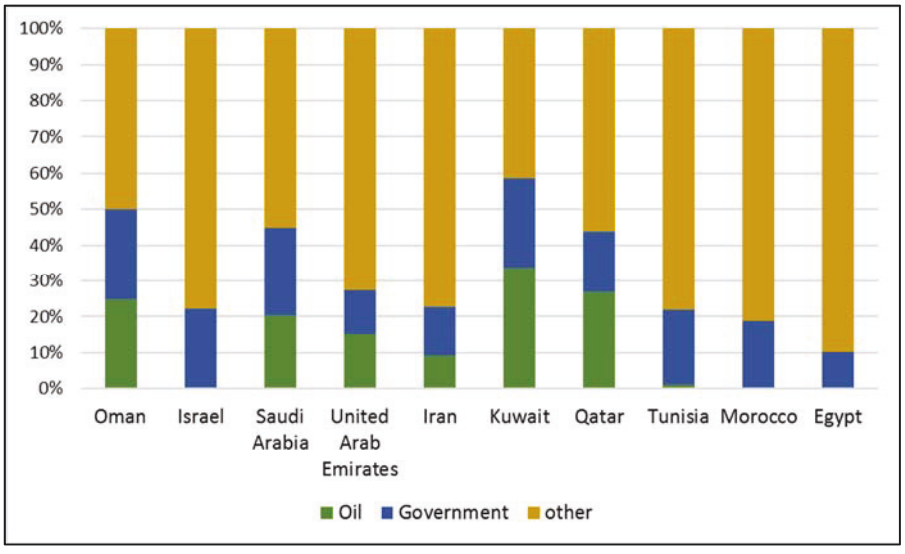
resources while labour is abundant. However, the GCC countries of Saudi Arabia, Kuwait, the UAE, Qatar and Oman (but not Bahrain) are labour importers and rich in hydrocarbons. Iran and Israel according to this classification are unique. Iran has considerable natural resources and labour is readily available, while Israel is weak in both its labour and resource availability but its economy is very diverse.

The above classification will be used in the following sections to analyse GDP, employment and poverty.

3.2.4.1 GDP trends in the region

Countries in the MENA region face significant income inequity as 50% of the wealth of the region is accumulated in only six countries. In the countries selected for this study, Morocco, Tunisia and Egypt are categorised as low-income, Iran as middle-income and the rest of the countries (Israel, Saudi Arabia, Kuwait, the UAE, Qatar and Oman) are ranked as high-income countries (World Bank, 2019). Among all these, Qatar had the highest GDP per-capita in the world in 2017, followed by the UAE and Kuwait (7th and 8th position respectively) (World Bank, 2019). However, GDP growth in the Middle East is highly dependent on the price of hydrocarbons. Saudi Arabia, the UAE, Qatar, Kuwait, Oman and Iran are the leading MENA oil exporting countries. Of these, Oman, Saudi Arabia, Kuwait and Qatar gain more than 40% of their GDP from hydrocarbons and government activities that rely heavily on oil revenue. In the other two countries, Iran and the UAE, this share ranges between 20% and 40% (Figure 3.9).

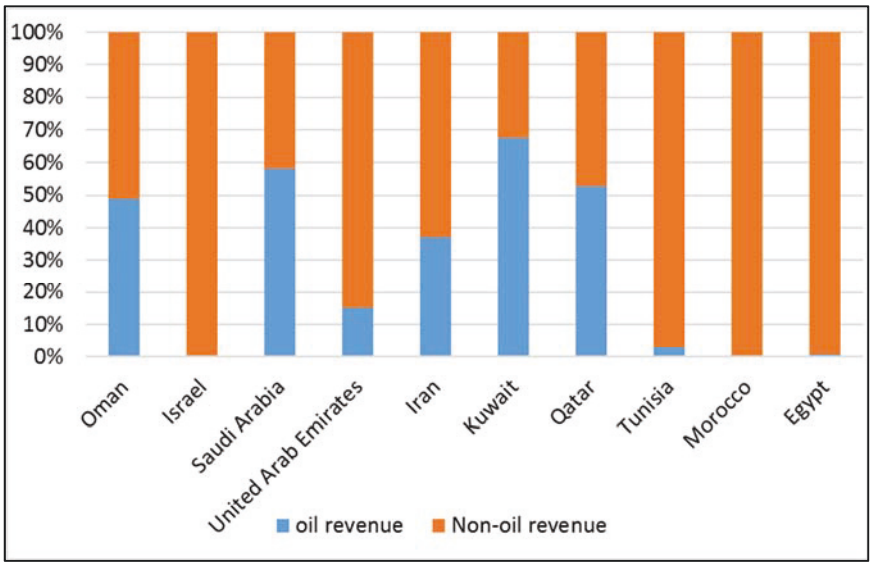
Figure 3.9: GDP composite based on oil revenue in 2017



Source: IMF, 2018b

The main issue with the oil exporting countries is their limited levels of economic diversification (Tagliapietra, 2017). Oil revenue accounts for more than 50% of export in Oman, Saudi Arabia, Kuwait and Qatar (Figure 3.10). The lack of diversification in economic structure and the dependency on the oil industry will make it difficult to speed up the economic growth when the market price of oil drops sharply (Fardoust, 2016).

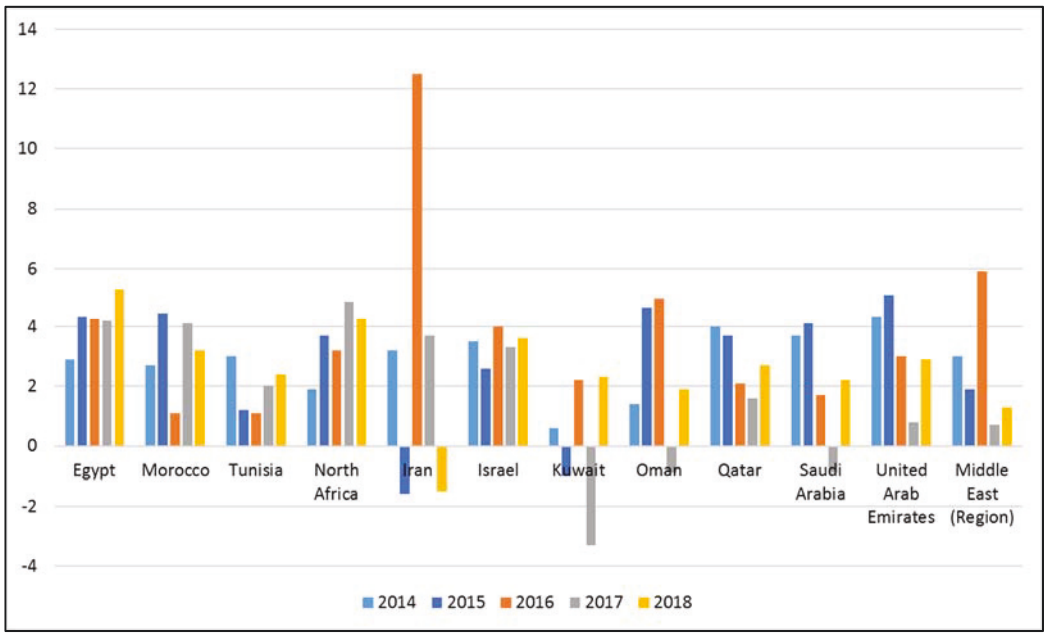
Figure 3.10: Oil and non-oil revenue in 2017



Source: World Bank, 2019

Overall, the region will experience low growth in GDP due to the current conflicts in the region, specifically in Yemen and Syria, and lower oil prices. Figure 3.11 shows the economic growth of the individual countries in this research compared to the MENA region between 2014 and 2018. As a result of the sharp drop in oil price between 2014 and 2016, economic growth in the oil-exporting countries declined (IMF, 2018a). Although the oil price rose in 2017, OPEC members decided to cut oil production (World Bank, 2017a), which again impacted their economic growth adversely. In 2016, Iran experienced around a 13% growth in its economy due to the rise in oil price and the removal of nuclear-related international sanctions (World Bank, 2017b). However, in 2018 looming sanctions resulted in a negative impact on economic growth (World Bank, 2018). From this discussion, one can notice the close relationship between oil price and economic growth in oil-exporting counties, which causes uncertainty about future economic growth (IMF, 2018a). Among Middle East countries, Israel's economy has experienced the most stable growth rate, slightly above 3%, since 2000, which indicates the strong foundation of the economy. However, poverty and income inequality are high, which causes social inequality among the Israeli population (OECD, 2018).

Figure 3.11: Real GDP growth (annual percentage change)



Source: IMF, 2018b

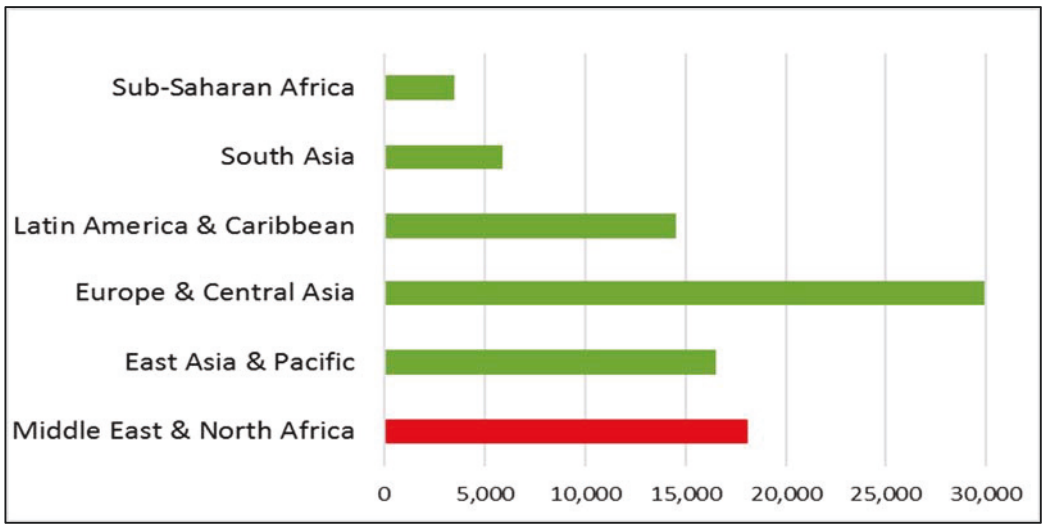
In the North African countries in this research, (Egypt, Morocco and Tunisia), economic growth currently relies on agriculture, tourism and light industry. Although these countries have been focusing on transferring the structure of their economy from agriculture to industry and services since the 1970s, agriculture still plays a significant role in their economy (ADBG, 2018). For example, in Morocco, economic growth declined sharply in 2016 due to the severe drought of that year (World Bank, 2017c). Egypt has the biggest economy in North Africa and its agriculture sector accounts for 11% of Egypt's GDP. In 2018, however, Egypt's economic growth reached its highest level in a decade as a result of a recovery in its tourism industry and sustainable growth in natural gas production. Government debt to GDP is an indicator of the health of the economy and an essential element in the sustainability of government finance (OECD, 2019). This indicator shows that Egypt's government debt –to- GDP ratio fell by 10% from 103% in 2017 to just above 90% in 2018 (El Ghouty, 2018). In terms of Tunisia, eight years after the revolution in 2011, the economy is gradually recovering (World Bank, 2016a; World Bank, 2017d). The average rate of economic growth between 2014 and 2018 was less than 2%, a figure that would make no significant improvement to its current account deficit.

3.2.4.2 Poverty

Although MENA is known as an oil-rich area, this image of a region that provides free social services and subsidises goods for its citizens could be misleading. This perception could be right for the GCC countries, but not for the rest of the countries in the region. Countries in the MENA,

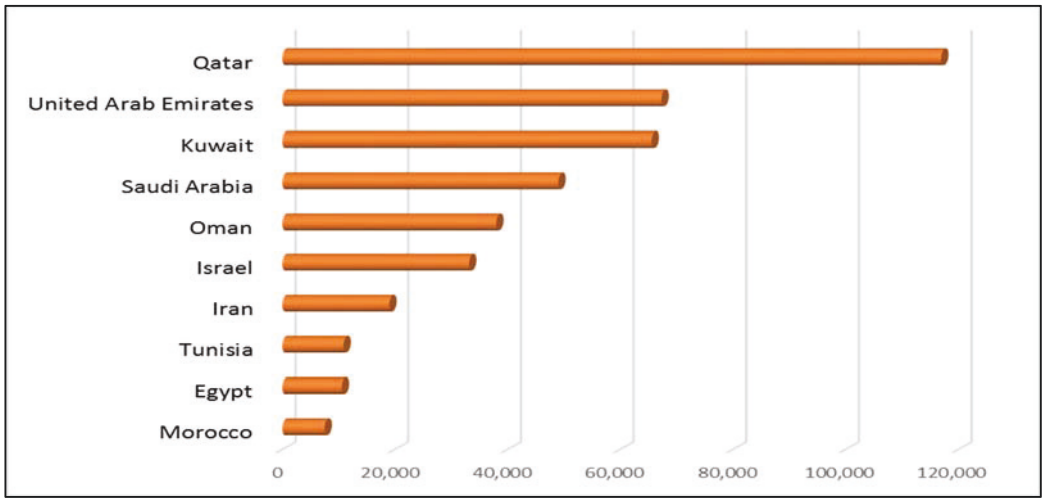
with or without oil resources, face substantial challenges to overcoming poverty (Iqbal & Nabli, 2007). Figure 3.12 compares the average GDP per-capita in different regions in 2017. Based on international standards, MENA, with a per-capita GDP of $18,093, ranks second after Europe and Central Asia (Figure 3.12). However, natural resources and a high per-capita GDP in the GCC countries improve the GDP of the MENA by almost 50% (Figure 3.13).

Figure 3.12: GDP per-capita in different regions, PPP (constant 2011 international $) in 2017



Source: World Bank, 2019

Figure 3.13: GDP per-capita, PPP between MENA countries (constant 2011 international $) in 2017

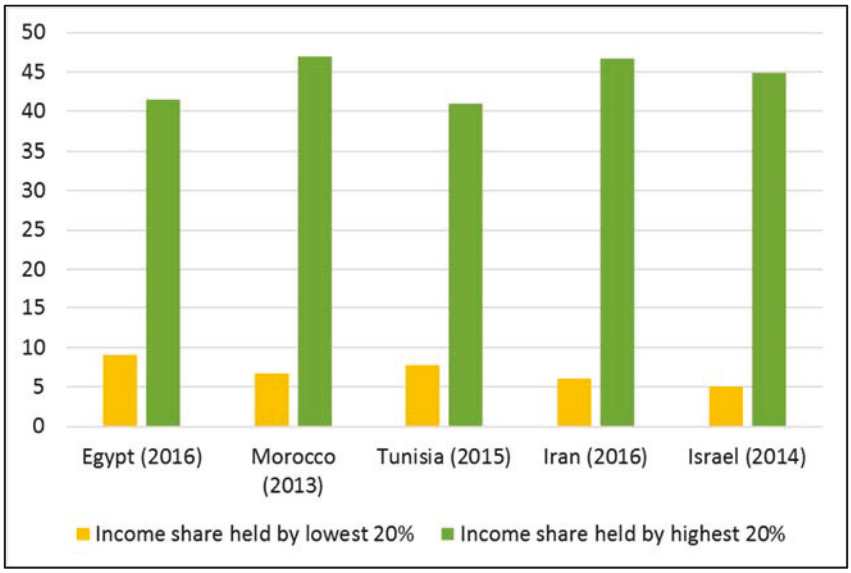


Source: World Bank 2019

Unfortunately, there are only limited data available for poverty rates in the MENA region and only a limited number of countries, such as Iran, Israel, Egypt, Morocco and Tunisia, gather systematic information related to income distribution (Iqbal & Nabli, 2007). Even in countries

that have data available, the percentage of the population that has the lowest income is negligible compared with the 20% of the population that has the highest income (Figure 3.14). Poverty is not only a deficiency in money but also a shortage of essential welfare elements in society. Therefore, poverty is a multidimensional concept that considers the monetary aspect as well as politics, education, basic infrastructure and security (Iqbal, 2006; Awulachew et al., 2010).

Figure 3.14: Income share held by the poorest and richest

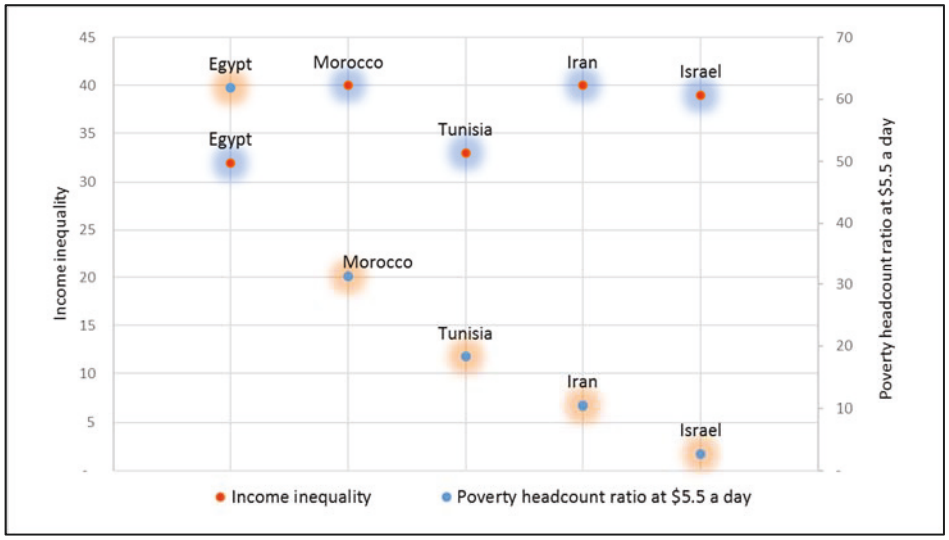


Source: World Bank, 2019

Poverty in MENA is persistent as economic growth is rapid and poverty by nature includes those who are the last to benefit from growth. Also, inequality is increasing steadily in the region as a result of the uneven distribution of gains from growth (World Bank, 2010a). Figure 3.15 compares poverty with income inequality in Egypt, Morocco, Tunisia, Iran and Israel. While the poverty headcount ratio (HCR)[9] at $5.5 per day is lowest in Israel (2.7% of population), the country ranked among the highest of the countries in terms of its income inequality. This is mainly due to the 10% of the wealthiest households who hold 13.3 times more income than the poorest in the country (OECD, 2018). This causes a large gap between the tangible and intangible dimensions of welfare in the society, specifically among seniors, due to the low pensions (OECD, 2016). In 2008, significant poverty mixed with the high price of food impacted nutrition and social and political stability in Egypt and Morocco (Ceccacci & Santos, 2015).

[9] The headcount **ratio** (HCR) is the proportion of a population that exists, or lives, below the **poverty** line.

Figure 3.15: Poverty and income inequality



Source: World Bank, 2019

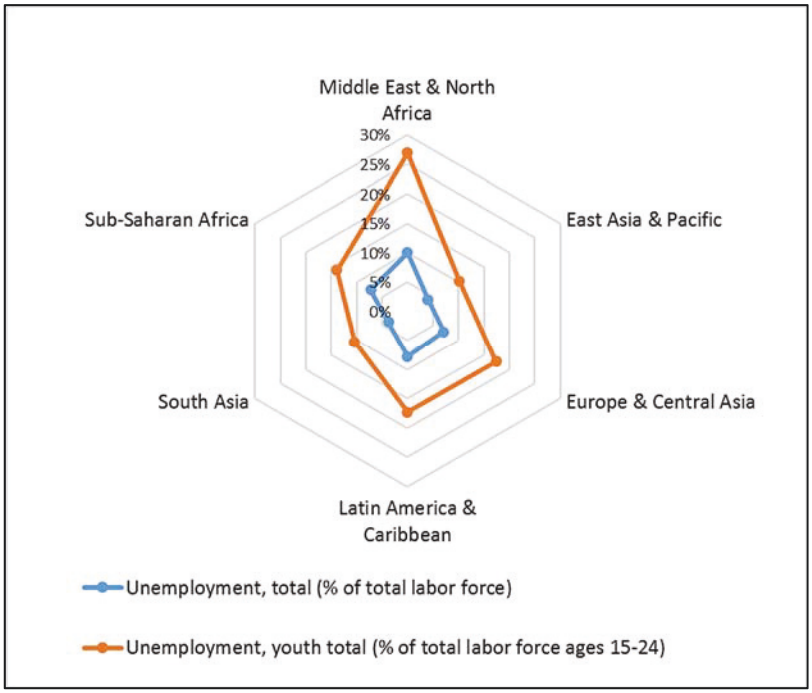
Although poverty declined sharply by 40% in Morocco between 2000 and 2010, the poverty rate in rural areas is high. The population of the rural areas in Morocco accounts for 43% of the total population; of this percentage, seven out of 10 are poor and the rural areas house one third of the poor in this country (Achy, 2011). In Tunisia, despite all the efforts in the last decade and despite the revolution and changes in the political system in 2011, poverty among the bottom 40% has not declined significantly. Vulnerability in Tunisia is high, which increases the risk of middleclass people falling into poverty (World Bank, 2016a). In the case of Iran, limited information is available about poverty and income inequality after 2008. This is due to the elimination of subsidies from the energy sector, sanctions and the falling oil price. However, based on available data in 2009 and 2013, both poverty and inequality decreased (Atamanov et al., 2016).

3.2.4.3 Unemployment

Although the MENA region has wealth, it still faces critical challenges, such as unemployment. In 2018, MENA had the highest unemployment rate in the world, including the highest percentage of unemployed youth (Figure 3.16). The youth unemployment rate of 27% in the region is in fact more than double the global average (13%). The phenomenon of unemployment deprives countries of their potential development and gradually destroys social and economic progress. The main reasons for high joblessness among youth are the distortion between supply and demand for skills, excessive dependency on the public sector for secure

jobs, the weak role of the private sector and low participation rates of women in the labour market (Salehi-Isfahani, 2010). In developing countries, youth unemployment could impact the political situation as their capacity for generating education and employment opportunities are limited (McKee et al., 2017).

Figure 3.16: Regional unemployment rates in 2018

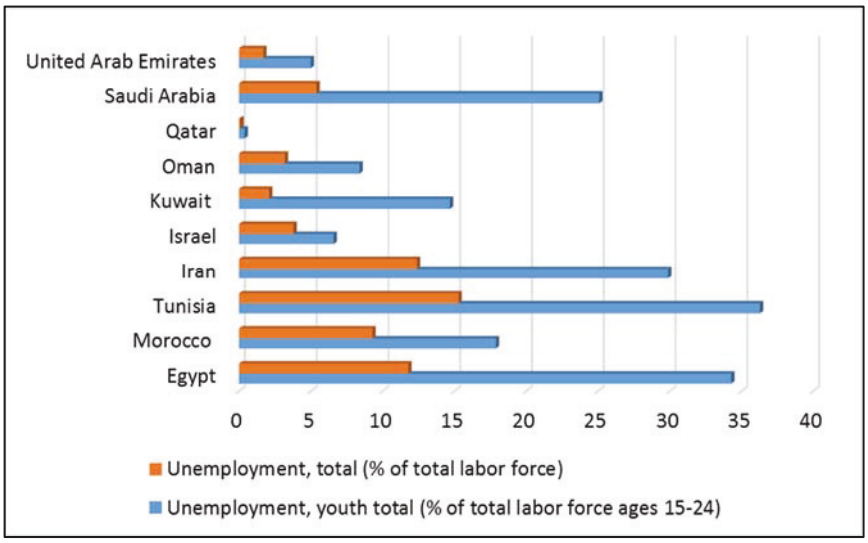


Source: World Bank, 2019

Within the MENA region, the unemployment rate differs from country to country. According to the International Labour Organization (ILO), the unemployment rate in 2013 was 29% in North Africa and 27% in the Middle East (Burrows, 2014).

In North Africa, the unemployment rate among the working-age population in 2018 ranged from 15.3% in Tunisia to 9.3% in Morocco (Figure 3.17). However, Tunisia and Egypt have the highest rates of youth unemployment in the MENA (Figure 3.17). Although the rate of unemployment dropped in these countries after the Arab Spring in 2011, unemployment is still higher than in any other part of the world, particularly among youth, women and university graduates (ADBG, 2018).

Figure 3-17: Unemployment rate in 2018



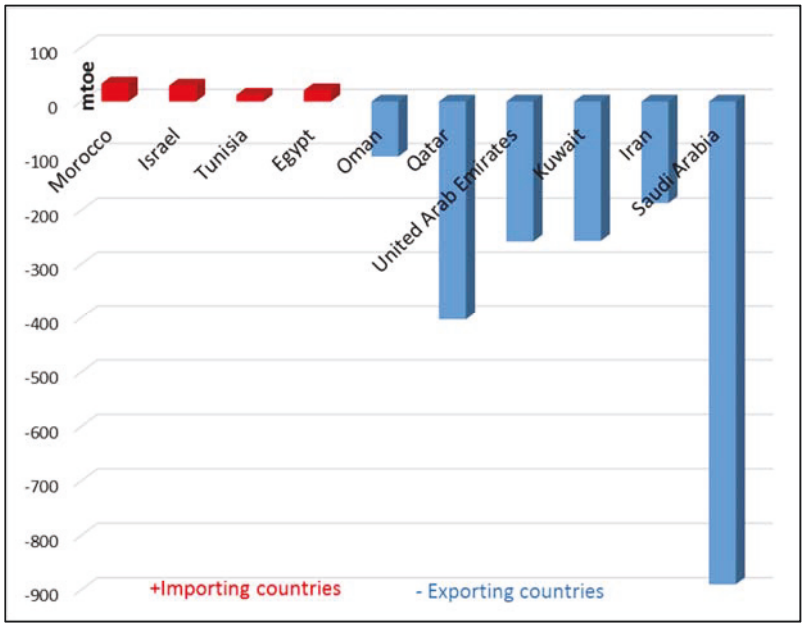
Source: World Bank, 2019

In the Middle East, the unemployment rate differs from country to country. Of all the MENA countries, Iran experienced the highest rate of joblessness (12.5%) and a youth unemployment rate of 29% in 2018. One could explain the high unemployment rate as a result of soaring inflation and an abundant labour force in the market (World Bank, 2016). GCC countries are not exempt from the unemployment trend in the MENA region. As labour importers, these countries have concerns about the rapid growth of unemployment while businesses prefer the low cost yet high expertise of foreign labour (EIU, 2009). Even though the GCC economies are supported by oil resources and fast economic growth in the last decades with substantial job opportunities, they face continuous high rates of youth joblessness (IMF, 2017). In 2018, unemployment rates were high in Saudi Arabia, Kuwait and Oman, but remained low in Qatar and the UAE. The main reason for the high rates of unemployment in the GCC countries is reliance on government subsidies, low-cost or free public services and the provision of public sector jobs (Crockett, 2014). Israel historically has a low unemployment rate, including long-term. With its stable economy and low inflation, the country is moving towards full employment (OECD, 2018)

3.2.5 Unsustainable energy

MENA is the wealthiest region in the world in terms of oil and gas reserves. However, it depends heavily on energy as a source of development (UNDP, 2011). Natural resources have not been distributed equally among these nations and massive gaps remain between the oil-rich countries and the poor countries. The MENA region has 48% of the world's proven recoverable oil reserves and 46% of the world's recoverable gas reserves (World Energy Council, 2016). Energy is therefore the source of economic growth and a critical player in sustainable development (Farhani & Rejeb, 2012). Economic growth has a direct relationship with energy consumption in that a higher level of energy consumption results in faster growth in the economy (Omri, 2013). Countries in MENA can be divided into two groups: oil exporters and oil importers (Figure 3.18). The North African countries selected for this study plus Israel are currently oil importers, while Saudi Arabia, the UAE, Oman, Kuwait, Qatar and Iran are net energy exporters.

Figure 3.18: Net energy export and import countries in 2017



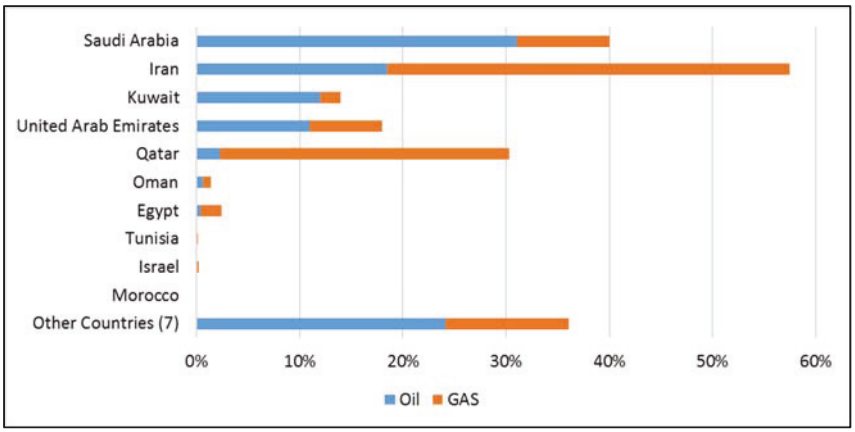
Source: EIA, 2017

3.2.5.1 Reserves of fossil fuels

As stated above, countries in the region are endowed with massive oil and natural gas resources (Figure 3.19). Saudi Arabia by itself is the second largest oil exporter and holds the second position in proved oil resources, while Iran counts as the second biggest natural gas recoverable resource in the world after Russia (World Energy Council, 2016). Oil reserves at the regional level are concentrated mainly in Saudi Arabia (31%), Iran (19%),

Kuwait (12%) and the UAE (11%). In natural gas, Iran has the highest reserves (39%), followed by Qatar (28%) and Saudi Arabia (9%).

Figure 3-19: Oil & Gas recoverable reserves by Country



Source: World Energy Council, 2016

Seven MENA countries (Iraq, Saudi Arabia, Iran, Kuwait, the UAE, Libya and Algeria) are members of OPEC, where they play a vital role in the world's energy supply and petroleum policies. Qatar and Iran are the largest exporters of natural gas in the region.

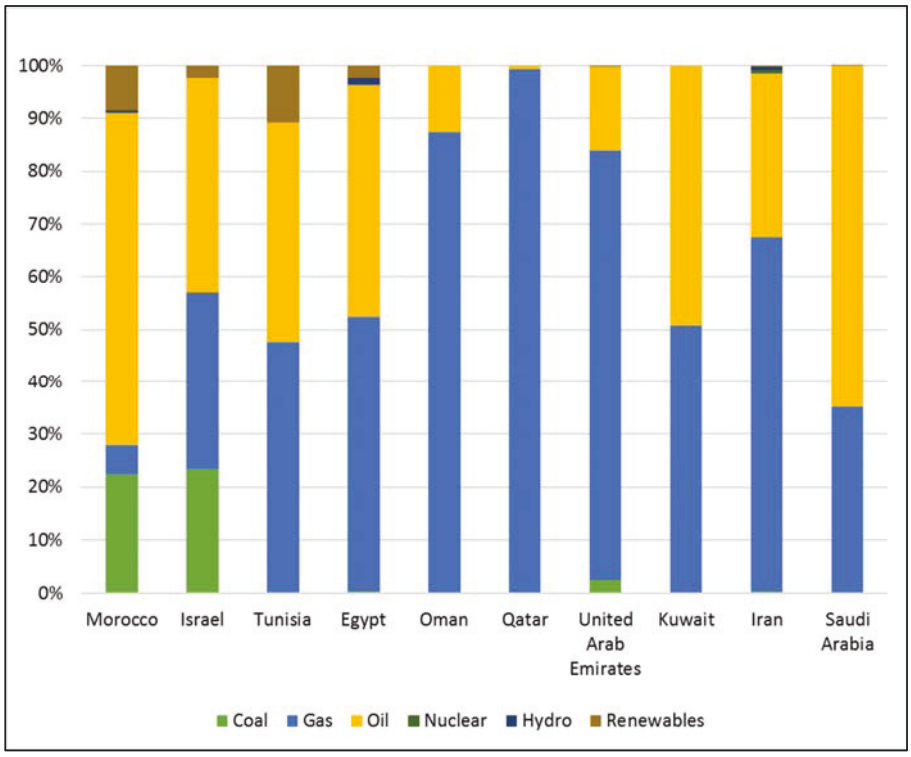
In terms of reserves, the oil industry in Iran, Saudi Arabia and the UAE is mature and these countries are not expected to make substantial discoveries in the future (World Energy Council, 2016). However, oil and gas resources in most areas in the Mediterranean countries are either under exploration or as yet unexplored (Menichettti et al., 2017).

3.2.5.2 Energy mix in MENA

The energy mix in MENA is heavily reliant on oil and gas resources. In 2016, 97% of energy in the MENA region was generated from a combination of oil (36%), gas (56%) and coal (5%), the coal being exported from Turkey and mainly to Morocco and Israel. In 2016, energy supply through renewable resources was negligible (3%), despite the potential in the region.

Although in 1990 oil was the primary (60%) source of energy in MENA, this share had dropped substantially to 36% by 2016. However, in 2016, oil still counted as the predominant source of energy in Saudi Arabia, Morocco, Israel and Kuwait.

Figure 3.20: Energy mix in countries in 2016

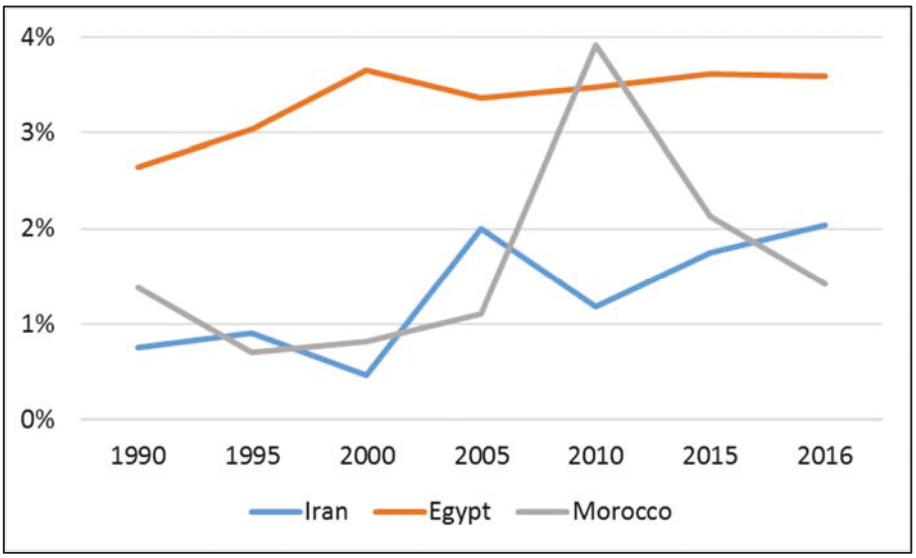


Source: IEA, 2016b

Nuclear energy is not part of the energy generation for any MENA countries except Iran, although nuclear power is part of the 2030 development plans in the UAE, Saudi Arabia and Egypt (Menichettti et al., 2017). However, the high up-front costs involved might not be practical for all countries, particularly those with low economic growth such as Egypt.

Renewable resources such as biofuels and geothermal power are employed mostly in net importing countries such as Morocco, Israel and Tunisia. Historically, hydropower was part of the energy generation in a few countries, such as Egypt, Iran, and Morocco. However, the historical trend shows that from 1990 the share of energy generation from hydropower was not sustainable in Iran and Morocco. This region has considerable potential for solar and wind energy development, due to its geographical position, climate conditions, abundant sunlight and good weather throughout the year (Nematollahi et al., 2016). However, the overall performance of the MENA region in terms of renewable energy compared to the global trend is weak, specifically the levels of investment, finance and private sector contributions (Amer et al., 2016).

Figure 3.21: Hydropower history in Egypt, Iran and Morocco between 1990-2016



Source: IEA, 2016b

Of all the sources of energy, natural gas is the primary resource. In some countries, such as Qatar (99%), Oman (87%) and the UAE (82%), natural gas plays a vital role in energy generation as a result of its abundant supply.

3.2.5.3 Energy demand in MENA

Between 1990 and 2017, MENA recorded an average growth rate in real GDP of 3.8%, making it one of the fastest economic growth regions in the world after South Asia, East Asia and the Pacific (World Bank, 2019). As a result of this rapid growth and industrialisation, energy consumption in the Middle East and North Africa is one of the highest in the world. Figures 3.22a and 3.22b show how electricity use (KWh per-capita) in some parts of MENA are increasing much more rapidly than the world average.

Figure 3.22a: Energy use (KWh per-capita) in North Africa

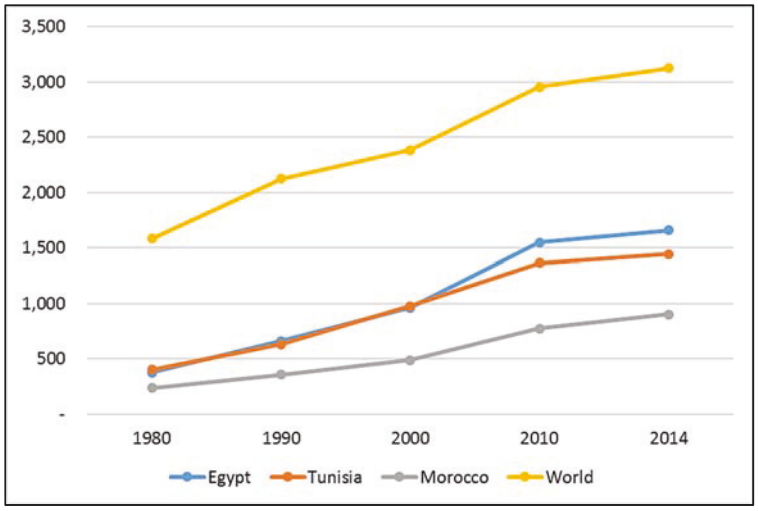
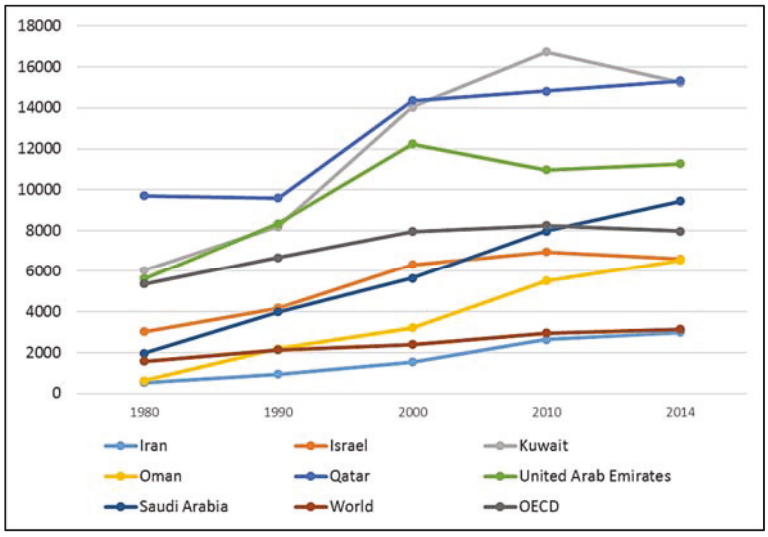


Figure 3.22b: Energy use (KWh per-capita) in the Middle East



Source: World Bank, 2019

Per-capita electricity usage varies across the MENA region. Except for Iran, the region uses much more energy than the world average. Indeed, Qatar, Kuwait and the UAE are some of the highest electricity consumers in the world. In 2014, electricity use per-capita in Qatar and Kuwait were double that of the OECD countries and five times more than the world average. Part of the explanation for the excessive electricity demand in this region is the industrial structure of the economy, the availability of low-cost oil and gas and government subsidisation (El Kharraz et al., 2012).The lowest energy consumption per-capita in the region was in Morocco, Tunisia and Egypt, where the average usage in these countries was just over half the world average in 2014. However, behind the low energy consumption was fast growth. For example, energy consumption in North Africa (except Tunisia) increased by 50% between 2001 and 2011, more than the average for middle-income economies in the world (Hong , 2014).

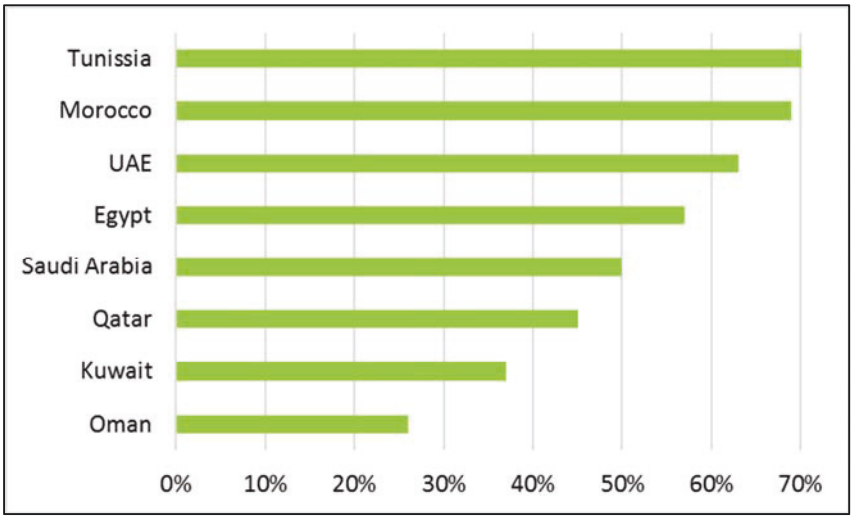
Fast growth in energy demand across the region and the depletion of oil and gas reserves is now a critical challenge which could impact the growth rate of those economies that are heavily dependent on oil and gas. The issue could also significantly affect export revenue and financial stability in the future (Amer et al., 2016).

3.2.5.4 Energy efficiency

To support sustainable economic growth, it is essential for countries in the region to revise their energy policies to meet the fast growth in energy demand (Menichettti et al., 2017). While focusing on a renewable resource could improve the energy supply and decrease the MENA's dependency on fossil fuels, energy efficiency remains the most cost-effective practice to reduce the energy intensity of the economy and manage the fast-growing energy demand (RCREEE, 2017).

Generally, the main factors for high energy intensity in the region could be categorised as (i) rapid rate of economic growth, (ii) rapid industrialisation, (iii) population growth and (iv) excessive subsidisation. The consequence of high energy intensity is the growth in CO_2 emissions and the GCC counties rank as the greatest per-capita CO_2 emitters in the world (RCREEE, 2017). Therefore, continued progress in energy efficiency is vital for managing and reducing demand, controlling the impact of human activity on climate change and for higher growth in the long term (Moshiri, 2013). Figure 3.23 shows the energy efficiency in the countries selected for this study.

Figure 3.23: Energy efficiency in 2017

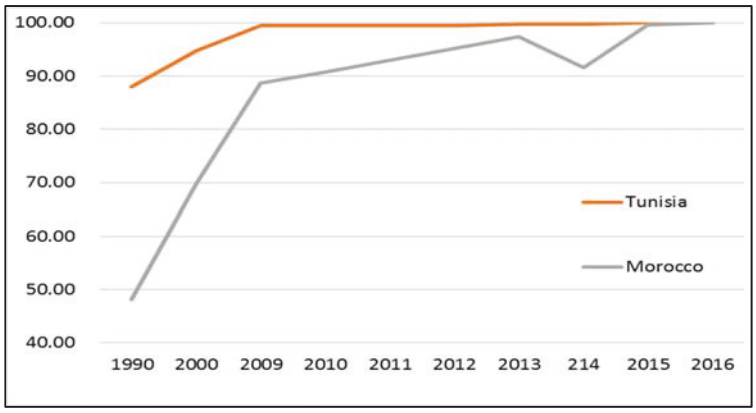


Source: RCREEE, 2017

Tunisia is shown here as the most energy-efficient country in the region. In Tunisia, the residential electricity price is high but the rate is subsidised in the commercial and industrial sectors (RCREEE, 2017). In Morocco, the fuel price is higher than the world average and the cost of electricity for the industrial sector is high. The UAE is the only country in the Middle East with energy efficiency of more than 50%. Moving towards renewable energy is one of the factors for promoting energy efficiency in the UAE.

Despite the significant availability of renewable and non-renewable resources in the region, the MENA is one of the areas in the globe with low energy security. Accessing energy resources is not enough to ensure the energy security of a region. Regional energy security can be met only through cohesive and proactive policies that manage demand by reforming energy subsidy policy and improve energy efficiency (Griffiths, 2017). Countries like Egypt and Morocco witnessed weak and unsustainable access to energy from 1990 to 2015 (Figure 3.24).

Figure 3.24: Energy access in Egypt and Morocco 1990-2016



Source: World Bank, 2019

3.2.5.5 Subsidy reform and results

In the GCC countries of Iran and Egypt, energy subsidisation has been part of government policy since 1970. In 2014 the governments of oil-producing countries began to decrease their subsidisation following the subsidy reforms carried out in Iran in 2010 and in Dubai in 2011.

When Iran removed its subsidy in 2010, diesel prices increased by 2000% and electricity by 1200%, reaching 90% of the international price. However, this subsidy reform stopped in 2012 due to high inflation and lack of parliamentary support and restarted only in 2015. In Saudi Arabia, reform started in 2015 and it increased the price of residential electricity and water by 400% for the first time. Diesel, gasoline and other related products surged in price by 122%. As a result of this reform, demand for diesel and refined products dropped

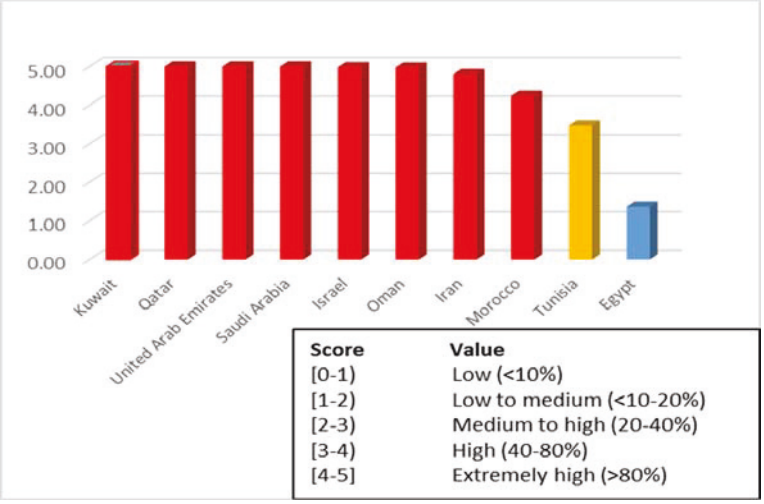
by 10% and 4% respectively. Also, and for the first time, Saudi Araba witnessed in 2016 a considerable decline in electricity demand. The subsidy reform also applied in Qatar and transportation fuel prices went up by 30%. In Qatar, water and electricity are free for Qatari nationals while the price for both increased for foreigners. While price changes in water and electricity resulted in only a minor difference in demand, demand in 2016 for gasoline dropped by 11.5% and for diesel by 2.3 % (Krane & Monaldi, 2017).

The above examples show how subsidy reform could reduce demand, even in countries such as Qatar and Saudi Arabia, which had never had any reform experience. However, energy subsidy reform could hold risks and uncertainty regarding results and the consequences on poverty and inequality (Amer et al., 2016).

3.2.6 Inadequate water

The MENA region is the most water-stressed region in the world, based on the World Bank definition:'Water stress arises when water withdrawals for human, agricultural and industrial uses are relatively high compared to the level of renewable water resources' (World Bank, 2017f), which means when the ratio of withdrawal is more than the water resources. Figure 3.25 shows the projected water stress in the MENA region by 2020. All countries except Tunisia and Egypt will be extremely stressed.

Figure 3.25: Water stress by 2020



Source: World Resources Institute, 2015

In addition to their scarcity, water resources in this region are the most variable and unpredictable sources in the world (Amer et al., 2016). More than 60% of the MENA population who are responsible for 61% of the MENA's GDP live in areas of high or extremely high water stress, while the average population of the world in the same water condition is 35% (World Bank, 2017f).

Figure 3.26a: Share of population exposed to high or very high water stress

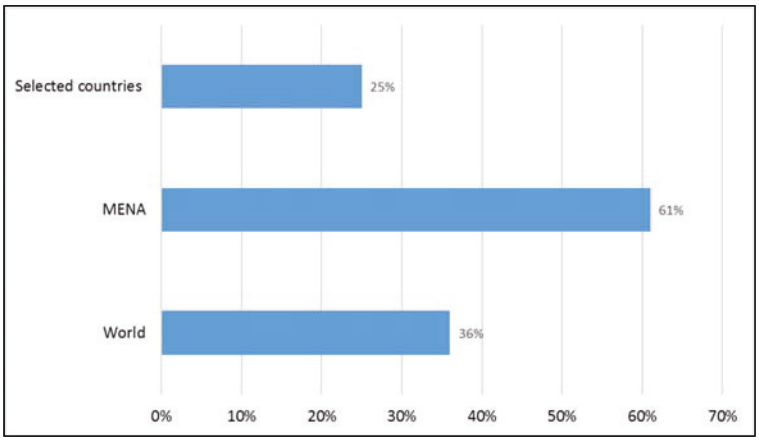
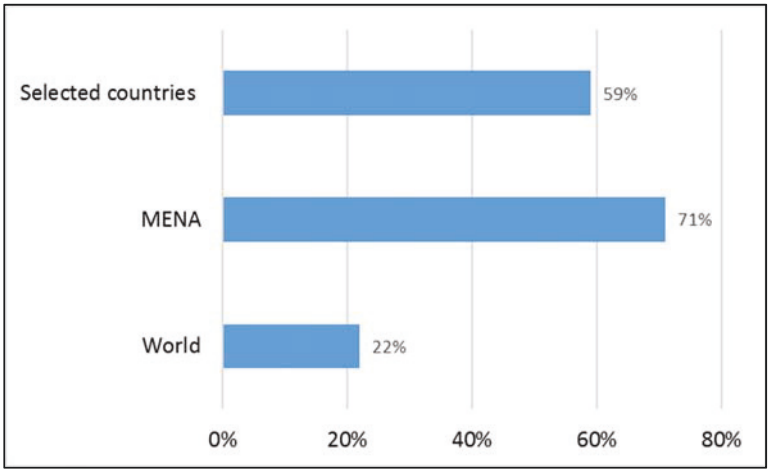


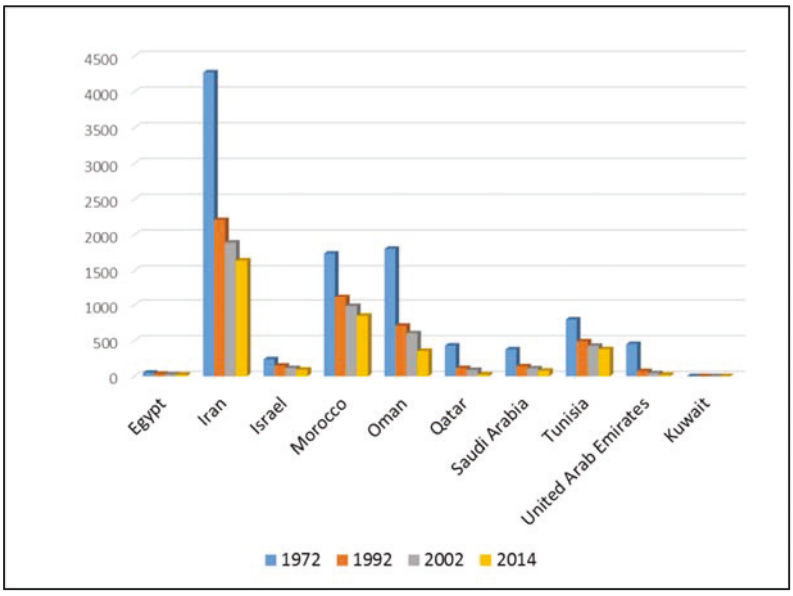
Figure 3.26b: Share of GDP exposed to high or very high water stress



Source: World Bank, 2017f; World Bank, 2019

As a result of the region's arid and semi-arid climate conditions, its shortage of conventional water resources and its rapid population growth, the amount of available fresh water per-capita has declined drastically since 1970 (Figure 3.27) (Amer et al., 2016; World Bank, 2017f). Based on population growth and estimations made in 2012, it is expected that by 2050, the demand for water in the region will increase by 30% while supply will drop by 12% (Droogers et al., 2012).

Figure 3.27: Renewable internal freshwater resources per-capita (m3)



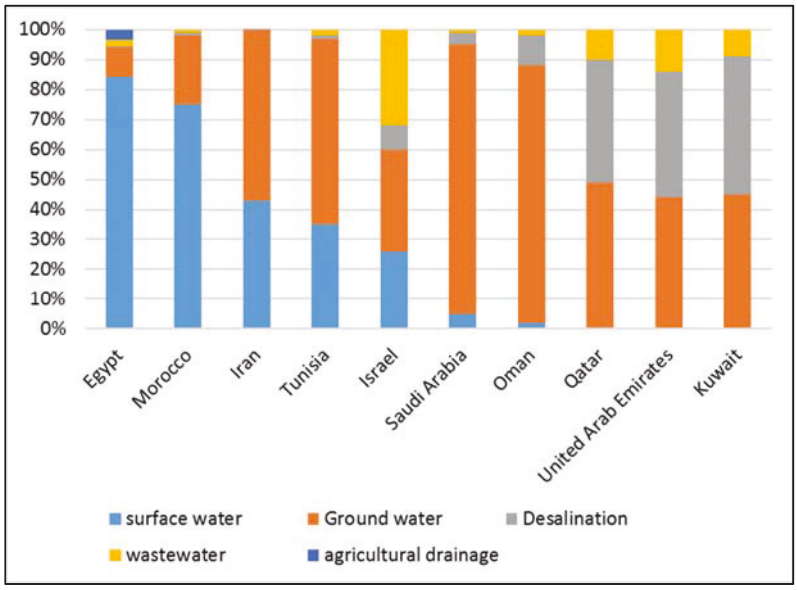
Source: World Bank, 2019

3.2.6.1 Available water resources

To meet the rapidly growing demand in MENA for water, which was estimated to be 261 billion m^3 (BCM) in 2010 (Droogers et al., 2012), countries in the region rely on both conventional sources, namely surface water and groundwater, and non-conventional sources, such as desalination, treated wastewater and irrigation drainage water. Iran, Israel, Egypt, Tunisia and Morocco depend primarily on conventional water sources while the GCC countries rely on the non-conventional. In general, countries in the Mashreq region[10] are rich in water resources while the GCC countries are the poorest. Surface water is the primary source of water in the area, supplying 80%. The agriculture sector consumes 85% of water resources and the municipal and industrial sectors 8% and 7% of supplied water respectively (FAO, 2009). Figure 3.28 shows the water resources needed to meet demand in the selected MENA countries, as discussed in the next sections.

[10] The Mashreq region consists of Egypt, Sudan, Saudi Arabia, Yemen, Oman, Kuwait, the UAE, Israel, Jordan, Lebanon, Syria and Iraq.

Figure 3.28: Water resources needed to meet demand



Source: AQUASAT, 2016

3.2.6.2 Conventional water resources

Conventional water resources include surface water and groundwater. Both are under stress in MENA.

a) Surface water

Surface water is defined as water from rainfall, rivers, springs and lakes (FAO, 2016). There are 23 watersheds in the region, the three main permanent rivers being the Nile, the Euphrates and the Tigris (FAO, 2009). Table 3.3 shows the specification of some of the critical watersheds in the region. There is no important river in the GCC region. From Figure 3.28, it can be seen that Egypt (84%) and Morocco (75%) are the countries that are most dependent on surface water to meet water demand. There is no surface water available in Qatar, UAE and Kuwait.

To provide sustainable supply, countries with high precipitation and vast transboundary water invest heavily in water storage and water transportation networks. In MENA, 95% of the capacity of existing dams belongs to five countries where the agriculture sector plays a significant role in the economy, namely Egypt (168.2 km^3), Iraq (151.8 km^3), Iran (32.24 km^3), Syria (19.7 km^3) and Morocco (16.9 km^3) (UNDP, 2014).

Table 3.3: Major basin in MENA

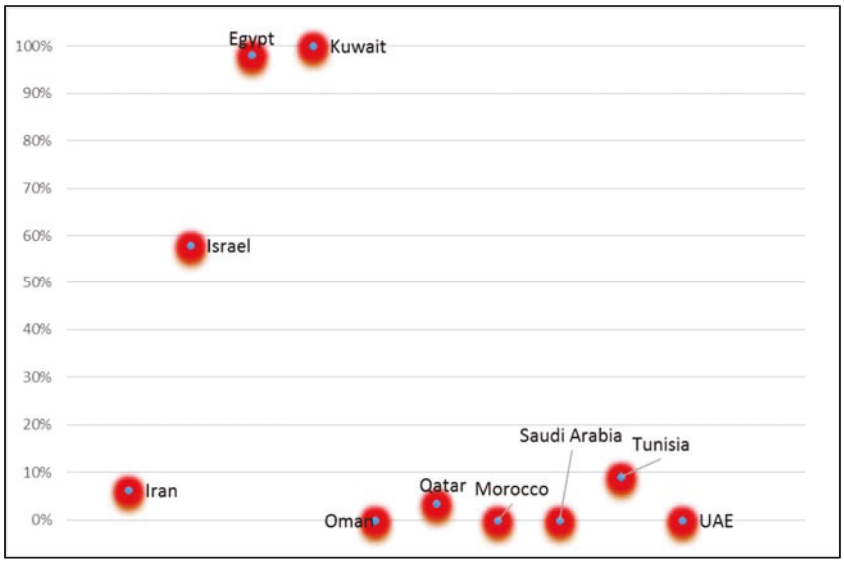
Basin	Basin size (1000 km^2)	River length (km)	Average discharge (BCM/year)	Riparian countries
Nile	3,173	6,693	109.5	Egypt, Sudan, South Sudan, Burundi, Democratic Republic of the Congo, Eritrea, Ethiopia, Kenya, Rwanda, Tanzania and Uganda
Euphrates	64,7075	2,330	32.0	Iraq, Syria, Turkey, Jordan and Saudi Arabia
Tigris	146,239	1718	52.0	Iraq, Syria, Turkey and Iran
Jordan River	19,839	251	1.34	Lebanon, Syria, Jordan, Palestine and Israel

UNDP, 2014

Transboundary water resources are one of the challenges between countries in the area as there is no agreement available for equitable sharing and augmenting of water. More than 60% of the surface water for resources in MENA originate from outside the region. For example, the Euphrates-Tigris Basin, which is shared by Turkey, Iraq and Syria, is the site of one of the historical conflicts over water in the area. The root of this conflict is the growing population and the demand for long-term food security and self-sufficiency (El-Fadel et al., 2002). The struggle over the Jordan River between Israel and its neighbour is another example. Based on international law, the water should be shared equitably between the two countries; however, Israel has had full control over this river since 1967. Israel has gained 40% of the water and the rest is shared with other countries (Shamir, 1998). Excessive usage and pollution were the main reason for starting war in 1967 (Drake, 1997).

Figure 3.29 shows the percentage of renewable water resources that originate from outside the border of MENA countries. It shows that Egypt and Kuwait are the countries that are most dependent on shared water resources beyond their borders.

Figure 3.29: Total external renewable water resources (%)



Source: AQUASAT, 2016

b) Groundwater

The second primary source of water in the region is groundwater, which is captured from under groundwater. Groundwater is usually used in the absence of alternative resources (World Bank, 2017f). As groundwater is accessed, the level of the aquifer falls and more energy is required to pump the water up. However, as the aquifer levels drop and get close to depletion, the chemical quality of the water will diminish until it is not suitable for human consumption (Soltani & Saboohi, 2008; World Bank, 2017f). The ongoing withdrawal of groundwater will impact the sustainability of irrigated agriculture, will deplete surface water and cause such environmental impacts as land subsidence (Tularam & Krishna, 2009).

In Saudi Arabia (90%), Oman (86%), Tunisia (62%), Iran (57%) and Qatar (50%), groundwater contributes to more than 50% of total water withdrawal (Figure 3.28). Even countries rich in surface water, such as Iran and Tunisia, count on groundwater to meet rising demand. Groundwater resources are used mostly for agricultural growth and development but with no integrated planning (UNDP, 2011), while governments subsidise the electricity used to drill wells. In Tunisia, Morocco and Egypt, a 25% subsidy is assigned to drilling and investment in pumps and piped networks (Closas & Molle, 2016).

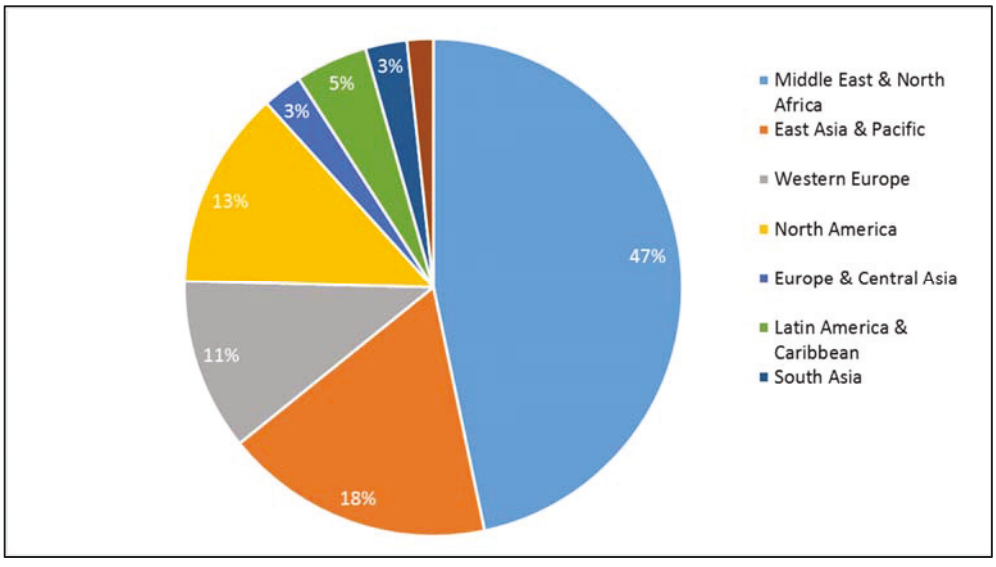
3.2.6.3 Non-conventional water resources

As water demand grows and supply declines, most countries are moving towards non-conventional water sources, which includes desalinated water, treated wastewater and agricultural drainage water. Egypt is the only country in this research that uses agricultural drainage water technology. In Egypt, agricultural drainage water resources increase the availability of water by 20% and it expects reuse of drainage water to rise by 1.5% from 2013 to 2020 (Allam & Negm, 2013).

a) Desalinated water

The MENA region is the biggest producer of desalinated water in the world, generating more than 47% of the total (Figure 3.30). In the GCC countries, dependence on desalinated water goes beyond the global average; together, they are the largest producer of desalinated water in the area (90%), followed by Israel (4%), Egypt (3%) and Iran (2%) (Figure 3.31). Based on a projection by Trieb and Mullersteinhagen, by 2050, desalination will account for 76% of all water needs in the region (Saif, 2012). However, the majority of desalination capacity will be focused on high-income energy exporters, predominantly the GCC countries (Al-Jamal & Schiffler, 2009).

Figure3.30: Desalination in different regions

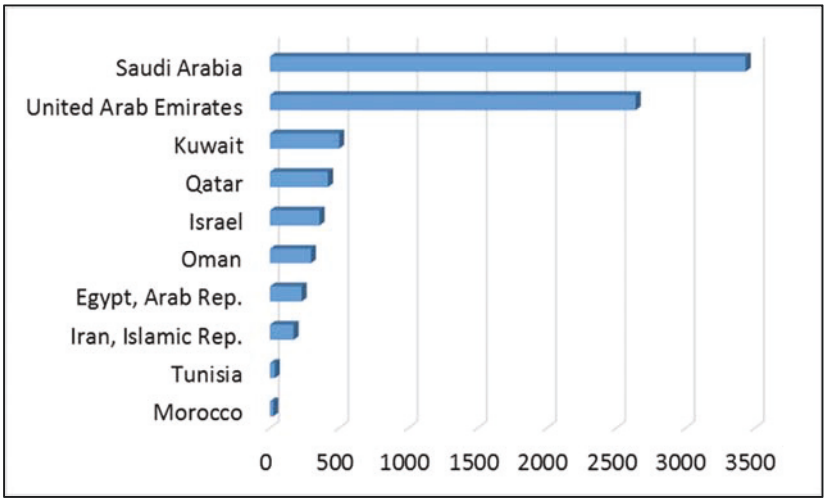


Source: World Bank, 2017f

The current desalination practices in the GCC countries arouse several environmental concerns, which can be grouped into input concerns and output concerns. In the inputs group, the region is currently using only fossil fuel, mostly natural gas, which is not a

sustainable energy source. Another issue is the impact of intake pipes on the marine environment and damage to aquatic organisms. In terms of outputs, using fossil fuels, and in particular natural gas, generates a massive amount of greenhouse gases and especially CO_2 emissions (refer to Section 3.2.3.1). The last but most important concern is managing the salinity of desalinated water. Brine discharge contains a mixture of saline concentrates and chemical pollutants which need major pre-treatment (Saif & Health Hamilton, 2012).

Figure 3.31: Desalinated water in 2010 (MCM/y)



Source: Immerzeel et al., 2011

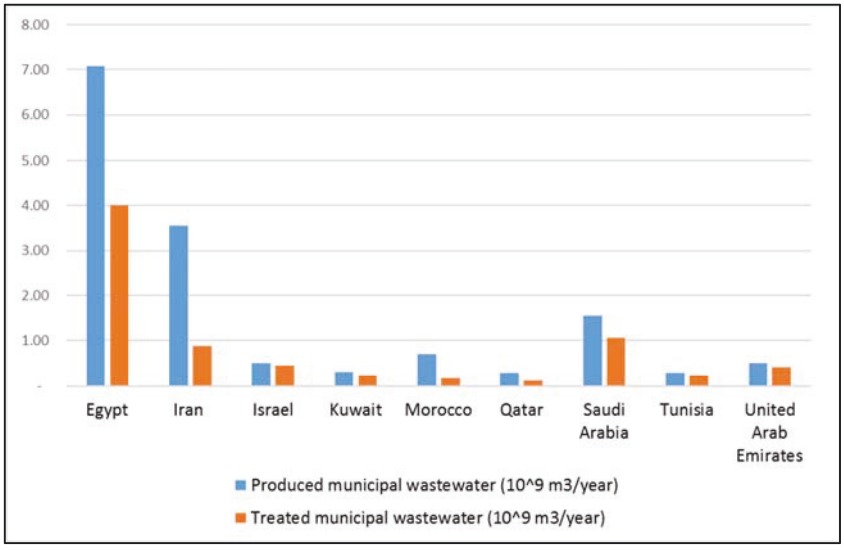
Furthermore, desalination is an energy-intensive process. In Saudi Arabia, 25% of oil and gas production is used domestically for generating electricity and water. In Kuwait, 50% of the total energy consumption is used in desalination plants (Amer et al., 2016). If the trend continues, Saudi Arabia can expect total energy consumption share to jump to 50% by 2030 (Kajenthira et al., 2012) while in Kuwait, demand for energy will be equal to the current level of oil production by 2035 (Darwish et al., 2009).

b) Treated wastewater

Treated wastewater as another non-conventional water resource is attractive to governments and decision makers in MENA to overcome growing water scarcity. The region treats 43% of wastewater generated, which is relatively high compared with other developing countries (Qadir et al., 2010). However, more than half of the wastewater generated in the Middle East and North Africa is returned to the environment without treatment, which has a substantial impact on human health and water resources (World Bank, 2017f). Although the region has the potential to benefit from treated wastewater, only a few countries have succeeded in developing safe and sustainable wastewater reuse programs (Jeuland, 2015). Egypt and Iran treat a significant part of their wastewater, but are not yet able to implement

water reuse on a large scale (World Bank, 2017f). Institutional and political limitations, technical obstacles and social acceptance are the main barriers to expanding water reuse in the MENA region (UNDP, 2011).

Figure 3.32: Total wastewater production and treatment between 2008 and 2012

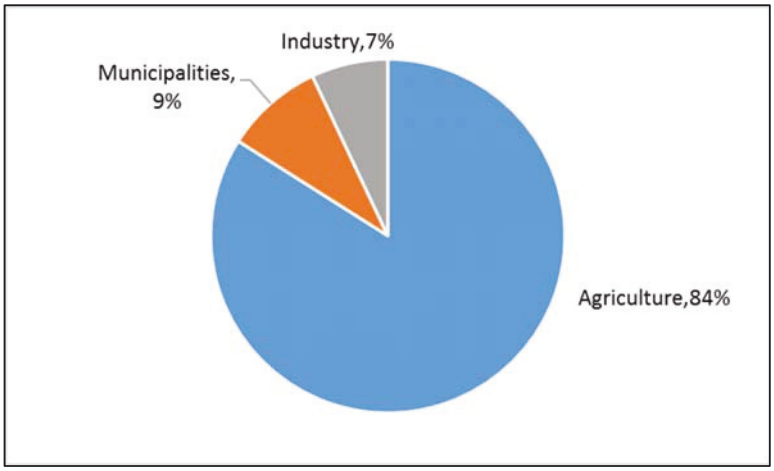


Source: AQUASAT, 2016. Data for the UAE collected from ACWUA (2010). Data for Oman was not available.

3.2.6.4 Water consumption

Although water resources are not secure in MENA, 82% of the total population has access to improved drinking water and more than two thirds of that 82% have access to improved sanitation water (UNDP, 2011). Water consumption is categorised into three: agriculture, municipal and industry. Of these three sectors, in MENA, agriculture is the dominant sector for water use.

Figure 3.33: Water withdrawal in MENA



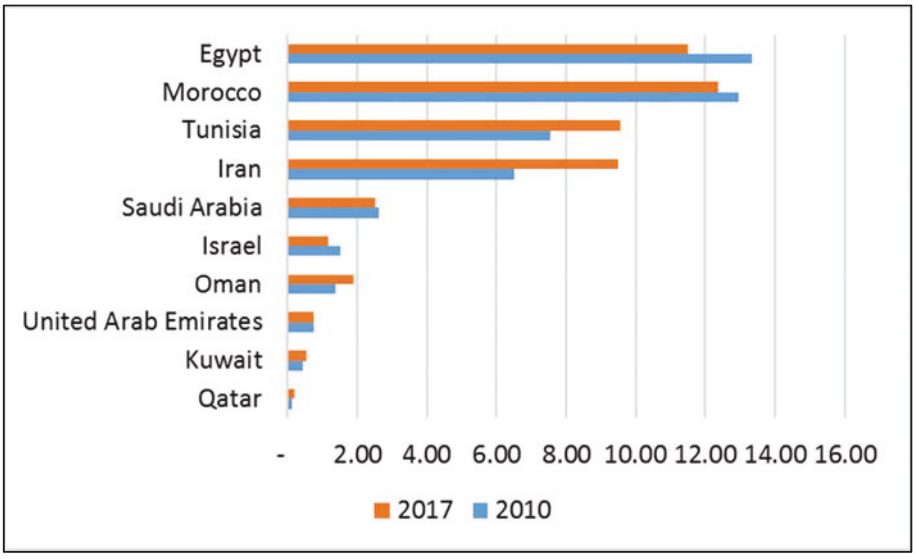
Source: FAO, 2009

a) Agricultural sector

Agriculture, an essential sector in all the countries in the region, consumes more water than urban demand. The demand for water in this sector mounted by 125% from 1995 to 2003 (UNDP, 2014). Overuse of surface water and groundwater in agriculture put more pressure on the water supply to the other sectors. Despite this growing demand, agricultural performance and food production have not been successful in many countries in the region and the share of agriculture in GDP declined between 2010 and 2017 in some countries, such as Egypt and Morocco, and in others, like Kuwait and Qatar, the share was negligible (Figure 3.34).

Since 1980, policies and investments have favoured agriculture and more attention was paid to developing supply rather than considering resource availability and integrating the management of resources (FAO, 2018). Self-sufficiency policies for food production put extra pressure on land and water resources such as groundwater. Providing energy subsidies for pumping water is another example of a lack of regulation in the region (Closas & Molle, 2016). Cheap energy prices impacted negatively on groundwater reserves.

Figure3.34: Share of agriculture in GDP in 2010 and 2017



Source: World Bank, 2019

Furthermore, irrigation is quite substantial in the MENA region; surface irrigation is used to produce 76% of the food, followed by sprinkler irrigation which is applied to a third of the agricultural area (Mancosu et al., 2015). Irrigation efficiency in the region is very low (30% to 40%), with 50% of irrigation water lost to evaporation (UNDP, 2014).

As pressure on water supplies will increase in the future, the agriculture sector in the region will face significant challenges. First, the need to produce food will increase; otherwise, the bill for imported food will increase dramatically (280 billion dollars in 2006). Second, a large number of people live in rural areas in this region and farming is their primary occupation. Agriculture will be further under pressure to generate job opportunities and help reduce the unemployment rate. In MENA, job opportunities in the agriculture sector dropped by 2% between 2006 and 2018 (World Bank, 2019). Last, overuse of water in agriculture puts extra pressure on the availability of water in other sectors. Lack of water will push agriculture to depend more on water reuse or governments will have to choose expensive options such as desalinated water, which is not viable for some countries

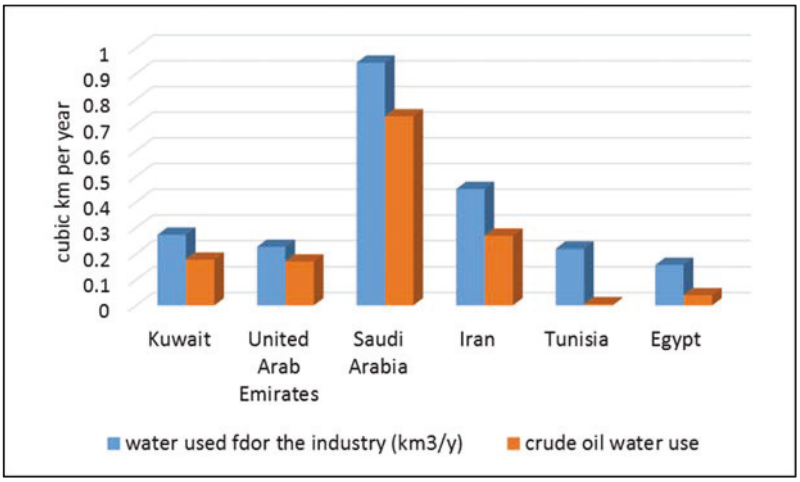
b) Municipal and Industrial sectors

Water availability in the MENA region is around 1200 m^3/person/day compared to the global average of close to 7000 m^3/person/day (UNDP, 2014). Based on UN estimates, the population in MENA will grow to twice its 2018 population (refer to Section 3.2.1) and reach 700 million in 2050. Hence, per-capita availability of water is expected to halve by that time.

Despite the shortage of water in the region, per-capita water consumption in the GCC is the highest in the world. In Saudi Arabia it is 943% of available renewable water and in Kuwait it is 2456% (Yamouri, 2010). The rise of water consumption in the GCC countries is due to ineffective policies, such as high subsidisation and low tariffs, which discourage demand management among consumers (Amer et al., 2016).

In the industrial sector, water is used mostly in the production of crude oil. Saudi Arabia is the most extensive water user in this industry sector, accounting for 42% of total water withdrawal in the country. In Kuwait, water used by crude oil accounts for 89% of total domestic water withdrawals (Sakhel et al., 2013).

Figure 3.35: Water used in industry in selected countries



Source: Sakhel et al., 2013

3.2.7 Food insecurity

Food security is one of the biggest challenges in MENA and it is impacted by many factors, such as unstable political and social conditions, constraints in resources and the effects of climate change, such as floods and droughts. Although many countries have progressed in meeting their MDGs, the FAO reported in 2015 that MENA was the only region in the world where the number of hungry people increased, reaching 33 million (due to wars in Syria, Iraq and Yemen) (FAO, 2015). The MENA region depends mostly on food imports to meet the demand of its growing population. It is the largest net importer of cereals in the world (FAO, 2015), importing 50% of the total wheat and barley, 40% of the total rice and 70% of the total maize requirements of the region (Martens, 2017). This reliance in the region on food imports is expected to increase by 40% between 2010 and 2030, which could affect the price and supply of food (Jägerskog & Swain, 2016). Despite progress in terms of the Global Hunger Index (GHI) in MENA countries, some countries were still classified as moderate, scoring between 10.4 and 14.8 (Table 3.4)[11] .

[11] The GHI is a multidimensional tool to show the state of hunger globally. GHI scores are calculated based on factors: UNDERNOURISHMENT, CHILD WASTING and CHILD MORTALITY. 0 presents no hunger and 100 absolute hunger.

Table 3.4: State of hunger in the selected MENA countries in 2018[12]

Country	GHI	Classification
Qatar	less than 5	Low
Kuwait	less than 5	Low
United Arab Emirates	less than 5	Low
Oman	10.8	Moderate
Saudi Arabia	8.5	Low
Tunisia	7.9	Low
Morocco	10.4	Moderate
Egypt	14.8	Moderate
Iran	7.3	Low

Source: IFPRI, 2018

Reaching a high degree of food self-sufficiency in MENA is unlikely as resources are limited and the population is growing fast (Amer et al., 2016). The self-sufficiency policy that started in 1970 in the region did not bring food security but contributed to unsustainable agriculture. However, some countries, such as Morocco and Israel, are major exporters of food and self-sufficient in most products, but the GCC countries rely heavily on food imports. Therefore, governments try to meet the demand with supplies from overseas while expanding their domestic capacities (EIU, 2014).

In recent years, political uncertainty such as the Arab Spring impacted the price of food. In North Africa, the highest increases in food prices between 2016 and 2018 occurred in Egypt (55%) and Tunisia (13%). In the Middle East, Iran with a 44% change in prices has experienced the highest inflation, while in countries such as Oman and Kuwait, food prices declined slightly.

[12] The state of hunger for Qatar and Oman was estimated in 2014 by Arab Organisation Agricultural Development (AOAD); no data available for Israel.

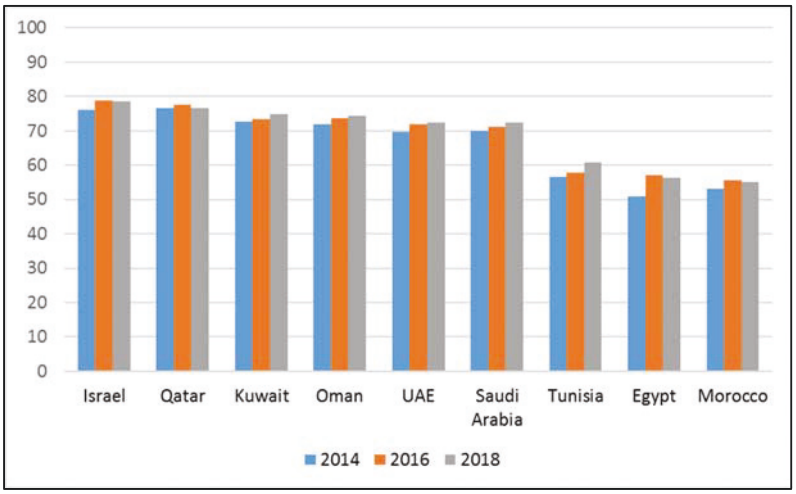
Table 3.5: Consumer food price index (2010=100)

Country	2016	2017	2018
Qatar	108.27	110.36	110.46
Kuwait	127.11	126.72	126.64
United Arab Emirates	119.58	121.02	125.33
Oman	109.54	110.15	109.31
Israel	106.53	106.58	107.45
Saudi Arabia	100.69	99.86	106.28
Morocco	110.87	110.87	112.02
Tunisia	138.82	146.53	157.12
Egypt	206.08	285.75	323.17
Iran	345.10	396.06	497.10

Source: FAO, 2019

The Global Food Security Index (GFSI) shows the food security in different countries according to four core criteria: affordability, availability, quality and safety, as well as natural resources and resilience (EIU, 2014). Figure 3.36 shows the overall GFSI in the selected MENA countries. Israel, Qatar and Kuwait have the highest ranking while Egypt and Morocco need improvement. However, the ranking could change if one looks at each dimension of the GFSI.

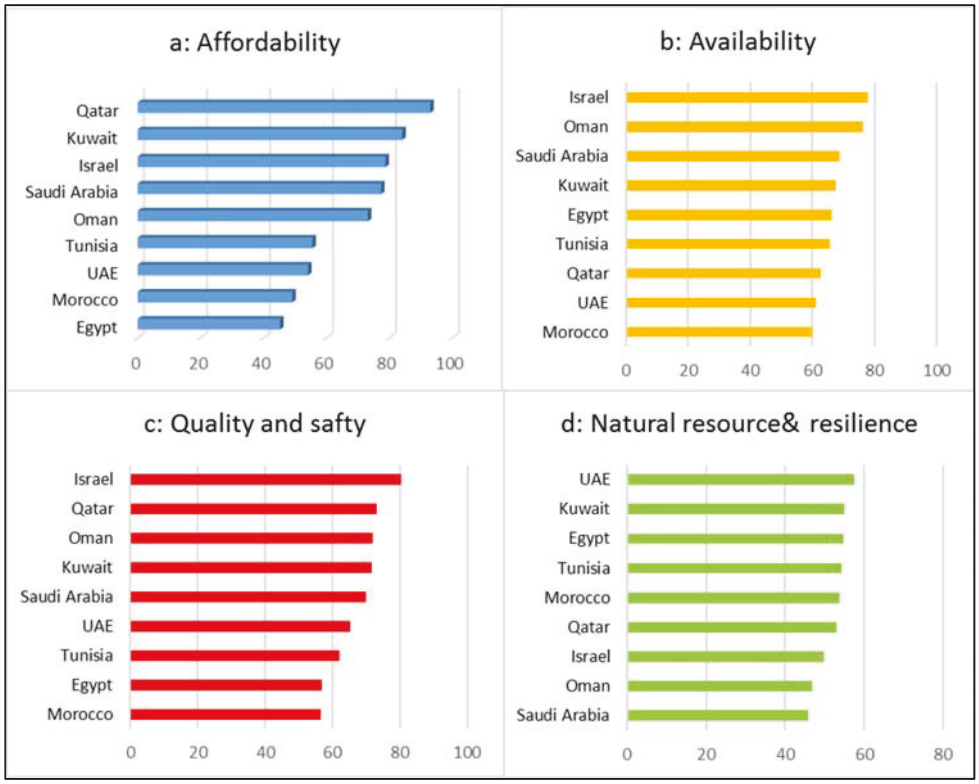
Figure 3.36: Overall Global Food Security Index



Source: USAID, 2019[13]

[13] GFSI (0-100, 100 = best environment); no data available for Iran.

Figure 3.37: Food security for different countries based on GFSI criteria



Source: GFSI, 2018

Figures 3.37a-d compare the countries according to each criterion as they were in 2018. The remarkable point is that in terms of natural resources and resilience, countries like Egypt and Morocco performed better than Israel and Qatar, the countries with the best position in the region in 2018.

3.2.8 Political state

The MENA is one of the most volatile regions in the world. The instability in the area is the consequence of continued disputes and tensions, poor governance, economic failures, poverty and unemployment (Cordesman, 2018). Lack of water, the high price of food, unequal distribution of energy resources and climate change add to the threat of volatility and war in the region.

Water as a scarce resource in MENA could act as a substantial factor for causing domestic social unrest, environmental stress and transboundary conflicts (Baconi, 2018).There is a long history of water conflict in the region (Gleick, 2014). One of the long-term examples of water conflict is tension over the Jordan River between Israel, Jordan, Lebanon, Syria and the West Bank and Gaza since 1967. Another example is the conflict between Syria,

Iraq and Turkey over water from the Tigris and Euphrates rivers during the 1980s and 1990s. Besides these water shortages, food shortages and dependency on food imports cause severe challenges in the region. In the Arab Spring of 2011, food as a 'threat multiplier' played a substantial role in the mobilisation of protests in Egypt and Tunisia (Buck, 2016). Climate change accounts for another risk of unrest in the region. In 2014, the World Bank called climate change a significant threat to peace in MENA because it put extra stress on already scarce resources and boosted political instability, poverty and unemployment (World Bank, 2014). Syria's war is one of the recent examples of the impact of climate change reinforced by the severe drought between 2006 and 2010, forcing 1.5 million farmers to migrate to cities, leading to social instability (Stang, 2016). UNHCR announced that as a result of recent wars in MENA since 2011, 5.6 million refugees in Syria, 3 million in Yemen and 1.5 million in Iraq were displaced, mostly to the neighbouring countries of Iran, Turkey and Jordan.

3.3 Summary and conclusion

By studying the current situation in MENA, one can understand the link between energy, water and food. However, in most MENA countries, despite the linkages between the sectors, existing policies have been developed in isolation. Sustainable development requires a deeper understanding of the interconnectivity between energy, water and food (Hoff, 2011). Therefore, in the face of concerns related to the security nexus of energy, water and food in the region, nexus thinking is required to guide the development of policies and consider the integration of energy, water and food with an understanding of the environmental constraints and people's needs (Amer et al., 2016).

Below are some of the challenges related to the current security of energy, water and food in MENA:

- The region faces rapid growth in population, urbanisation and economic growth, which is creating an upsurge in demand and consumption and putting extra pressure on the availability of resources, particularly water.
- Climate change is one of the significant threats for the region. Extreme heat will spread across the region and make some parts of the region unliveable and impact agricultural activities.
- Energy endowment is abundant but it is not distributed equitably in the region.

Even though energy is essential for growth, unsustainable consumption due to subsidisation, low energy efficiency, increasing environmental impact (excessive CO_2 emissions) causes doubt about the sustainability of energy resources in MENA.

- Water is the scarcest resource in the region and management of future demand requires policy reconsideration. Transboundary water is a critical challenge which could impact political stability. Water policies could play a key role in forming the EWF nexus in the future and that nexus will require integration and collaboration among policymakers for countries with shared boundaries.

- Agriculture and food supply are among the biggest challenges for MENA. While countries in the region have made substantial progress in producing food, supply in MENA is highly dependent on imports. Self-sufficiency policies have not been able to improve food security in the region and low agricultural efficiency and subsidised energy have impacted the water sector and land significantly and in a negative way.

- Unemployment, poverty and water deficiency could cause political uncertainty in the region. In general, political unrest for any reason reinforces the risk of instability in managing energy, water and food resources which ultimately will affect the security nexus between the sectors.

Chapter 4: A review of EWF nexus methodologies

In Chapters 2 and 3, the current EWF nexus situation was discussed in detail. It was found that a strong dependency exists between sectors in which the interlinkages between EWF have multidimensional and dynamic characteristics. Capturing these features requires an integrated framework which will enable the interlinkage between the sectors to be considered and give a balance between technology and policy outcomes. There are several methods for evaluating the EWF nexus, which all poses some challenges.

This chapter aims to review the methods that are used most in evaluating the EWF nexus to identify their relative strengths and weakness and assist in the selection of an appropriate methodology for this research. Section 4.1 outlines the criteria required to review these methodologies. A brief background of some of major nexus methods is presented in Section 4.2. In Section 4.3, the reviewed methods examine based on the outlined criteria and a summary of the major findings of this chapter is given in Section 4.4.

4.1 Criteria for examining nexus methodological approaches

Since the first nexus conference 'The water, energy and food security nexus solution for the green economy' in Bonn in 2011, several studies have focused on the EWF nexus concept. However, the limited number of these studies present methods to explore the relationships between the energy, water and food sectors and their linkages in the wider economy (Albrecht et al., 2018). This is because the nature of nexus is complex, multidimensional and dynamic. The method selected must therefore consider certain features to address such a complicated process. The key features consist of:

a) The ability to identify complex interactions and feedback between sectors because this is essential for sustainable development and adaptation. Understanding the interactions between energy, water and food could improve resource-use efficiency and develop policy integration between sectors (Smajgl et al., 2016, Gain et al., 2015, Rasul and Sharma, 2015).

b) The method must assess the impact of internal and external changes that one resource can bring to another. Because a nexus is multidimensional, improving system efficiency could enhance economic progress and create more with less, reduce negative impacts on the environment and promote social equity (Mohtar & Lawford, 2016, Mayor et al., 2015, Biggs et al., 2015).

c) The method must provide useful outcomes for policy-making and resource management. This is because recognising cohesive policy solutions could maximise synergies across sectors and minimise trade-offs. Such policies could improve cooperation and coordination between sectors (Bazilian et al., 2011, Siddiqi et al., 2013, Guillaume et al., 2015, Rasul and Sharma, 2015).

In addition to the above criteria, this study discusses methods based on the following criteria:

I. **Goal**: this research examines the interdependencies, multidimensionality and dynamics of EWF security, and provides a platform for assessing the impacts of alternative policy pathways in terms of addressing the challenge at national and regional levels. Therefore, the selected framework must also be able to analyse the interlinkages among the EWF sectors and assess their impacts from both the socioeconomic and the environmental dimensions.

II. **Spatial scope**: the spatial scope must consider two elements. The first is that the EWF nexus could impact different sectors of the economy differently depending on the sectoral influence on the EWF nexus. Hence, the framework selected must allow analysis to be implemented at a disaggregated level to capture linkages. Second, the framework must consider technology/policy outcomes and be able to draw a balance between them.

III. **Temporal scope**: due to the long-term environmental impact of nexus issues, the framework must be able to undertake a medium- to long-term analysis.

IV. **Dynamic character consideration:** one of the main attributes of any modelling study is dynamism. The selected framework must be able to consider technological changes over time, which can occur, for example, as a result of innovation, changes in consumer and producer preferences, or policy adjustments.

V. **Price impacts assessment:** changes in sector prices will induce substitution among factor inputs, which could change the price of sectoral outputs. The selected framework must be able to assess the impact of price changes in different sectors across the economy.

VI. **Data consideration:** data availability is one of the challenges in any model and particularly in this research, which considers the detailed linkages among sectors

across the economy. Therefore, the selected framework must be able to use publicly accessible data.

4.2 Methods for assessing the EWF nexus

As discussed in Section 4.1 above, there are three key features that the methodologies selected for this review must consider for evaluating the EWF nexus. Several studies have used different methods to show these key features. However, recalling the studies listed in Table 2-1, some applied qualitative methods solely to describe the nexus approach. These include the policy integration model (Conway et al., 2015), the Delphi process, questionnaires and surveys (Foran, 2015, Halbe et al., 2015). Due to the nature of qualitative methods, these methods do not meet the required criteria for modelling in this research.

The other group of the selected studies in Table 2-1 applied quantitative models, such as the hydrological models and coupled model (Conway et al., 2015), regression analysis (Kurian and Policy, 2017) and a water management model (Scott, 2011). In this group of studies, the applied models are mostly mono-sectoral and are quite narrow to capture the linkages at the disaggregated level and capture all the environmental, economic and social impacts.

Table 4.1 shows a list of the studies selected and the methods applied for the EWF nexus. In this section, these models will be discussed in detail. The selected research for this table must focus on a regional or national scale and apply the model for all three sectors (energy, water and food).

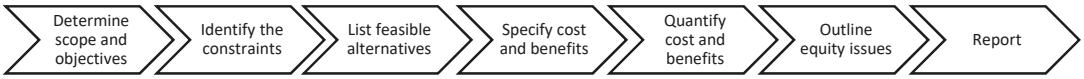
Table 4.1: Selection of applied methodologies in the EWF nexus

Author	Scope	Method used	Study period
Hermann et al. 2012	National	CLEW model	2012-2050
Endo et al. 2015	Regional	Cost-benefit analysis Hydrologic modelling	n.a
Daher& Mohtar 2015	National	Input/output analysis	n.a
Halbe et al. 2015	National	System dynamic	2009-2014
Damerau et al. 2015	Regional	Econometric modelling	2015-2050
Ozturk 2015	National	Econometric modelling	1980-2013
Al-Ansari et al. 2015	National	Material flows analysis Life cycle assessment	2010-2025
Haie (2015)		Input-output modelling	2015
White et al. 2017	Regional	Input-output modelling	2005
Bellezoni et al. (2018)	National	Input-output modelling	2008-2030
Owen et al. (2018)	National	Input-output modelling & cost-benefit analysis	1997–2013
Xiao et al. (2019)	National	Input-output modelling	2013

4.2.1 Cost-benefit analysis (CBA)

Cost-benefit analysis is a quantitative analytical tool that provides monetary information for decision makers. The aim of CBA is to optimise allocation of resources in projects while considering the cost and benefits of the projects. In addition, implementing this tool helps to analyse the monetary impact of projects on society. Figure 4.1 illustrates the steps for CBA analysis. (DFA, 2006).

Figure 4.1: CBA analysis steps



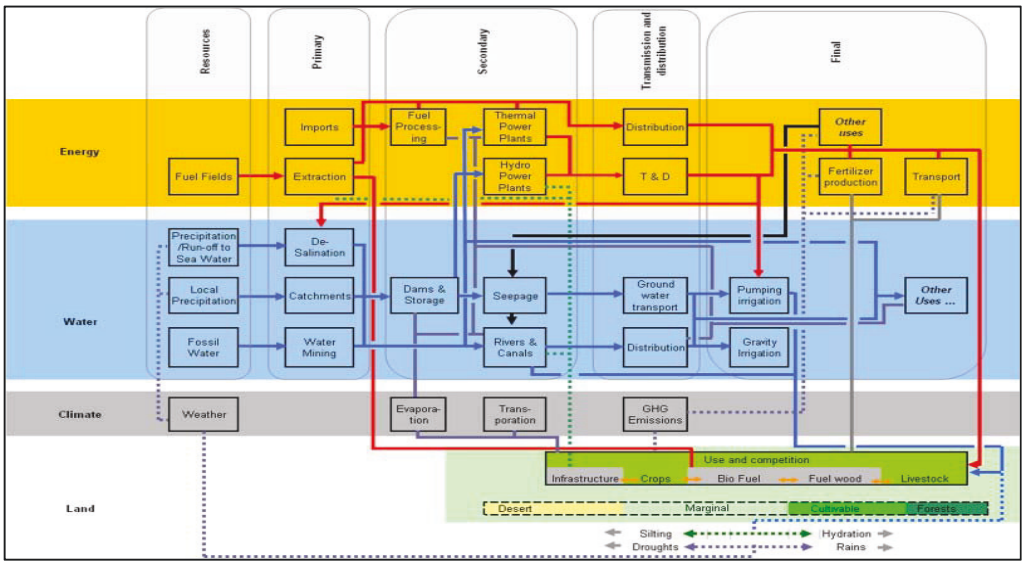
Source: DFA, 2006

The strength of the model is its ability to analyse data consistently and deliver a comprehensive assessment of projects to determine the appropriateness and efficiency of allocation of resources. However, CBA is biased and able only to include consequences which can be identified. Therefore, the non-monetary impacts of activities, such as environmental impacts, may not be sufficiently considered.

4.2.2 CLEW model

The climate, land, energy and water (CLEW) model is an integrated framework that has been developed by a research group from the KTH Royal Institute of Technology in Sweden. The model provides an opportunity to assess resource systems and determine how a change in one sector could affect others. The model examines EWF interlinkages while considering the impacts of human activity on climate change and the effects of climate change on the availability of resources in the future. The model consists of three main submodules: an energy model-LEAP, a water model- WEAP and a land use model- AEZ (agro-ecological zoning). Figure 4.2 as presented by the International Atomic Energy Agency (IAEA) is a schematic diagram of ethanol production and the EWF linkages obtained by the CLEW model.

Figure 4.2: schematic of ethanol production and EWF linkages



Source: Bazilian et al., 2011

CLEW modelling aims to support the following aspects of CLEW nexus (Bazilian et al., 2011):

- Decision making: CLEW as an integrated framework would assist policymakers in evaluating their options against any change in CLEW system. The tool can present trade-offs across any option.

- Policy assessment: due to limitations in available resource and the interlinkages between them, policies must cover more than one objective. The model can assist in assessing policies and avoid any silo thinking when creating strategies.

- Improving policy integration: in some systems, policies contradict each other. The CLEW model can help remove any inconsistencies and conflicts and move towards harmonised strategies.

- Technology assessment: similar to policies, some technologies selections can impact several resources. The CLEW model could provide a comprehensive evaluation of different technologies options.

- Scenario development: another aim of the model is presenting compatible scenarios to evaluate the impact of different policies and technologies on resources. Such assessments can help give in-depth understanding and identify opportunities.

The following four scenarios analyse the linkages between climate, land, energy and water under the same assumption for energy supply and the potentiality of renewable energy generations. The aim of the following scenarios are to investigate how introduction of tax on fossil fuels could impact water consumption, emission and investment in energy and other sectors (IAEA, 2019):

- The baseline scenario is the business-as-usual scenario. In this scenario, GHGs are expected to increase by average temperature between 4°Cand 6°C.
- 4°C Scenario: in this scenario, the use of fossil fuel is limited and the average temperature will rise by no more than 4°C.
- 2°C Scenario: in this scenario, the usage of fossil fuel is limited, and the average temperature will rise by no more than 2°C.
- Carbon Tax Scenario: in this scenario, there is no limitation on fossil fuel usage but the global carbon tax goes up from US$1 per ton of CO_2 eq. in 2016 to US $25 in 2050.

The CLEW model used by Welsch et al. (2013) for the island of Mauritius showed how results could vary when an integrated nexus framework was used instead of considering sectors separately. A national study by Hermann et al. (2012) in Burkina Faso provided a deep understanding of the current substantial challenges in this resource-constrained country.

A significant limitation of the CLEW model is that the food sector is not considered explicitly, the main focus being on land and the agricultural landscape (McGrane et al., 2018). In addition, the large amount of data required for the CLEW model makes the model complex. A large amount of data such as cost, is difficult to obtain, and, in many cases, there is a need for detailed technical and economic parameters in the energy sector. Also, the model is presented in aggregated levels on a global scale in the short to medium term. The number of scenarios is limited, and users are not able to develop the scenarios they desire.

4.2.3 Material Flow Analysis (MFA)

Material flow analysis (MFA) is a systematic assessment that originates from society's metabolism. The base of the model is mass balance and it is used to assess the flow and stocks of materials in a system within a specific time and space and at regional, national and industry levels (Hunt et al., 2014, Bao et al., 2010). MFA is a popular approach among industrial ecologists as it can track the physical movement of materials and energy through to the final stage (Hunt et al., 2014) and has the potential for material substitution. This model is manageable with limited materials and it can consider the material flows within a single industry or the whole economy (Hunt et al., 2014).

The main principles of MFA are (Brunner and Rechberger, 2004):

- reduces the complexity in a system
- evaluates all the flows and stocks in measurable terms and finds weak points which could improve the system
- shows the flow and stocks in a comprehensive and transparent way
- consider priorities in managing resources and reducing environmental impacts

The model is based on equality between input and output; however, the results of some studies show that the MFA model cannot capture all the material flows in the system. For example, in 1997 the method was applied to measuring the total material requirements in Japan, the USA, Germany and the Netherlands (Adriaanse et al., 1997). The report found that the flows in the national accounts of all four countries were underestimated by 55% to 70% as the method was not able to capture the environmental impacts of activities. Another study in 2001 assessed the total material requirement for the European Union the results of which showed a decline in direct material consumption despite the fact that the total material consumption was increasing (Bringezu and Schütz, 2001).

Some case studies applied MFA in the context of the EWF nexus. Al-Ansari et al. (2015) used MFA to build the input-output inventory for all flows involved in food production systems. In another study, Covarrubias (2019) used MFA to trace and analyse the flow of materials so as to understand the urban nexus and sustainable urban development which used the results to evaluate the impacts on the environment.

From the above discussion, it can be seen that MFA is a useful approach for evaluating material flows for particular technical choices, such as declining the CO_2 emissions from a specific sector by applying recycling. The model requires a large amount of data, which is expensive and sometimes hard to obtain. MFA is also a short term and static approach that shows only the current material system (Sandu, 2007). The model struggles to provide feedback that is useful for policy assessment and decision making (Covarrubias, 2019).

4.2.4 Life Cycle Analysis (LCA)

Life Cycle Analysis (LCA) is a tool that evaluates the environmental consequences of a product throughout its lifespan, in other words, from 'cradle to grave'. This process covers extraction, manufacturing, distribution, waste treatment, maintenance and recycling of a product or system. Similar to MFA, LCA can capture all flows and impacts while focusing on the function of the product, rather than on the product itself (Bouman et al., 2000).

The LCA procedure has four steps (Roy et al., 2009), as described below and as shown in Figure 4.3.

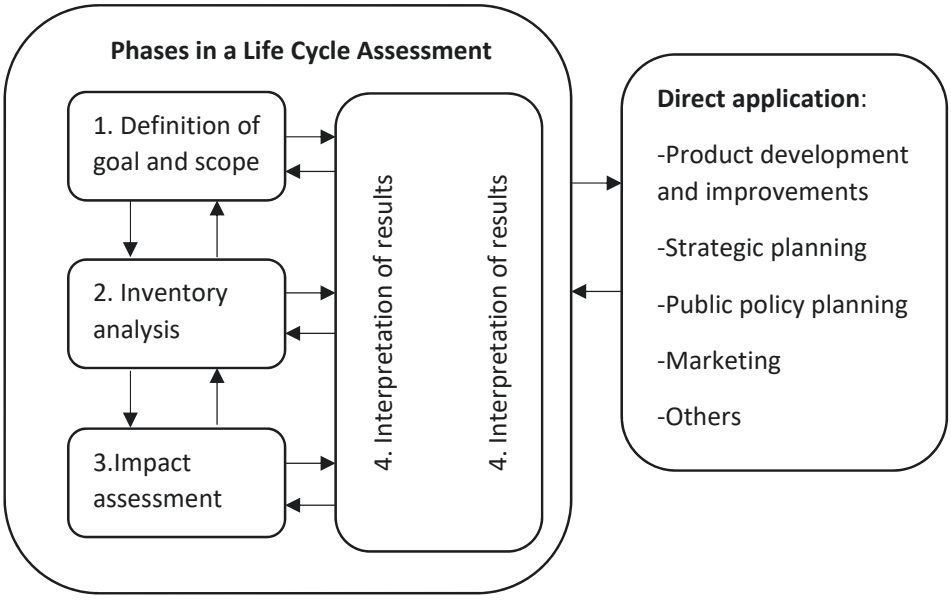
1. Definition of goal and scope: the step is the most important phase for LCA as the rest of the evaluation is based on the statement in this section. This phase consists of defining the purpose of the study, required data, system boundaries and the functional unit in the production system.

2. Inventory analysis: this second phase is about data collection. The data should include input data (energy, water, raw materials, etc.) and output (products, co-products and emission, etc.).

3. Impact assessment: this step is designed to evaluate the environmental impacts based on the findings from inventory analysis.

4. Interpretation: this final step is about conclusion and recommendation grounded in the inventory and the results of the impact assessment. The outcome of this phase could provide a comprehensive LCA.

Figure 4.3: Life Cycle Assessment Framework



Source: ISO, 2006

LCAs have been applied from the early 1960s to evaluate the natural resources required for various products. Some EWF nexus studies used LCA to show the linkages between sectors and to assess environmental impacts. Al-Anasari et al. (2015) built an integrated LCA to evaluate the environmental effects of the EWF value chain. Chang et al. (2016) used LCA to gain a better understanding of any water and food linkages with various kinds of energy production. Salmoral and Yan (2018) recognised LCA as the key tool for quantifying energy and water flows and used an available LCA database for a food product. Pacetti et al. (2015) used LCA and water footprinting to evaluate biogas in Italy.

Although LCA has been used in many recent nexus studies, the model has its limitations. LCA requires excessive data which is expensive and time-consuming. As the main focus of LCA is environmental impacts, the method has limitations in evaluating economic, technical and social issues.

4.2.5 System Dynamics (SD)

This approach involves the application of a set of conceptual and numerical methods to understand the structure and behaviour of complex systems over time, such as a socio-ecological system. System Dynamics was initially developed by Professor Jay Forrester from MIT in 1961.

He described the methodology as being based on three fundamental principles: feedback control theory, understanding the decision-making process and using computer-based technologies for developing simulated models.

The SD model presents cause-effect relationships, feedback loops, delays, physical/information links and decision rules that are thought to generate the system's behaviour (Wolstenholme, 1999). This representation is known as the system 'dynamic hypothesis', which is a description of reference mode behaviour and needs to be uniform with the model purpose (Albin, 1997).

Since the development of the SD approach, it has long been debated as it has been tied to three distinct views: as philosophy, paradigm or methodology. The epistemological and ontological stance of this approach is also a topic of debate, as either positivist or interpretivist (Lane & Oliva, 1998). The fundamental premise in SD is that dynamic Behaviour Over Time (BoT) is endogenously produced as a result of 'systemic structure' or the network of connections that tie system components together (El Sawah et al., 2012). Therefore, the key to understanding and managing complex systems is to understand this causal structure. As SD has a learning-oriented nature, it can have close relationships with similar concepts such as systems thinking, cognitive psychology and organisational learning. Another feature of the model is the significant contribution policy sciences, especially in environmental and natural resource management (Kelly et al., 2013).

The model has been applied in some recent nexus studies. Zhuang (2014) built an integrated SD model to investigate the interlinkages between human, ecological and social elements of the energy and water system over 100 years in the Tampa Bay Region of Florida. Helb (2015) applied a causal loop diagram (CLD) to system thinking among stakeholders to reveal dominant problems in the EWF nexus in Cyprus. A similar study was run by Pittock et al. (2016) for water and food nexus in the Mekong River Basin. The authors used CLD to understand the cross-sectoral relationship and identify points of intervention to reduce impacts and improve beneficial linkages.

Systems dynamics modelling is favoured as a quantitative method of beside its ability to model feedback, delays and non-linear effects, it brings several advantages to the modelling process. One of the main benefits of systems dynamics conceptual and analytical models is their useful learning tools which help enhance deeper system understanding and improve system thinking skills and knowledge integration for modellers and end users (El Sawah et al., 2012). For instance, the distinction between stocks and flows sharpens thinking about the process that drives the behaviour of the system. The focus on identifying and modelling feedback loops encourages thinking in terms of interdependent variables rather than linear and unidirectional links (Richmond, 1993). The SD method has become more widely accessible due to progress in the modelling software applications as well as the collection of literature on the approach. It is also

more versatile as the user does not require prior technical knowledge of the mathematical details of the models.

Some of the drawbacks of systems dynamics modelling relate to the relative simplicity of linking variables, resulting in the rapid growth of the models in both size and complexity. This may lead to developing elegant yet less useful models, which obscure the key structures that generate the dynamic behaviour and draw attention from the most influential leverage points (points in a system at which a minor change can result in a significant shift in the behaviour of the system). The simplification of the approach can be considered a disservice to users as the underlying principles. Also, the accuracy and validity of the model is compromised the more variables and processes are added without considering the underlying conditions, i.e. inclusion of uncertain or hypothesised feedback loops may create complex model behaviour that does not correspond to real-world behaviour, and as a result its validity may be difficult to verify (Kelly et al., 2013). The model is struggling with data availability and limitation in considering climate change in decision-making. SD, however, would be more preferential in cases where conceptual, rather than practical methodologies are more suited. In terms of quantifying future demand for major sectors and forecasting the implications and interaction of these sectors with the wider economy can be a challenging task, and provided that the approach is more qualitative in nature, a more quantitative approach would be preferred.

4.2.6 Econometric modelling

The term 'econometrics' was first put forward by Ragnar Frisch (1895-1973), one of the three principal founders of the Econometric Society and the first editor of the journal *Econometric*. The discipline is described as a unified study of economic models, mathematical statistics and economic data (Hansen, 2014). The econometrics field has different sub-divisions and specialisations. Applied econometrics is a term that describes the development of quantitative economic models and the application theory for the analysis of the economic phenomenon and forecasting the economic behaviour, such as demand, supply, production, investment and consumption.

The method is a standard quantitative approach for economic analysis that demonstrate the linkages between dependent variables and particular independent variables by statistical analysis of historical data. Once the linkages are determined, they can then be used for forecasting the effects on the dependent variables by considering changes in the independent variable. Econometrics aim to give empirical content to economic relations for testing economic theories, forecasting, decision making and for ex-post decision/policy evaluation. The set of potentially important variables to be tested in the model can be drawn from the appropriate theory, and the influence of these factors is evaluated statistically.

This model was used by Damerau et al. (2016) to evaluate the current pattern of water consumption and investigate the increase in resource usage in the absence of policy intervention and technological improvement. Ozturk (2015) applied a dynamic panel of modelling as one of the subdivisions of the econometric approach to evaluate the dynamic links among EWF and to find out if the current trend is sustainable.

Although econometric analysis has been predominantly used for forecasting long-term energy demand in response to changes in price and income (Bhattacharyya and Timilsina, 2010), the approach can be extended to other major sectors of the economy. In the last 50 years, the econometric approach has made major progress; the main aim is to understand the relationship between the sector in question (primarily energy) and other economic variables. There have been three major developments in econometrics since the 1970s: the trans-log revolution, panel data methodology and the discrete choice method (Griffin, 1993). Discrete choice modelling was found to be of limited econometric use due to lack of capital stock data as it relies on the stock and utilisation decision to determine overall demand. Irrespective of the developments made in econometric modelling, the approach has several shortcomings that can compromise the reliability of any analysis conducted based on the results. Some of these issues include non-stationary error process, the autocorrelation of explanatory variables, non-standard distribution of coefficient estimates and endogeneity problems.

The available literature on this method suggests that the general focus of the approach when used to formulate energy demand models was on the aggregated demand and little consideration was given to driver variables such as GDP and price; the approach fails to capture any technological changes or other non-price related policies (Bhattacharyya and Timilsina, 2010). Another limitation of this methodology is that prior knowledge or understanding of the sectoral interlinkages that need to be captured is required. For instance, to be able to determine the dependent variables and to formulate the equation that forms the basis of the relationships, a foresight into what the set of interlinkages maybe is needed. As a result, the results of the analysis will be narrow and depend on the input data, and the chances of overlooking the actual interlinkages can be high. Developing policy models based solely on econometrics as the core methodology would lead to less reliable feedback data and might fail in highlighting the interlinkages that exist between the different sectors of the economy.

4.2.7 Input-output analysis (IOA)

IOA is a widely applied analytical technique for identifying the interdependencies between various economic sectors and the economic system. The method of analysis was developed by Wassily W. Leontief (1905-1999) in the 1930s and has been widely applied to examine sectoral interactions and their implications on the economy as a whole. An input-output table is a matrix

that is used to depict inter-industry relations of an economy by showing how the output from one industry is input to other industries. The IOA table consists of three components of an economic system, which is shown in Figure 4.4:

- The inter-industry table shows that the flow of goods and services produced by one industry are used as input into the production of goods and services of another industry.
- Primary inputs are payments for primary factors of production. The payments include wages, salaries, rent gross operating surplice and taxes less subsidies.
- Final sectors comprise household consumption, public expenditure, investment and exports.

Figure 4.4: Basic structure of an IO table

Outputs to sector j / Inputs from sector i	Production sector (j)	Final sectors	Total output
Production sector (i)	Inter-industry table (xij) (intermediate demand)	(Yi) (final demand)	(Xi)
Primary inputs (k)	(vkj)		
Total input	(Xj)		

This format shows the dependencies between each of the industries in the economy, both as consumers of inputs and suppliers of outputs. While most uses of the IOA focus on the matrix set of inter-industry exchanges, the main focus of applying this approach is to capture the interactions at both the micro- and macro level. The discernible benefits of using this methodology, besides analysing the interdependencies, are the flexible nature of inclusions and exclusions in the IO table, and to produce quantifiable linkages between sectors of the economy. Thus far, the application of the general IOA has been confined to mostly energy consumption and total demand estimations. However, given that the underlying assumptions are considered, IO metric accounts can be developed to include other major sectors of the economy, such as the energy, agriculture/food, and water industries, to address the total demand of each of the sectors, and their economic, social and policy implications for a considered region.

The flexibility of this methodology in incorporating as many sectors as required makes it an attractive option. Technological advancements in computational modelling have also made it possible for the widespread application of IOA and the approach has proved to be a useful tool

for economic analysis at many geographic levels – local, regional, national and international. The data required for the IO model is built in most countries' statistical offices periodically and there are some databases, such as the Multi-Regional Input-Output table (MIRO) and the Global Trade Analysis Project (GTAP), available for this purpose. Another advantage of the IO framework is the detail it provides at a disaggregated level, which could break down further to the required level of detail. Also, the IO model is flexible as it allows long-term analysis.

The IO framework has been applied by many studies for empirical analysis of different types of nexus. For example, Daher & Mohtar (2015), White (2017), Bellezoni et al. (2018), Owen et al. (2018) and Xiao et al. (2019) employed this model to examine the direct and indirect interlinkages between energy, water and food for various economic sectors. Further, White (2017) and Bellezoni et al. (2018) used this method to investigate the environmental flows between sectors. The IO model has been applied not only for exploring interactions between resources, but also for scenario analysis. Bellezoni et al. (2018) applied the model for future scenario analysis to assess energy, water and land uses, GHG emissions and employment level in six different scenarios. Daher and Mohtar (2015) and Haie (2015) used the input-output methodology to identify strategies for the sustainable allocation of EWF resources.

The main limitation of this framework is that the input-output production function which traditionally characterised by Leontief's production function considers fixed proportions of factors with no elasticity of substitution between factors which does not let one input be substituted by another input. Therefore, IO analysis is not able to capture technological changes as part of the analysis. However, in reality, this coefficient could change due to innovations, changes in customer/supplier preferences and changes in policies (Rose, 1984). Such changes could have an effect on input prices, which in turn changes technology by changes in factor input. To overcome to this limitation, the input-output coefficient can be calculated endogenously rather than by assigning fixed parameter exogenously (flexible production function). This means Leontief's production function can be changed to another type of production function. Such an adjustment enables the IO framework to consider substitution in response to price changes in their analysis. This issue is discussed further in Chapter 5.

4.3 A summary of observations

The review of studies of the EWF nexus using different methods (see Section 4.2.1-7) demonstrates that each method has its strengths and weaknesses. These strengths and weaknesses are summarised in Table 4.2.

From Table 4.2, it can be observed that among the EWF nexus methods selected for review, IOA is the most suitable approach to satisfy the criteria outlined in Section 4.1. Some of the key points which support this selection are:

- In terms of spatial scope, this study requires analysis at a disaggregated level in the wider economy to provide a balance between technology and policy outcomes. Although most of the work presented in this model is at an aggregated level, the user can expand the model without compromising the integrity of the framework.

- In terms of temporal scope, this study covers the medium to long term. Among the methods discussed, the econometric methodology and input-output model are suitable for this purpose. However, econometric modelling is not appropriate for disaggregated levels of analysis. Therefore, the input-output model is the only suitable method for this purpose.

- An input-output model can capture the criteria of the dynamics by using flexible production function which allows the model to consider technological changes while balancing technology/policy outcomes.

- Studying the EWF nexus requires price assessments, particularly for analysing the impacts of the nexus. An input-output model with a flexible production function can satisfy these criteria as it allows the economic agents to make decisions based on price changes.

- In terms of data requirement, the input-output model is the most suitable framework as the data required can be obtained from national statistics offices and other publicly available databases, such as GTAP and MIRO.

Therefore, the input-output model with the flexible production function is nominated as a suitable framework for this research.

Table 4.2: Key features of selected methods for EWF

Methods / Criteria	**Cost-benefit analysis**	**CLEW model**	**Material Flow Analysis**	**Life Cycle Assessment**	**System Dynamic**	**Econometric modelling**	**Input-output analysis ***
Goal	Identify cost and benefits of activities & evaluate monetary impacts on society	Examine interlinkages between sectors and evaluate impacts of climate change & vice versa	Assess flow of materials and potential material substitution	Examine life cycle & environmental impacts of a sector	Assess the cause-effect relationships between sectors	Examine interactions between sectors and in wider economy	Examine interlinkages between sectors in wider economy and evaluate impacts of EWF- environmental and social policy
Spatial scope	Policy (X)	2 products, policy/technology (X)	1 product (X)	1 product (X)	sectors, policy (X)	sectors, policy (X)	sectors, technology/policy (✓)
Temporal scope	Long (✓)	Long (✓)	Short (X)	Short/Medium (X)	Short (X)	Long (✓)	Long (✓)
Dynamics	NO (X)	Yes (✓)	NO (X)	NO (X)	Yes (✓)	NO (X)	Yes (✓)
Price assessment	Yes (✓)	NO (X)	NO (X)	NO (X)	NO (X)	NO (X)	Yes (✓)
Data requirement	High (X)	High (X)	High (X)	High (X)	High (X)	High (X)	Low/Medium (✓)

Notes:

Symbols in the parentheses displays the compatibility with represented criteria in section 4.1.

(✓) presents compatible while (x) displays incompatible

* This research consider input-output analysis with flexible production function

4.4 Summary and conclusion

This chapter reviewed various studies and various methodologies used for the nexus of energy, water and food. This review investigated the strengths and weakness of the methodologies to select the most appropriate method for this research. The main findings of this chapter are:

- The methods that can be used for evaluating the EWF nexus can be categorised into two: qualitative and quantitative. The qualitative methods can capture specific dimensions of the nexus modelling approach, such as the social and political; however, these are not sufficient for the purposes of this research. The quantitative methods can be classified into seven categories: Cost-Benefit Analysis (CBA), the Climate, Land, Energy and Water (CLEW) model, Material Flow Analysis (MFA), Life Cycle Analysis (LCA), System Dynamics (SD), Econometric Modelling and Input-Output Analysis (IOA).

- CBA is not a suitable method for this research. The model cannot present sectors at disaggregated levels as its primary purpose is to identify cost and benefits of activities and to evaluate their monetary impacts on society. Nor does the method allow for technological changes. In addition, the model requires excessive data for price assessments.

- CLEW model provides an integrated method for assessing the linkages between sectors and allows scenario analysis. However, the model does not focus on the food sector explicitly. Also, the available scenarios are limited, and the user can not present variations in the scenarios. Data requirements is another major issue for the model, as it requires cost and detailed technological information.

- MFA is not an appropriate method for this research. The aim of the model is to assess the flow of materials and identify potential material substitution. The spatial and temporal features of the model are limited and it does not allow for technological changes and price assessment. Also, the model requires considerable collection of data.

- LCA is similar to the MFA method, and is similarly not suitable for this research. Although the model captures a longer span compared to MFA, the model focuses only on assessing the life of one product and evaluating the environmental impacts

of that product. The LCA model is static and does not capture the technological and price changes. Similar to MFA, the data requirements for LCA are significant.

- SD is not suitable for this method. The model concentrates on assessing the behaviour of sectors in closed loops. Although the model considers all the sectors, the system can be complex and challenging to complete the task. The model is limited in its scenario analysis and cannot capture technological and price changes. The model is data intensive and requires detailed information.

- Econometric modelling is not an appropriate method. The model can capture linkages at macro level but without considering technological changes. It is also limited in responding to price changes, and it requires excessive data to assess the interlinkages.

- The IO model with its flexible production function is a suitable model for this study. Further details of this model will be discussed in the next chapter.

Chapter 5: Development of integrated framework for this research

In Chapter 4, various methods for developing an integrated framework were reviewed. The input-output (IO) model with flexible production function was found to be the most appropriate framework for this study. A flexible IO model has the potential to capture the direct and indirect linkages between sectors at disaggregated levels in the wider economy while considering the technological changes. This flexibility enables the model to respond to changes in sectoral prices and allows analysis over the long term. Compare to the other methods in the previous chapter, the IO model was found to be less data intensive.

This chapter aims to describe the development of the methodological framework in detail. Section 5.1 presents a brief description of the integrated framework. A detailed description of the stages involved in every stage of this framework is provided in Sections 5.2 to 5.5. Section 5.6 discusses the sources of data required for this method. The last section, Section 5.7, summarises the main findings of this chapter.

5.1 Overall description of the integrated framework

This section presents the overall description of the integrated framework applied to technology/policy trade-offs in the use of resources for satisfying EWF demands. The framework is multidimensional in character to capture the various nexus dimensions discussed in Chapter 2. The following steps form the foundation of an integrated framework for this study: an historical study, a flexible IO modelling approach, a scenario analysis and an assessment of policy implementations. Figure 5.1 presents the steps for the integrated framework.

Figure 5.1: Integrated framework for security nexus of EWF

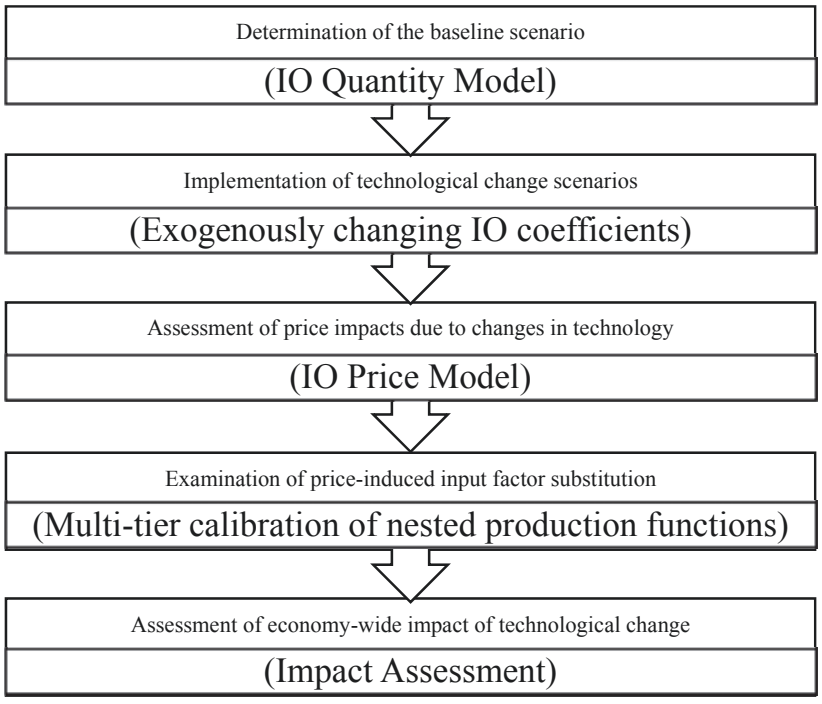
The following discussion briefly explains each method in this framework (detailed descriptions are provided in sections 5.2 to 5.5).

An **historical analysis** was undertaken in this research to achieve a better understanding of EWF security challenges in the MENA region. The historical analysis developed for this research was described in Chapter 3.

Flexible IO modelling is the core methodology applied in this research. This modelling approach was developed based on the discussion in Chapter 4. The modelling undertaken consists of five consecutive steps, as shown in Figure 5.2.

- The first stage of the model forms the core of the analysis in this research. Economic accounts were extracted from the GTAP9[14] database into a form of IO table in monetary units. 'Satellite' accounts of energy, water and employment[15] were created here and a detailed explanation and mathematical discussion of the first module is presented in Section 5.3.1.

Figure 5.2: Overall modelling procedure



[14] GTAP: Global Trade Analysis Project
[15] In this research, the environmental dimension of the EWF nexus is not included as the data is not available for all the selected countries.

- The second stage of the model is the implementation of technological change scenarios. In this stage, a model assesses how a shock (or change in technology) in one sector can affect the rest of the economy. To reflect any technological changes, the IO technical coefficients are adjusted exogenously based on the literature review, historical trends and the scenario focus. A detailed description of the second step is given in Section 5.3.2.

- In the third stage, price impacts due to technological changes are assessed. As a result of technological changes in the input-mix of different production sectors, the price of sectoral output would change. These sectoral price effects of EWF-related measures are estimated using an IO price model. The detailed mathematical description of these price impacts is presented in Section 5.3.3.

- The fourth stage focuses on the substitutional effect as a result of a change in sectoral prices in the previous (third) stage. Substitutional elasticities are employed for this purpose. These elasticities are estimated based on the one typically used in general equilibrium models, which assumes a nested structure for IO coefficients. The technical IO coefficients are then modified based on these elasticities to present a new economic structure. The details of this module with the mathematical substitution specification and the estimated parameters are discussed in Section 5.3.4.

- The fifth and final stage describes the macro-economic impacts of technological changes. The new economic structure derived from the fourth stage is then compared with the structure developed in the first step. The difference between the two economic structures shows the economic impact of technological change. The new economic structure impacts will consist of the EWF securities, economic and social impacts. A description of the mathematical requirements for this section is provided in Section 5.3.5. The results of this stage, which is the economy-wide impact resulting from technology/policy trade-offs in the use of resources, are shown and explained in detail in Chapters 6 and 7.

A **scenario analysis** approach was adopted for this research to determine the technology/policy trade-offs in the resources used to meet EWF demand. The scenarios explore the outcomes of alternative technological and economic developments in the future. This study developed five scenarios and analysed the impact of these scenarios economy-wide, including on EWF security from 2015 to 2050. This examination is based on the IO model with flexible production function forms. The attributes of the scenario impacts are discussed in detail in section 5.4.

The policy perspective of the EWF security nexus in MENA reflects the process of examining the outcomes from all applied scenarios and provide a complete policy perspective. It is particularly effective in determining the trade-offs that may occur in the various scenarios among policies with different and sometimes conflicting objectives. The assessment and implications of these policies are discussed in Chapter 8.

5.2 Historical analysis

The first part of the model aims to assess the security challenges of the EWF nexus in the MENA region. For this purpose, applying historical analysis can assist in gaining a deeper understanding of how the nexus has been developed in the past. In this research, Chapter 3 provides an historical time profile for the nexus in MENA by focusing on various dimensions, such as the economic, environmental, technological, social and political. This historical analysis considers three periods:

- The first period (1950-1970) includes decolonisation, socio-economic improvement and state-building process in countries in the region

- The second period covers the 1980s, when countries started structural adjustment, Islamism became widespread and population growth in the region accelerated

- The third period is after 1990 and covers the transition towards advanced developments, rights for women, a higher level of education and such conflicts in the region as the Gulf War, the Arab Spring and the Syrian civil war (Yüceşahin & Tulga, 2017).

Each time frame shows substantial improvement in the development of economic structure and change in the demographics of the region that have impacted the availability of resources. Various dimensions of the nexus will be analysed based on these time frames.

5.3 Flexible IO modelling

The second objective aims to explore the interlinkages between EWF with different economic sectors at disaggregated levels in selected countries. An overview of the IO model developed for the analysis undertaken in this research is shown in Figure 5.3.

In this model, the technology structure of a particular sector is presented in the Intermediate Demand column; this comprises technical coefficients (A), import coefficients (D) and primary factors coefficients (F). The technical coefficients (A) represent the proportion of inputs required from other domestic sectors for each unit of production of a particular sector. The import coefficients (D) describe the proportion of inputs from sectors located in a foreign country per

unit of production of a sector. The primary factor coefficients (F) describe the unit production costs of a particular sector, in terms of the payment for the primary factors of production (or value-added) and taxes.

The Final Demand column in this model consists of exports, investment, household consumption and government expenditure. The first category (i.e., exports) shows the share of a domestically-produced commodity that is exported (export coefficient B). Each of the last three demand categories describes the share of the commodity in meeting domestic final demand. Final demand is considered to be sourced from domestic production (final-use coefficient C) and imports (import coefficient E).

This model thus captures the national accounts at both aggregated (such as GDP) and disaggregated (such as industry value-added) levels. It also captures the trade dependencies (i.e., export and import) linkages captured in matrices B, D and E. It therefore constitutes an extremely useful analytical framework for examining the economy-wide impact of sectoral policies and strategies aimed at redressing the EWF security challenge.

Figure 5.3: Overview of an Input-Output model

Country			Intermediate Demand				Final Demand			
			Food	Energy	Water	Other	Export	Investment	Household consumption	Government expenditure
Sectors/Commodities	Domestic	Food	A				B	C		
		Energy								
		Water								
		Other								
	Imports	Food	D					E		
		Energy								
		Water								
		Other								
Primary Factors			F							

The analysis consisted of five steps, as discussed in section 5.3 above (Figure 5.2). In the following sections (5.3.1 to 5.3.5), the steps are described in detail.

5.3.1 Determination of the baseline scenario

This section describes in detail the methodology applied to develop the base-year IO table and various 'satellite' accounts (energy, water and employment) to correspond with the sectoral classification in the IO table. The baseline scenario is defined in this research as one where there is no technological change. This scenario was developed specifically to demonstrate how technological change will be implemented in the second stage of the model (Figure 5.2).

The baseline scenario was developed using the standard IO model displayed in Figure 5.3 The base IO can be transformed into IO coefficient matrices that creates the foundation of the model for this study. The IO table applied in this research was adapted from the GTAP 9 database (Aguiar, Narayanan & McDougall, 2016).

Extracted IO and associated 'satellite' account tables from the different databases were rebased to the year 2015 by using information published by various sources (refer to Section 5.6). The steps applied for rebasing the IO table and 'satellite' accounts are explained in the following section.

Rebasing the IO and associated 'satellite' account tables

Figure 5.4 is an overview of the IO coefficients table applied to rebase the IO model. In this coefficients structure, the technology structure of a particular sector is presented in the Intermediate Demand column, which comprises technical coefficients (a_{ij}), import coefficients (c_{mj}) and primary factors coefficients (c_{vj}). The final demand in this model is considered as final use coefficients (b_{ik}) and import coefficients (d_{mk}).

Figure 5.4: IO coefficients table

IO table ($Bn)	Intermediate Demand	Final Demand	Total Output
Domestic Production Sectors	a_{ij} [A]	b_{ik} [B]	X_i
Import sectors	c_{mj} [C]	d_{mk} [D]	M_m
Primary Factors	c_{vj}	d_{vk}	V_v
	X_j	F_k	

Assuming the Leontief fixed-proportion production function, the inputs to a particular intermediate sector can be expressed by the linear relations:

$$z_{ij} = a_{ij} \cdot X_j;\ m_{mj} = c_{mj} \cdot X_j \ \text{ and } \ v_{vj} = c_{vj} \cdot X_j \quad (1)$$

where

z_{ij}: output of sector i used by sector j,
m_{mj}: import from foreign sector m used by domestic sector j,
v_{vj}: factor v used by sector j, and
X_j: total output of sector j.

Similarly, the sources of final demand can be determined by the linear relations:

$$f_{ik} = b_{ik} \cdot F_k;\ m_{mk} = d_{mk} \cdot F_k \ \text{ and } \ v_{vk} = d_{vk} \cdot F_k \quad (2)$$

where

f_{ik}: output of sector i used by final demand k,
m_{mk}: import from foreign sector m used by final demand k,
v_{vk}: factor v paid by final demand k, and
F_k: total final demand k.

The relationship in both Equations (1) and (2) captures the national accounts at both aggregate and disaggregate levels. For example, GDP can be determined either from an income approach (i.e., $\sum V_v$) or an expenditure approach (i.e., $\sum F_k$ - $\sum M_m$), while the sectoral output can be determined from X_i.

Further, Equations (1) and (2) form the basis of determining the baseline scenario in our model. The information from the IO table in the base year (s) is used to develop the forecast of the IO table for the future year (t). To do this, there is a need to assume future macroeconomic conditions, particularly economic growth and contributions to this growth by various final demand categories (i.e., F_k^t).

The starting point is to calculate total final demand for year (t) for each row of the IO table. This includes total final demand that would be fulfilled from domestic production sectors (F_i^t), total final demand that would be fulfilled from import sectors (F_m^t) and total tax paid by final demand sectors (F_v^t), which can be determined from Equations (3) and (4).

$$F_i^t = B^s \cdot F'^t_k \quad (3)$$

$$F_{m+v}^t = D^s \cdot F'^t_k \quad (4)$$

where B and D are the coefficients matrices for the base year (s).

The outcomes from Equations (3) and (4) are then used to estimate total sectoral output (X_i), total imports (M_m) and total factors of production, including taxes (V_v) for the year (t), by using the following IO identity.

$$X_i^t = \left(I - A^s\right)^{-1} \cdot F_i^t \tag{5}$$

$$M_m^t + V_v^t = \left[C^s \cdot \left(I - A^s\right)^{-1} \cdot B^s + D^s\right] \cdot F''^t_k \tag{6}$$

Finally, the individual components in the IO table (including z_{ij}, m_{mj}, v_{vj}, f_{ik}, m_{mk} and v_{vk}) can be estimated using the linear relationship similar to Equation (7).

$$z_{ij}^t = a_{ij}^s \cdot X_j^t \tag{7}$$

where $X_j = X'_i$.

In addition to the economic account (as above), following Sandu (2007), the 'satellite' accounts such as energy, water flow in each sector of the economy and employment are also developed to correspond with the sectoral classification in this research. These satellite accounts allow an estimation to be made of energy consumed, water consumed, emissions and employment through the inter-sectoral relationships in the economy, without making any adjustments to the IO table, thereby avoiding the need for any arbitrary price assumptions (Proops, Faber & Wagenhals, 1993). Figure 5.5 presents the 'satellite' accounts structure applied in this research. The mathematical formulation shown below is for the estimation of energy demand in the economy. A similar principle was also applied to develop the estimates of other satellite accounts.

Figure 5.5: 'satellite' accounts table

'Satellite' Accounts	Intermediate Demand	Final Demand
Domestic Production Sectors		
Import Sectors		

To begin with, let E_{fi} be the energy of type *f* consumed by production sector *i*. From above, the total output (X_i) of the production sector *i* goes to satisfy intermediate and final demands. Therefore, the energy intensity of sector *i* - denoted by e_{fi} - can be expressed as:

$$e_{fj} = \frac{E_{fj}}{X_j} \tag{8}$$

This expression can be written in matrix notation as:

$$e = E.X^{-1} \tag{9}$$

where

e: matrix of energy intensities (e.g., toe per $) and
E: matrix of total energy use (toe).

From Equation 9, the energy requirements for the production sectors can be represented as:

$$E = e.X \tag{10}$$

By substituting total output (*X*) from Equation 5 into Equation 10, the sectoral energy requirement for year (t) can be estimated by:

$$E_{fi}^{t} = e_{fi}^{s}\left(I - A^{s}\right)^{-1} \cdot F_{i}^{t} \tag{11}$$

The term $e.[I - A]^{-1}$ in Equation 11 also represents the sectoral energy intensities for the baseline scenario.

Similar to the emission of energy demand, water demand can be determined by applying the following equation:

$$W_{fi}^{t} = w.X = w_{fi}^{s}\left(I - A^{s}\right)^{-1} \cdot F_{i}^{t} \tag{12}$$

where

w: matrix of water intensities (m^3 per $) and
W: matrix of total water demand (bn m^3).

Further, a similar extension is also used for estimating sectoral employment. As with energy and water intensities, labour intensity (or labour-output ratio) can be defined as the amount of labour required to produce one unit of economic output. This is represented as:

$$l = L.X^{-1} \tag{13}$$

where

l: matrix representing people employed per unit of output in each sector (persons per $) and
L: vector representing the level of employment (persons).

From Equation 13, the employment for each production sector is determined by:

$$L_{fi}^{t} = l.X = l_{fi}^{s}\left(I - A^{s}\right)^{-1} \cdot F_{i}^{t} \tag{14}$$

Once the base year economic, employment, energy and water data are formulated, the assumptions regarding future economic growth and other variables can then be applied to develop the projections of the annual IO tables for the BAU scenario up to the year 2050.

The model provides a high level of commodity/sectoral disaggregation, especially for the EWF sectors. Such a disaggregation of the IO table enables detailed analyses to be made at the technological and sectoral levels. These analyses include, for example, the assessment of the impact that a policy targeted at one sector is likely to have on the wider economy through the underlying sectoral interdependencies. Moreover, the trade linkages in these databases enable an assessment to be made of the trade implications for a country of strategies to redress the security challenge in the country and other countries in the region.

5.3.2 Implementation of alternative scenarios

The second stage is how to change (such as a change in technology) in one sector can impact the rest of the economy. In each column, as shown in Figure 5.4, the IO coefficients describe the intensity of inputs (both intermediate and primary) used in a production process. This information is useful for designing future technology scenarios. Hence, in the alternative scenarios (refer to Section 5.4), the IO technical coefficients of columns representing specific technologies are exogenously adjusted. These adjustments are based on the literature review, historical trends and the scenario focus. The remaining coefficients in each column of the IO coefficients table are normalised so that the summation of each column is equal to one.

For example, a switch from one type of power plant technology to more efficient power plants requires adjustment in technical coefficients. The column representing electricity supply in the IO coefficients table shows the shares of electricity produced by various technologies. In this column, the technical coefficients of the previous technology are reduced while those of a later technology are increased in the same proportion.

This adjustment in technical coefficients has long been suggested and used to examine the impact of changes in energy technologies in an IO framework (Fontela & Rueda-Cantuche, 2005; Gowdy & Miller, 1991; Just, 1974; Wilting, Faber & Idenburg, 2004). CGE modellers also apply the

same principle in introducing technology shock into their models (Fatai et al., 2004; Nasseri & Konan, 2012). The degree of adjustment in the technical coefficients is based on the scenario assumptions. These assumptions and the values of each scenario driver used to adjust the technical coefficients are explored more in detail in Section 5.4.

5.3.3 Assessment of price impacts due to changes in policy

In this stage, the change in the input-mix of various production sectors as a result of technological change is estimated. The introduction of new policies would change the price of sectoral outputs. The sectoral price effects of EWF-related measures are evaluated by applying the standard Leontief IO price model. This model can be used to "assess the impact on prices throughout the economy of an increase in the price of one or more sectors" (Kula, 1996; Miller & Blair, 1985).

The changes in sectoral prices can be determined from Equation 15 (Sharma et al., 2019):

$$P_i = \left[I - A^{'} \right]^{-1} \cdot C_j^{'} \tag{15}$$

where Cj is the sum of factors of production and imports for each sector (j).

To assess the price impact, first, the base year price level needs to be evaluated. In this method, applying Equation 15 with base year IO coefficients will make a vector of base year prices for all sectors equal to one as a result of the normalisation of prices. As the base IO data includes only value (price x quantity) flows, the method translates value data into price and quantity data by normalising the initial (base) prices in the model into 1. The coefficients for each column in the IO model are thus interpreted as the quantity of input per $1 of produced output, instead of the value of input. This is the same method that is typically applied in CGE models as it significantly moderates the required information to develop a model database, without losing the capability of the model to generate meaningful results (Burfisher, 2017).

Next, the new sectoral prices in year (t) are determined based on new technical coefficients, which are updated exogenously in the previous stage, as shown in Equation 16.

$$P^t = \left[I - A^{'t} \right]^{-1} \cdot C_j^{'t} \tag{16}$$

where

P^t: vector of new sectoral price levels
A^t: matrix of IO technical coefficients, adjusted for new energy technology
C^t: matrix of primary factor (and import) coefficients for year (t).

This would provide the index of changes in sectoral prices while compared to the base year prices:

$$\frac{P'}{P} = \frac{P_t - P_s}{P_s} \quad (17).$$

5.3.4 Examination of price-induced input factor substitution

The changes in sectoral prices, as described in the previous stage, based on the microeconomic theory, will induce substitution between one another or other factor inputs, such as labour and capital. The traditional IO model assumes perfect complementarity between factor inputs through the use of the Leontief fixed-proportion production function, thus ignoring substitution possibilities. However, in reality, these coefficients are likely to change due to innovation, change in consumer/producer behaviour and changes in policies (Rose 1984). Such changes could impact on the price of inputs and cause a change in technology by applying changes in factor inputs. These substitution possibilities could be considered by introducing flexible neo-classical production functions in the standard IO model. The substitution possibilities are presented in terms of elasticities of substitution, which can then be used to modify IO coefficients (Rose 1984).

The procedure for introducing the flexible production function in this research is similar to that typically employed in computable general equilibrium (CGE) models. Several studies have employed CGE models to estimate the impacts arising from trade integration and the role of agricultural policy for MENA (Calzadilla, Rehdanz & Tol, 2008; Dessus & Ghaleb , 2006; Minot et al., 2010; Rutten & Kavallari, 2013; Thissen, 1998). In this part of the model, the behaviour of producer and consumer are presented in the form of a nested structure. The focus of this structure from the producer side of the economy is the input pattern usage and in terms of the demand side of the economy, the nested structure considers the consumption pattern. Also, the relationships in the nested structure show the behavioural equations of functional forms.

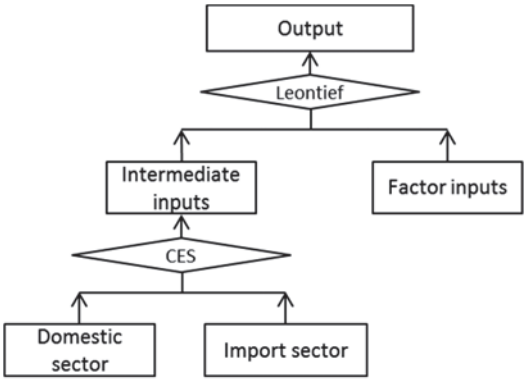
The procedure for applying the flexible production function in this research consists of the following steps:

- it assumes a nested structure for IO coefficients
- it assumes a particular production functional form, mainly Leontief and constant elasticity of substitution (CES)
- it assumes the values for elasticity of substitution (based on the literature review and, if sufficient data are available, these elasticities can be estimated)
- finally, it calculates each tier in the nested structure to obtain the values for an updated IO table.

The substitution possibilities between various input factors are considered for both the demand-side and supply-side analyses for each country included in this research. However, before describing the nested structure for different input factors, the discussion below can assist in

understanding how elasticities of substitution modify IO coefficients. Assume the simplified nested structure (Figure 5.6) with two nests (or tiers). The first tier shows that a final output of a particular sector is produced according to a nested Leontief function, using intermediate and factor inputs. The second tier employs the intermediate inputs from domestic and import sectors, according to a nested CES function.

Figure 5.6: Typical nested structure of IO coefficients



The study assumes a cost minimisation behaviour for the system. In the first tier in Figure 5.6, a Leontief production function (zero elasticity of substitution) represents final output (X_j) as:

$$X_j = \min\left[\frac{h_{ij}}{\alpha_{ij}}, \frac{v_{vj}}{c_{vj}}\right] \tag{18}$$

where

h: intermediate inputs, which include inputs from domestic sector (z_{ij}) and import sector (m_{mj}) and

α: coefficients for intermediate inputs, which comprises of a_{ij} and c_{mj}.

Since the elasticity of substitution in this function is zero, changes in price will not have any effect on the choice of inputs used. Thus, the amount of intermediate inputs can be determined from the formula, which is similar to Equation 7:

$$\begin{aligned} h_{ij} &= \alpha_{ij} \cdot X_j \\ v_{vj} &= c_{vj} \cdot X_j \end{aligned} \tag{19}.$$

In the second tier, intermediate inputs are provided by flexible domestically produced and importable inputs through a CES production nest as:

$$h_j = \left[a_{ij}^{Leontief} \cdot z_{ij}^{\frac{\sigma-1}{\sigma}} + c_{mj}^{Leontief} \cdot m_{mj}^{\frac{\sigma-1}{\sigma}} \right]^{\frac{\sigma}{\sigma-1}} \quad (20)$$

where σ is the elasticity of substitution between zij and mmj.

Equation 20 can also be shown as an input demand function:

$$z_{ij} = 1^{\sigma-1} \cdot a_{ij}^{Leontief} \cdot \left(\frac{p_j}{p_{ij}} \right)^{\sigma} \cdot h_j$$
$$m_{mj} = 1^{\sigma-1} \cdot c_{mj}^{Leontief} \cdot \left(\frac{p_j}{p_{mj}} \right)^{\sigma} \cdot h_j \quad (21)$$

where

h_j: total intermediate inputs used in sector j;
p_j: unit costs of total intermediate inputs used in sector j and
p_{ij}: unit costs of domestically produced intermediate inputs i used in sector j and
p_{ij}: unit costs of importable intermediate inputs m used in sector j.

Using Equation 21 instead of Equation 20 thus allows us to capture substitution possibilities within the IO framework. Equations 19 and 21 are used (depending on what type of production function is assumed within the nested structure) to update the IO table for the future year that resulted from technological change (changes in IO coefficient in stage 2). This equation is derived from a CES input demand function. In this way, the substitution possibilities can be accounted for within the IO framework. The nesting structure of the IO coefficients assumed in this research is, in fact, more complicated than in Figure 5.6, which is described in the next section.

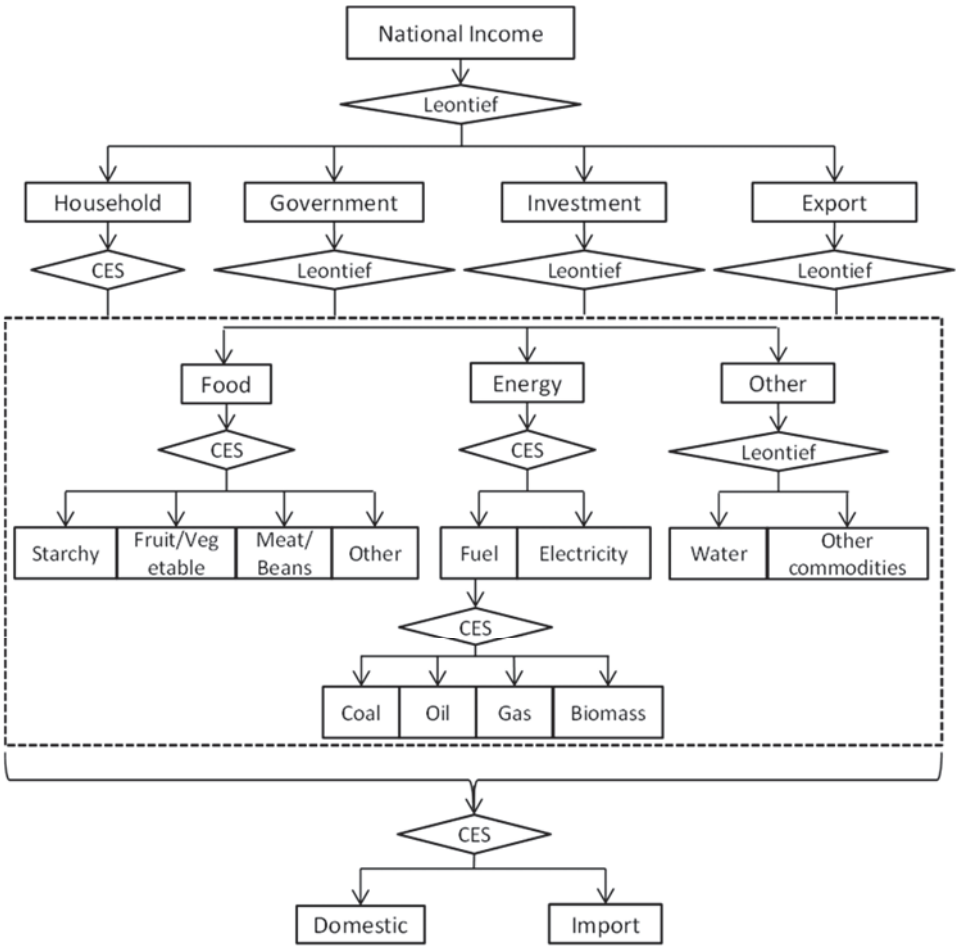
5.3.4.1 Applied nested structures for demand-side analysis

The analysis for the demand-side, presented in Figure 5.7, focuses on final demand, or the consumption end, of society, which includes four groups of consumers, namely, household, government, investment and export sectors. These sectors jointly maximise national welfare through their optimally selected combinations of consumer products – energy, food and others. These consumer products further diverge into higher levels of user-specified sub-categories, which usually end at the selected combination of domestically acquired and imported products. For example, energy products consumed by the household sector are further divided into electricity and fuel(s). Fuels are then broken up into coal, oil, gas and combustible renewables. The first three are fossil fuels, which can be supplied from both within and outside the country,

whereas local suppliers provide the last. The household sector consumes these energy products together with an optimally chosen bundle of food and other products. A similar approach of categorisation is applied to the other three final demand categories, government, investment and exports.

The demand-side analysis concentrates on the national level for sectoral consumption activities where an aggregated view is more favourable than a detailed one. Therefore, the top tiers of consumer products, that is, food, energy and others, are assumed to be non-substitutable. Hence, the Leontief production function will be characterised the choice of consumer group for product-mix at this level (except for households). As the branches of the activity tree break down more into subcategories, further detailed assessment is needed on the impact of the technology decision. Therefore, the selection of the same-level product mix takes into account substitution possibilities that are characterised by the CES production function.

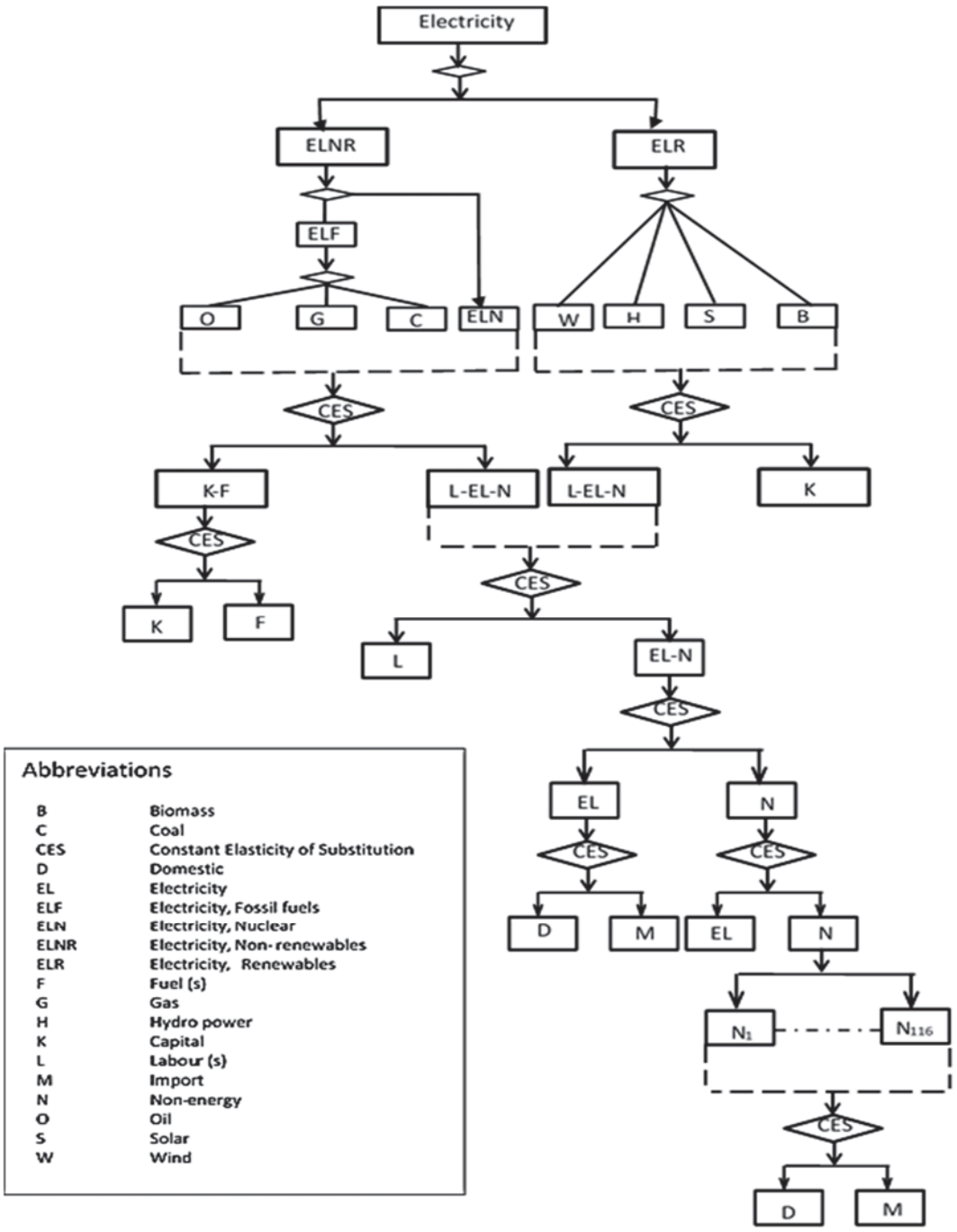
Figure 5.7: Nested structure of demand-side analysis



5.3.4.2 Applied nested structures for supply-side analysis

The supply-side analyses presented in Figures 5.8 to 5.10 focus on the production end of society, where producers opt for optimal technology bundles to produce food, energy and other products to meet the final demand from the consumption end. In this model, the producers' input structures are classified into three broad categories, namely, electricity, food and other.

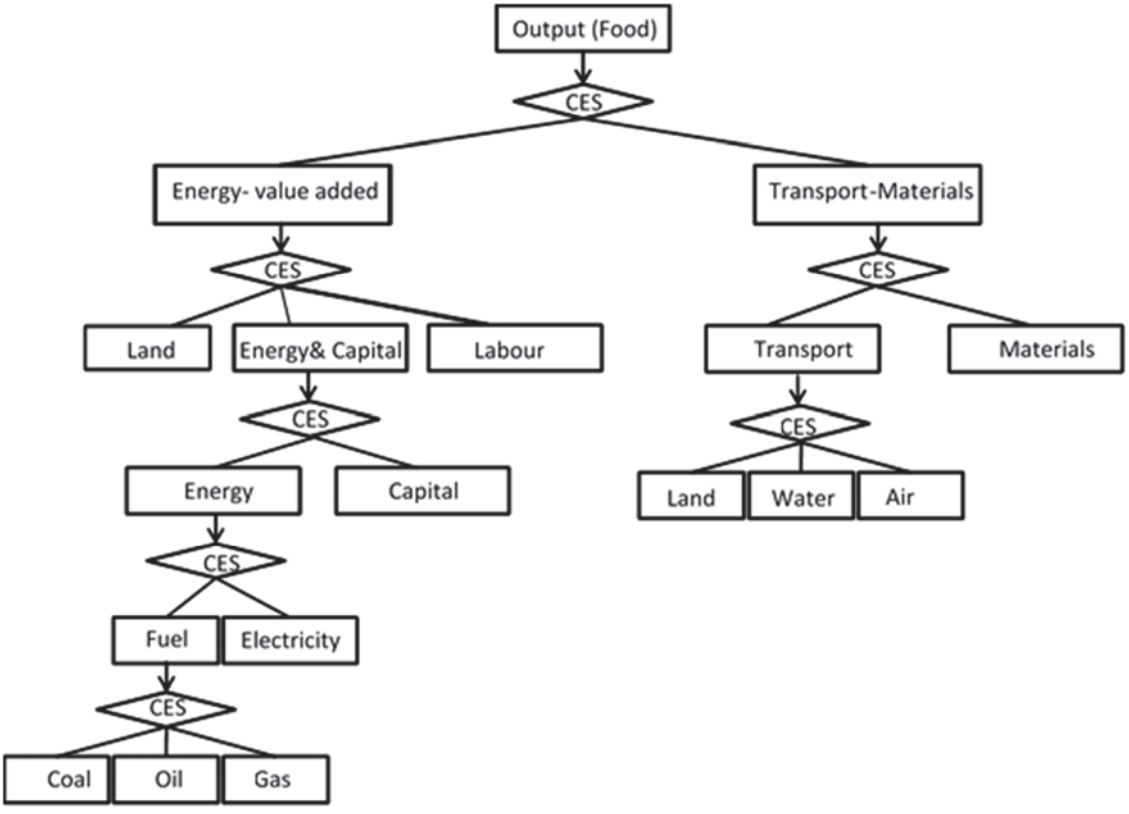
Figure 5.8: Nested structure for electricity generation sector



The electricity sector employs coal, oil, gas and renewable energy to produce electricity using various electricity generation technologies. This study applied Timilsina and Shrestha (2006) guidance which characterised each generating technology with a CES combination of factor input mixes. The nested structure for electricity generation in this thesis is based on 1) the capital-fuel mix and 2) the labour/electricity/non-energy input mix. In both mixes, each input is further broken up into a CES combination of relevant sub-categories (Timilsina & Shrestha, 2006). Non-energy inputs are assumed to be non-substitutable. Therefore, the choice of these non-energy input mixes used for each technology is characterised by a Leontief production function.

The food production sector is similarly characterised as a CES combination of factor input mixes: 1) land/energy/capital/labour and 2) transport/materials (Figure 5.9) (Timilsina, 2011). For both mixes, each input is further broken up into a CES combination of relevant sub-categories. Material inputs are assumed to be non-substitutable. Therefore, the choice of these material input mixes is characterised by a Leontief production function.

Figure 5.9: Nested structure for food production sector



For other production sectors, the factor inputs are grouped into two CES bundles: 1) the capital/labour/energy bundle and 2) the non-energy (materials) bundle (See Figure 5.10) (IER, 2016). In the first bundle, the energy inputs are broken up into electricity and fuel inputs. The fuel

inputs are further divided into coal, oil and gas. The segregation tree of capital and labour have the same characteristics as those in the electricity and food sectors, as discussed above. In the second bundle, non-energy inputs are assumed to be non-substitutable; hence the choice of a non-energy input mix is characterised by a Leontief production function.

Figure 5.10: Nested structure for other production sectors

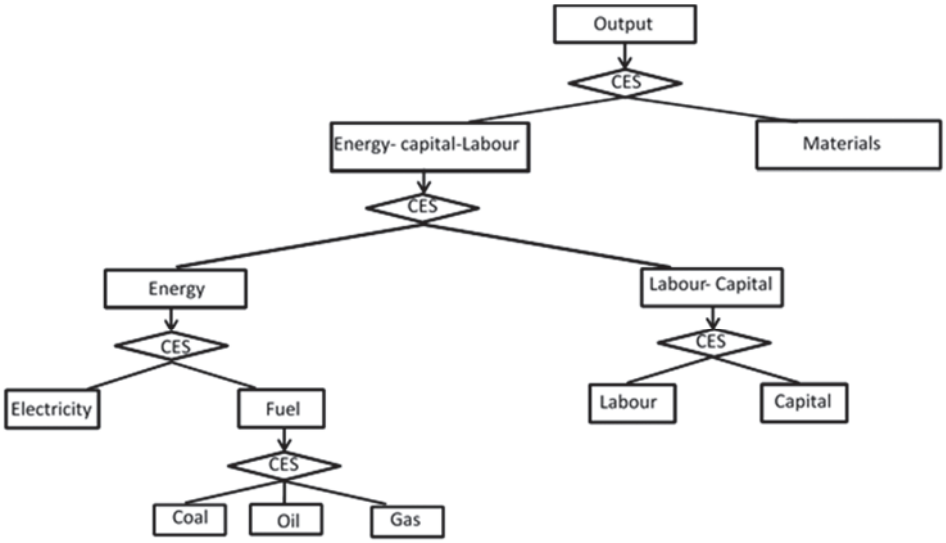


Table 5.1 and Table 5.2 list the assumed values for CES in this research. These values are based on the study by Timilsina and Shrestha (2006) and the value for technology parameters used the GTAP database. Elasticity values between domestic and import for each sector are presented in Appendix A, Table11.

Table 5.1: Assumed values for CES in nested structure

Sector	Elasticity Values								
	$\sigma^{M-K,L,E}$	$\sigma^{K,L-E}$	σ^{K-L}	σ^{F-EL}	$\sigma^{N\&R,L,K,E}$	$\sigma^{R\&K,E\&L}$	$\sigma^{E\&K}$	$\sigma^{F\&F}$	$\sigma^{N\&N}$
Agriculture	0.30	0.40	0.60	0.60	0.30	0.23	0.25	2.00	1.00
Food	0.30	0.40	0.60	0.60	-	-	-	2.00	1.00
Non-Food Agriculture Products	0.30	0.40	0.60	0.60	0.30	0.23	0.25	2.00	1.00
Light Manufacturing	0.30	0.40	0.60	0.60	-	-	-	0.80	1.00
Wood	0.30	0.40	0.60	0.60	-	-	-	2.00	1.00
Heavy Manufacturing	0.30	0.40	0.60	0.25	-	-	-	0.80	1.00
coal	0.20	0.40	0.60	0.50	-	-	-	0.80	1.00
oil	0.20	0.40	0.60	0.50	-	-	-	0.80	1.00
Gas	0.20	0.40	0.50	0.10	-	-	-	0.10	1.00
Gas Distribution	0.20	0.40	0.50	0.10	-	-	-	0.10	1.00
Uranium	0.20	0.40	0.60	0.50	-	-	-	0.10	1.00
Water	0.30	0.25	0.60	0.25	-	-	-	2.00	1.00
Intensive Commercial Services	0.30	0.25	0.60	0.25	-	-	-	2.00	1.00
Private Consumption	-	0.50	-	0.20	-	-	-	1.00	1.00

Table 5.2: Assumed values for CES in nested structure for electricity sector

Electricity Sector	Elasticity Values					
	$\sigma^{K,F\&L,EL,N}$	σ^{K-F}	$\sigma^{L-EL,N}$	$\sigma^{EL\&N}$	$\sigma^{F\&F}$	$\sigma^{N\&N}$
Transmission & Distribution	0.30	-	0.20	0.01	-	1.00
Nuclear Power	0.30	-	0.20	0.01	-	1.00
Coal power	0.30	-	0.20	0.01	0.80	1.00
GasPower	0.30	0.60	0.20	0.01	0.80	1.00
OilPower	0.30	0.30	0.20	0.01	0.80	1.00
HydroPower	0.30	-	0.20	0.01	-	1.00
Wind power	0.30	-	0.20	0.01	-	1.00
Solar power	0.30	-	0.20	0.01	-	1.00
OtheRnewabl	0.30	-	0.20	0.01	-	1.00

Note : K-Capital; L-Labour; E- Energy; El- Electricity; N-Materials; F-Fuel; L-Land

Source: (Timilsina & Shrestha, 2006)

5.3.5 Assessment of economy-wide impacts of technological change

The macro-economic impacts of technological change are analysed in the final stage. These impacts include, for example, energy demand, water demand, economic growth and employment. In particular, the new IO structure (as developed in the previous stage using Equations (19) and (21), as well as changes in sectoral prices across alternative scenarios, would lead to variations in gross state products, employment, energy consumption and water consumption. Therefore, these results are compared with those developed in the first stage for the baseline scenario (BAU), using Equation 7. The difference thus shows an economic impact of technological change.

Further, similar to the first stage, the updated IO table in the fourth stage is used as a basis to develop other 'satellite' accounts, including energy, water and employment. Again, the difference between these results with the one estimated in the first stage (baseline scenario) shows impacts on energy, water and employment.

5.4 Scenario analysis using the IO model

This research applies the IO model with flexible, functional forms to assess various scenarios between 2015 and 2050. The main advantage of using the IO model for scenario analysis is that no inbuilt economic assumption (such as profit maximisation) is considered in the model that could impact the scenario outcomes. Instead, the framework accommodates other drivers, such as social, economic, consumption and policy-making activities (Marsh, 2008).

The aim of scenario analysis in this research is to demonstrate technology/policy trade-offs in the use of resources to satisfy EWF demands. The scenarios represent possible futures that reflect different economic and technological developmental pathways. This study developed five different scenarios and assessed their economy-wide impacts (including on EWF security) over the period from 2015 to 2050. In the scenarios presented, the reality of the markets (resource constraints) was considered for each country. These resource constraints are presented in the

scenario variables (such as in Table 5.4), which were estimated based on resource availability in the selected MENA countries. For example, if hydropower technology is not considered in some countries (such as Kuwait, Qatar, Saudi Arabia and Oman), it means this technology will not have a significant role in the modelling of the electricity mix of these countries.

Section 5.4 is divided into three sections. First, Section 5.4.1 explains the indicators used in this research to assess the impact of various scenarios. Second, the description and key features of the analysed scenarios are presented in Section 5.4.2, including their underlying assumptions. Finally, the assumptions of the key scenario variables are discussed in Section 5.4.3.

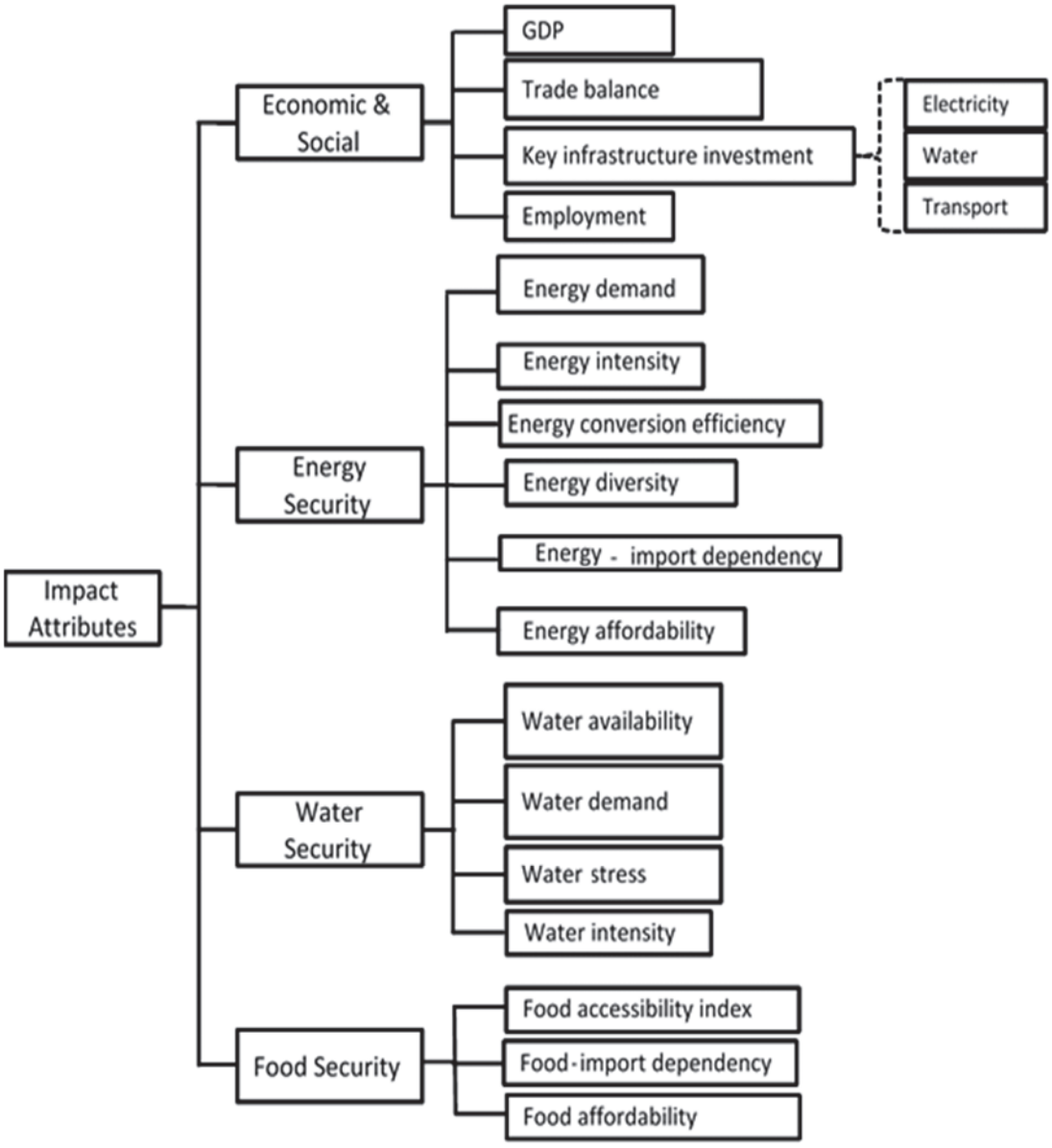
5.4.1 Attributes for assessing scenario impacts

This section determines which attributes needed to be considered when assessing the scenario impacts in this research, all of which are presented in Figure 5.11. The selected attributes capture the various dimensions, including economic, social, environmental and political associated with EWF security, which were discussed in Chapter 2.

The economic and social attributes employed in this research are GDP, trade (export-import) balance, investment in key infrastructure (electricity, water and transport) and employment. Quantitative estimates of these attributes were developed from information and data obtained from several sources, particularly national accounts and economic IO tables.

As discussed in Chapter 2, EWF security is a manifold concept and primarily captures the attributes of efficiency, availability and affordability related to these resources. In this research, energy security is defined according to six attributes, namely energy intensity, energy conversion efficiency, energy diversity, energy-import dependency, energy affordability and energy (electricity) access. The first five attributes were included to assess the impact of the scenarios (Figure 5.11), while the last attribute (electricity access) was included as a main scenario driver (see Section 5.4.3). Electricity access is defined in terms of the percentage of the population that has access to electricity (World Bank, 2019). Water security is defined in terms of three attributes, namely, water availability, water stress and water intensity. Food security is also defined in terms of three attributes, namely, food accessibility, food-import dependency and food affordability.

Figure 5.11: Attributes for assessing the impacts of scenarios



In this research, *Energy intensity* is measured in terms of the total primary energy (in tons of oil equivalent) used by per dollar of GDP (IEA, 2019a). Similarly, water intensity is expressed as the amount of water demanded (in litres) for each dollar of GDP. These two indicators measure the dependence of the economy on energy and water resources, respectively.

Energy conversion efficiency indicates the ratio of final energy to primary energy. It evaluates the level of efficiency of converting primary energy (such as gas) to the final energy (such as electricity).

Energy diversity expresses the degree of diversification of primary energy sources in the economy, measured in this research by the Herfindahl index. The Herfindahl index represents a range between zero and one in which the lower the value, the greater the diversity. For example, the Herfindahl index is equal to one when the entire energy used in the country comes from just one source and the index is close to zero when the energy used comes equally from all primary sources available in the country.

Energy-import dependency is expressed in this research in terms of the value of total net energy imports (imports-exports) as a percentage of total primary energy consumption. It indicates the reliance of a country's economy on energy imports. A lower value means low dependency. Food-import dependency is expressed in a similar manner.

Energy (food) affordability is measured in terms of the percentage of household income spent on the purchase of energy (food). It expresses the vulnerability of the households in terms of increases in energy (food) prices.

Water stress is measured as the ratio (or percentage) of total available freshwater that can be withdrawn to meet water demand. It reflects the pressure of water demand faced by a country relative to its water supplies.

The *Food accessibility* indicator provides information on both physical and economic access to the basic food needed (Napoli, 2011); it is defined in terms of the proportion of road network in the country's land area (FAO, 2019a). Based on this definition, increased transport services imply better physical access to food. This relationship is expressed in this research as the ratio of food supplied (measured in dollars) to each dollar of transport service.

5.4.2 Scenario descriptions and key features

This study develops five scenarios that represent different likely futures for the MENA region. These scenarios are labelled Business-As-Usual (BAU), Energy-Oriented (ESC), Water-Oriented (WSC), Food-Oriented (FSC) and Nexus-Oriented (NSC). A brief description of these scenarios is given in this section. The assumed values for the scenario drivers are explained in Section 5.4.3.

Scenario 1: Business-As-Usual (BAU)

The BAU scenario broadly represents the continuation of current trends in terms of policies, technologies and socio-economic conditions. In particular, it reflects trends that have been experienced over the past decade, without any significant changes taking place. The other four scenarios assume alternative technological and policy pathways in the years to come. Overall, in this scenario, the economic growth (to the year 2050) will follow the trends observed over the previous decade.

Scenario 2: Energy-Oriented (ESC)

The energy-oriented scenario considers the transition from inefficient fossil fuel power plants to large-scale renewable electricity generation technologies, improvements in end-use energy efficiency at a modest rate and a reduction in energy subsidies. The availability of energy in the region is also assumed to support seawater desalination to mitigate water shortages, while energy resources could be used to supply the chemical industry to improve agricultural productivity.

Scenario 3: Water-Oriented (WSC)

The water-oriented scenario focuses on increasing the utilisation of seawater desalination and wastewater technologies rather than using surface and groundwater as the main sources of water to overcome the water shortage in the region. The WSC will support a reduction in the water subsidy for irrigation and household consumption and will reduce the production of intensive agricultural products and less use of chemical materials in the agriculture sector.

Scenario 4: Food-Oriented (FSC)

The food-oriented scenario envisages reductions in food loss and waste, increased agricultural productivity through expanding the usage of energy-efficient fertilisation and more advanced technologies such as genetic modification techniques and developments in crop production. In this scenario, small improvements in water use on farms can significantly increase water availability and other sources of water for irrigation, such as wastewater and drainage water, are introduced.

Scenario 5: Nexus-Oriented (NSC)

The nexus-oriented scenario considers the application of small-scale technologies that recognise the importance of the EWF nexus. For example, in this scenario, inefficient fossil fuel power plants are selectively replaced by small-scale distributed and renewable electricity generation technologies. This emphasis on distributed renewable technologies, it is argued, is an attractive proposition for increasing access to modern energy in the region. In terms of tackling the water supply issue, this scenario assumes the application of wastewater treatment technology, which is less energy-intensive than desalination technology. A significant change considered in this scenario is the selection of alternative crop-production patterns based on their water and energy intensities; in particular, it is assumed that crops that consume large amounts of water and energy during the production stages will be substituted with similar crops (e.g., sorghum with maize) that use less water and energy for their production. The dynamics of food production and consumption patterns are important factors in reducing poverty and improving well-being in MENA countries (World Bank, 2009a).

Table 5.3 summarises the key characteristics of the five scenarios. The characteristics present the underlying assumptions for scenarios that are not specified for any particular scenario. For example, some concepts, such as cross-border trade opportunities, are not specific only to the nexus scenario but are also relevant to the other four scenarios. The only difference is that the nexus scenario supports additional cross-border trade to improve EWF security, something more than what is considered in the other scenarios. The assumption emphasises that increased cross-border trade is likely to encourage, for example, a country that is water scarce to import products that require extensive water, rather than producing them domestically. This could improve the water security of a country. This assumption is consistent with the viewpoints expressed in several studies (Andrews-Speed et al., 2012; Waughray, 2011; Willaarts, Garrido & Llamas, 2014).

5.4.3 Scenario assumptions

This section presents the assumptions of the key scenario variables. These variables were selected based on the previous description of the characteristics of the different scenarios. The assumptions for the MENA region overall for 2050 are summarised in Table 5.4, and the actual values for 1990 and 2015 are also shown. This section is followed by a discussion about and justification for the values selected to be the scenario drivers. The individual assumptions for each of the selected MENA countries are shown in Appendix A.

Table 5.3: Alternative scenarios considered in this research

	BAU	ESC	WSC	FSC	NSC
Economy	- Continue as an energy-based economy - Domestic consumption as the source of growth	- Transitioning towards the diverse economy - Rely on Investment as the source of growth	- Transitioning towards the diverse economy - Rely on Investment as the source of growth	- Transitioning towards the diverse economy - Investment as the source of growth	- Transitioning towards the diverse economy - Investment as the source of growth
Energy	- Population rely on gas and oil for domestic use - Fossil fuels dominate the electricity supply mix - End-use energy efficiency improves at historical rates	- Increase the penetration of advanced fossil-fuel and large-scale renewable electricity generation technologies - Reduce energy subsidy - End-use energy efficiency improves at modest rates	- Population rely on gas and oil for domestic use - Fossil fuels dominate the electricity supply mix - End-use energy efficiency improves at historical rates	- Population rely on gas and oil for domestic use - Fossil fuels dominate the electricity supply mix - End-use energy efficiency improves at historical rates	- Increase the penetration of distributed (small-scale) renewable electricity generation technologies - End-use energy efficiency improves at higher rates
Water	- Conventional water supply (Surface and groundwater) - Continue to expand irrigated agricultural land	- Increase penetration of seawater desalination and wastewater reused treatment technologies - Modest expansion of irrigated agricultural land	- Increase use of seawater desalination and wastewater and agricultural drainage technologies - Modest expansion of irrigated agricultural land - Reduce water subsidy	- Increase penetration of wastewater and agricultural drainage technologies - Modest expansion of irrigated agricultural land - -Improve water productivity	- Increase use of recycled water and adoption of advanced wastewater treatment technologies - Considerable expansion of irrigated agricultural land
Food	- Rely on importing basic foods - No significant effort to improve agricultural productivity	- Improved agricultural productivity through expanded use of energy-efficient fertilizers - End-use energy efficiency improves at modest rates	- Improved agricultural productivity to the world average with less fertilization and applying genetic modification techniques	- Improve in agricultural productivity applying energy-efficient fertilisers - Increase penetration of Practice organic agriculture	- Agricultural production based on less intensive resource-use patterns - Improved agricultural productivity through capital-intensive genetic modification techniques
Transport	- No significant effort to improve transport infrastructure	- Improved transport infrastructure at modest rate	- Improved transport infrastructure at modest rate	Improved transport infrastructure to reduce food wastage in the supply chain	- Improved transport infrastructure to reduce food wastage in the supply chain

Note: The description in the table for variables reflects overall regional trends. These variables are likely to assume different values for different countries (see Appendix A).

Table 5.4: Assumed values for the scenario drivers in the MENA region

MENA	1990	2015	2050				
			BAU	ESC	WSC	FSC	NSC
POPULATION (million)	256	421	657	657	657	657	657
ECONOMY							
GDP per capita (constant 2005 US$)	4,933	7,485	14,564				
Components of GDP (%)							
Household consumption	58	45	45	51	51	51	51
Government spending	20	18	18	16	16	16	16
Investment	24	28	28	33	33	33	33
Economic structure (%)							
Agriculture	10	5	5	5	5	6	2
Industry	43	46	40	47	47	40	37
Services	47	49	55	48	48	54	61
ENERGY							
Access to electricity (% of population)	86	97	100	100	100	100	100
Energy productivity growth* (% pa)		0.18	0.12	0.12	0.12	0.12	0.12
1. Electricity supply mix (%)							
Fossil-Fuel	96.0	97	97	94	97	97	94
Nuclear power plant	-	1	1	1	1	1	1
Hydro power plant	4.0	2	1	1	1	1	1
Wind power plant	0.0	0	0	1	0	0	1
Solar power plant	-	*0*	*0*	*3*	*0*	*0*	*3*
Other Renewables	-	*0*	*1*	*1*	*1*	*1*	*1*
WATER							
Water supply mix (%)							
Surface water	70	62	55	55	47	55	47
Groundwater	27	33	35	35	27	35	27
Desalination	2	3	5	5	14	5	14
Treated wastewater	1	1	4	4	11	4	11
Reused agricultural drainage water	-	1	1	1	1	1	1
FOOD							
Agricultural productivity growth* (% pa)		82%	0.46	0.5	0.5	0.5	0.5
Crop selection for:							
Grains (%)							
Barley	57	40	40	40	40	41	41
Maize	34	51	51	51	51	53	53
Sorghum	8	7	7	7	7	4	4
Oats	1	1	1	1	1	1	1
Millet	0	1	1	1	1	1	1
Veg & Fruit (%)							
Potatoes	33	38	38	38	38	40	40
Tomatoes	48	43	43	43	43	41	41
Nuts and nut products	2	3	3	3	3	2	2
Bananas	3	4	4	4	4	7	7
Dates	13	12	12	12	12	10	10
Vegetable oil (%)							
Soybean Oil	10	35	35	35	35	38	38
Groundnut Oil	2	3	3	3	3	1	1
Sunflower seed Oil	14	4	4	4	4	2	2
Rape and Mustard Oil	10	23	23	23	23	22	22
Cottonseed Oil	18	3	3	3	3	7	7
Sesame seed Oil	4	3	3	3	3	1	1
Olive Oil	41	27	27	27	27	23	23
Maize Germ Oil	1	2	2	2	2	6	6
Beverages (%)							
Coffee	16	11	11	11	11	9	9
Tea	84	89	89	89	89	91	91
Meat (%)							
Bovine Meat	25	21	21	21	21	13	13
Mutton & Goat Meat	25	15	15	15	15	19	19
Pig Meat	1	1	1	1	1	1	1
Poultry Meat	49	63	63	63	63	67	67
TRANSPORT							
Land transport investment* (% pa growth)	na	0.0	0.1	0.29	0.29	0.29	0.29

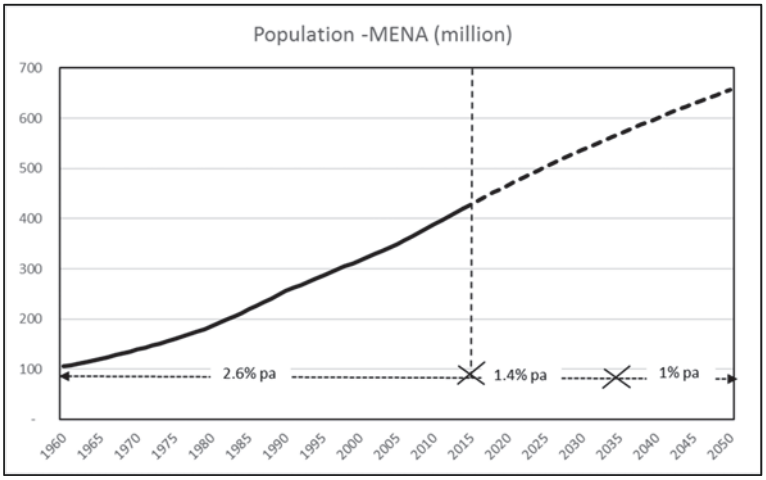
Notes:

- *Annual growth rates for 2015, 2030 and 2050 represent average annual growth over the period 1990-2015, 2015-2030 and 2030-2050, respectively.*
- *Similar tables for individual country assumptions are provided in Appendix A.*

Population

The population of MENA is assumed to increase at an annual rate of 1.4% over the medium term (2015-2035) and by 1% over the long term (2035-2050) in all five scenarios. The rate was 2.6% over the previous 50 years (from 1960 to 2015) (Figure 5.12). Based on this assumption, the population of the region is expected to reach 657 million by 2050. The figure is consistent with the population predicted by the United Nations (United Nations, 2017).

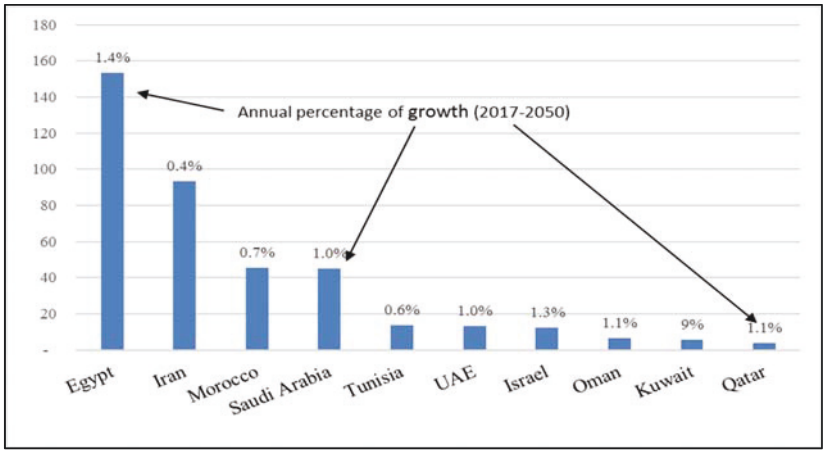
Figure 5.12: Population of MENA from 1960 to 2050



Source: United Nations, 2017

Population in the countries selected for this research are assumed to grow at a different rate from 2017 to 2050. Iran, the second most populated country in the region (Figure 5.13), will have the lowest growth (0.4% per year) while Egypt, with the biggest population will experience the fastest growth rate (1.4%) by 2050.

Figure 5.13: Population of Selected Countries by 2050

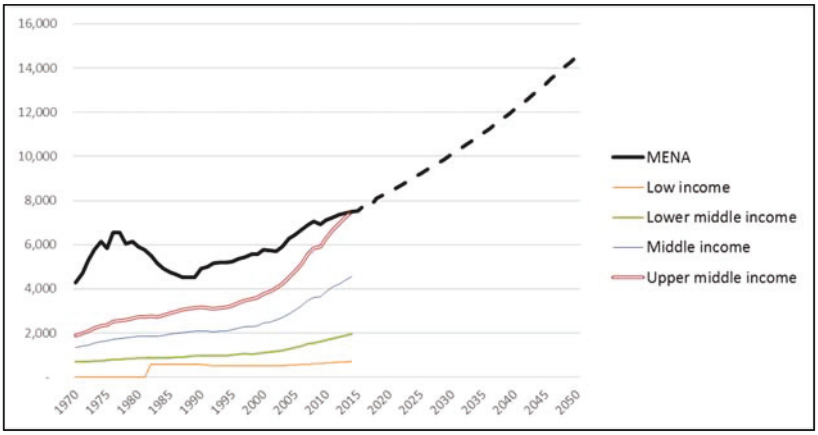


Source: World Bank, 2019

Economy

The economy of the MENA region has fluctuated over the last four decades. For instance, the region experienced an increase in GDP per-capita of 3.2% per year during the 1970s, a decrease of -1.8% in the 1980s and a rise of 1.8% after that (Figure 5.14).

Figure 5.14: GDP per-capita in different income groups



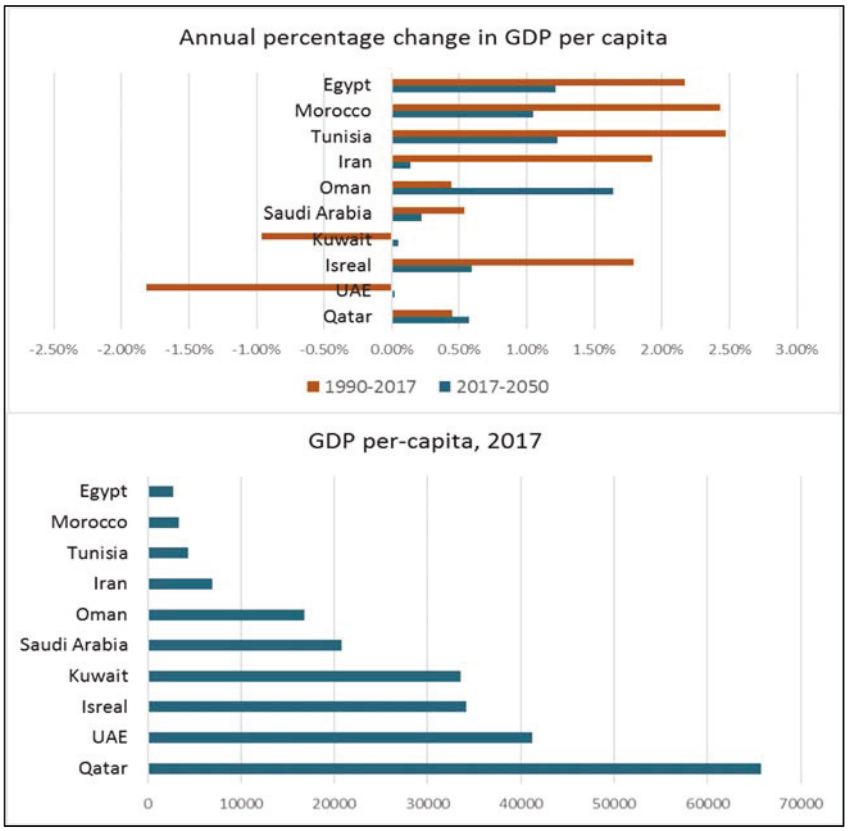
Source: World Bank, 2019

The assumptions for the key economic variables include:

Based on the historical economic growth, this study assumes that per-capita GDP will increase by 1.9% over the period of 2015-2050 in this research. This growth rate is consistent with what the region experienced in the previous 30 years (1.8%). Therefore, based on the population and the assumed GDP per-capita growth, GDP will grow by 3.1% per year, from around $7,000 to above $14,000 in 2050 (Figure 5.14). This growth rate is consistent with what upper-income countries experience.

Further, in the BAU scenario the per-capita GDP growth rate in each of the selected MENA countries differs from one period to another (Figure 5.15). The assumed rates are from 0.03% per year for the UAE to 1.64% per year for Oman. The assumptions are based on the historical reviews that the countries experienced in the previous three decades (from 1990 to 2017). Although the UAE and Kuwait experienced a negative GDP per-capita growth rate during 1990-2017, the research assumes positive growth rates for years to come in these countries.

Figure 5.15: Per-capita GDP in the selected MENA countries

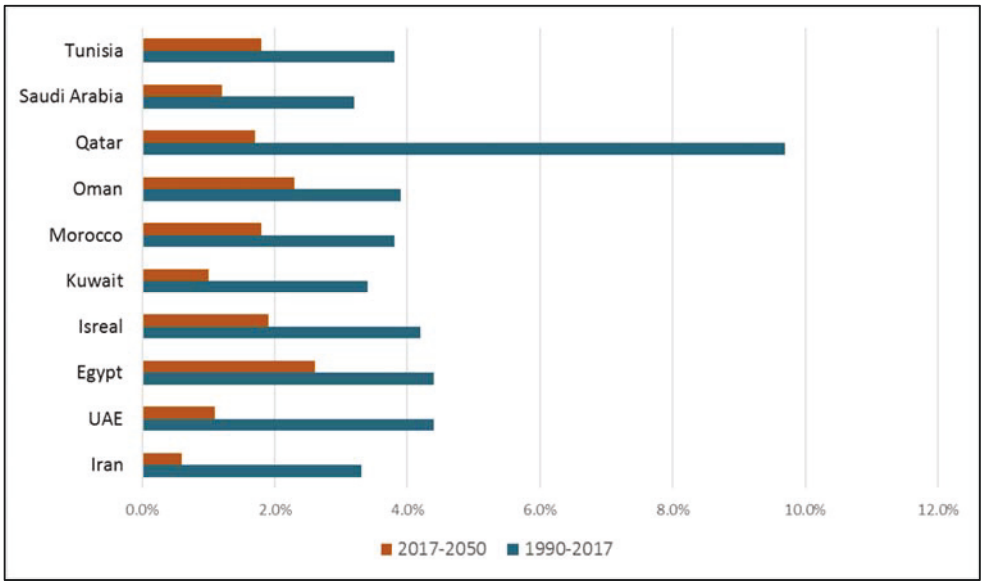


Source: World Bank, 2019[16]

The assumed growth rates (GDP per-capita and population) indicate the GDP growth rates in the BAU scenario in these counties (Figure 5.16). Iran has the lowest growth rate (0.6%) due to the assumed population growth rate (4%) per year; according to the same assumption, Egypt will experience the highest growth rate in the region. The GDP of the other countries will be between 1% for Kuwait and 2.3% for Oman.

[16] Data for Kuwait and Qatar was available from 1995 and 2000 respectively in the World Bank database.

Figure 5.16: Annual percentage of change in GDP

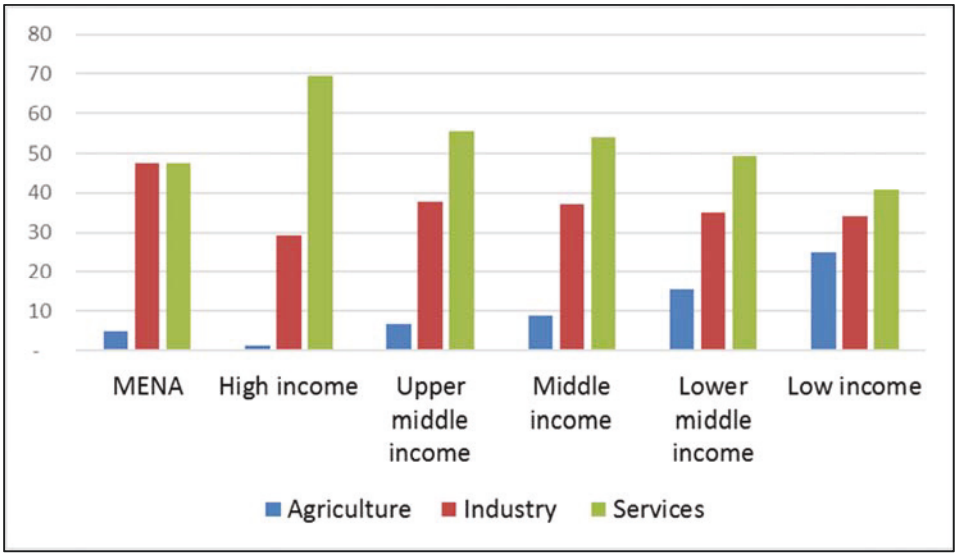


Source: World Bank, 2019

The economic structure of the selected countries in the MENA region would collectively remain similar to as of 2015 in the BAU scenario, implying that GDP is mainly focused on the industrial and service sectors (Figure 5.17). However, at the individual country level of this region, the economic structure is different, as shown in Figure 5.18. The countries selected for this study are grouped into three different income levels based on World Bank definitions: high income, upper-middle income and lower-middle income. Further, in the BAU scenario and over the period 2015-2050, the selected countries can be expected to have different sectoral shares (agricultural, industrial and services) in their GDP. That is, Saudi Arabia, Qatar, Oman, Kuwait and the UAE will continue to have the highest share (between 50% and 70%, approximately) of the industrial sector compared to the sectors within them and in Israel the services sector would be nearly 80% of its GDP. Accordingly, the other income-group countries in this research will have different patterns of sectoral share in their GDP.

Further to this explanation, in this research it is assumed that countries classified as low-to-middle-income and where agriculture output has a strong role will follow the economic structure of upper- to middle-income countries, showing a decrease in the role of agriculture and an increase in the share of industry. The economic structure of the middle- to upper-income countries is also assumed to follow the trend observed in the high-income countries, that is, an increase in the share of the services sector.

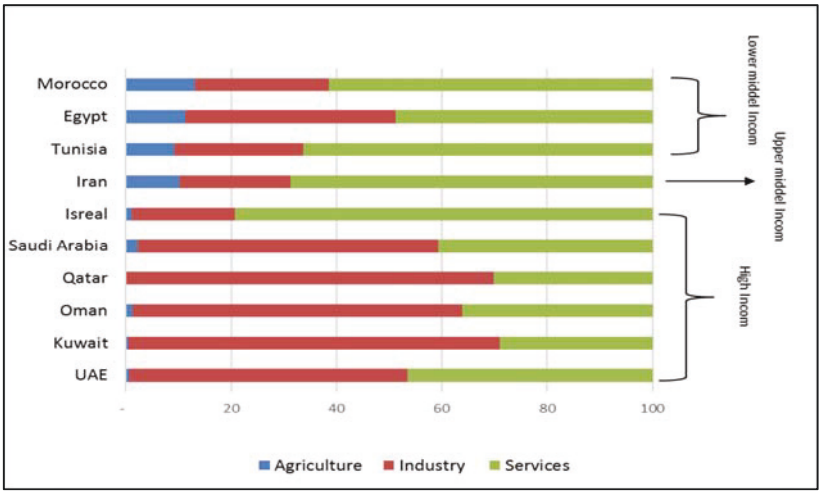
Figure 5.17: A comparative overview of economic structure (%), 2015



Source: World Bank, 2019

The structural change of the selected economics for all other scenarios, namely, ESC, WSC, FSC and NSC scenarios is determined in accordance with the pace of change in the share of industry and services sectors out of the GDP. In the ESC, WSC and FSC scenarios, the industry sector would have relatively higher share growth while in the NSC scenario, the services sector would have higher share growth. Further, while the *direction* of change will be the same for all the countries in the scenarios, the *rate* of change will be different for each country (Figure 5.19), depending on whether a country is classified as lower-middle income, upper-middle income or high income.

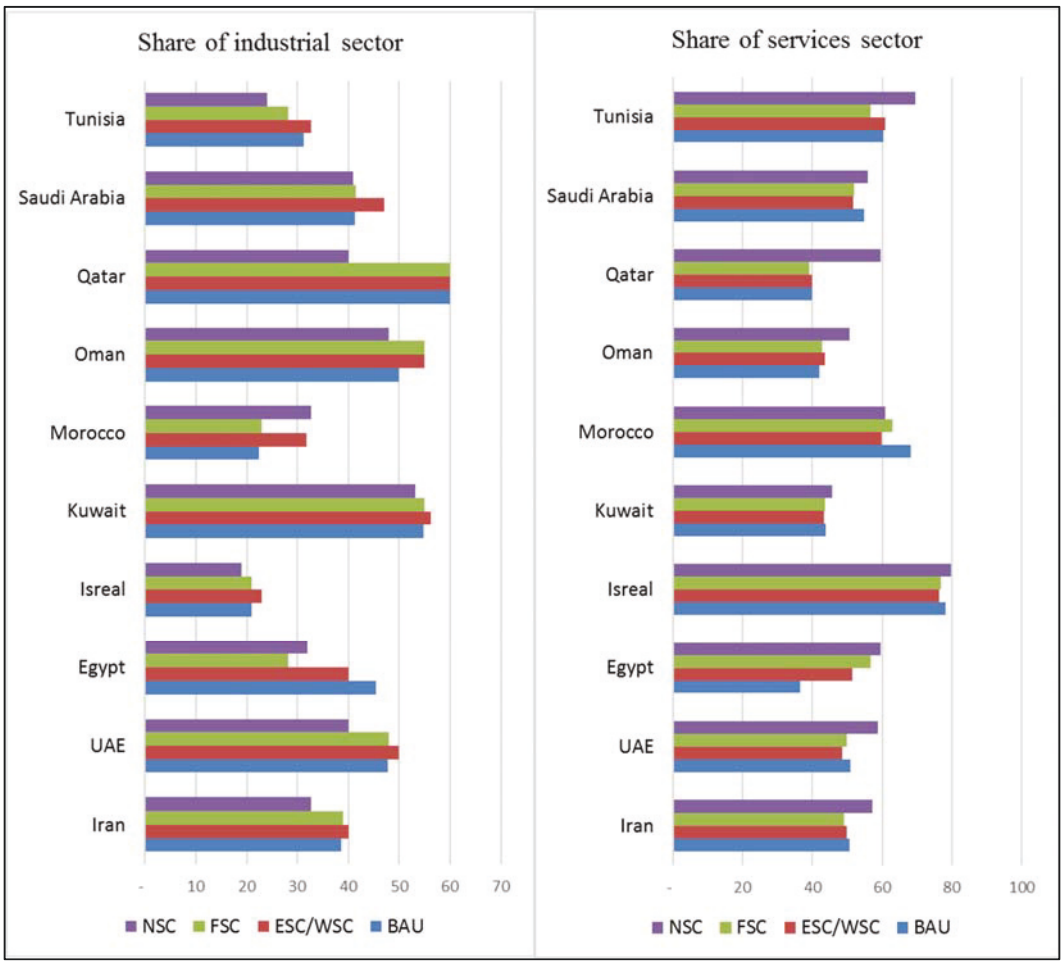
Figure 5.18: Economic structure (%) of selected countries in MENA, 2015



Source: World Bank, 2019

These assumptions are generally consistent with the individual strategic plan for individual countries and international development agencies (IMF, 2013; IMF, 2016; OECD, 2019; Tagliapietra, 2017; World Bank, 2004) which support the view that sectoral structural change is the key to improving living standards and reducing poverty in the countries of the region.

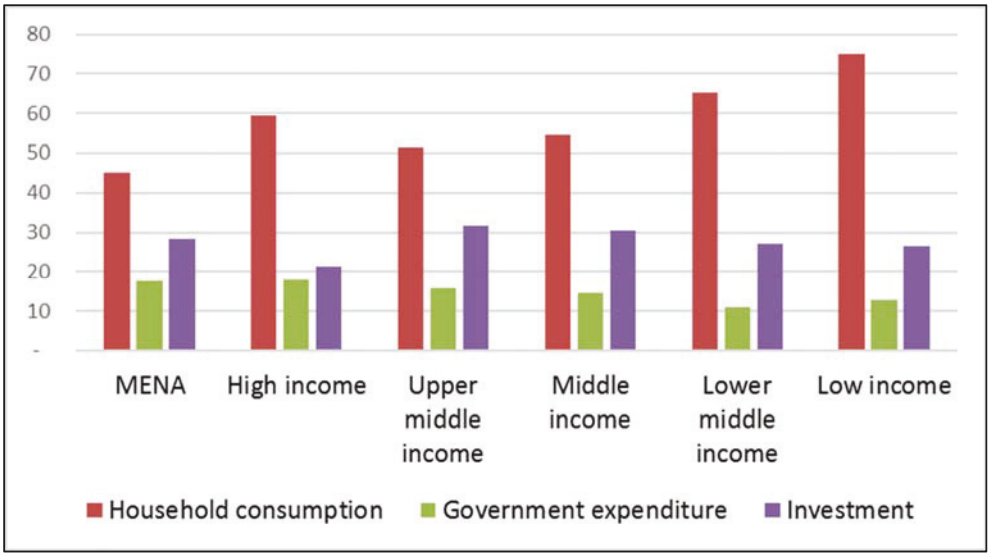
Figure 5.19: Change in economic structure in the alternative scenarios (except BAU)



Source: World Bank, 2019

The sources of economic growth in the selected MENA countries in the BAU scenario are assumed to be broadly similar to those that are dominant today; household consumption, government spending and investment are likely to contribute 45%, 18% and 28% respectively to the GDP of 2050 (Figure 5.20). In the other scenarios, investment is assumed to play a greater role while the role of household consumption is reduced. For example, in these scenarios, investment is assumed to contribute 33% to the overall GDP by 2050, values that are similar to those observed in middle-income countries. The shown value of the investment is the overall perspective of the region while at individual country level, different share growth for each source of economic is considered.

Figure 5.20: A comparative overview of components of GDP (%), 2015



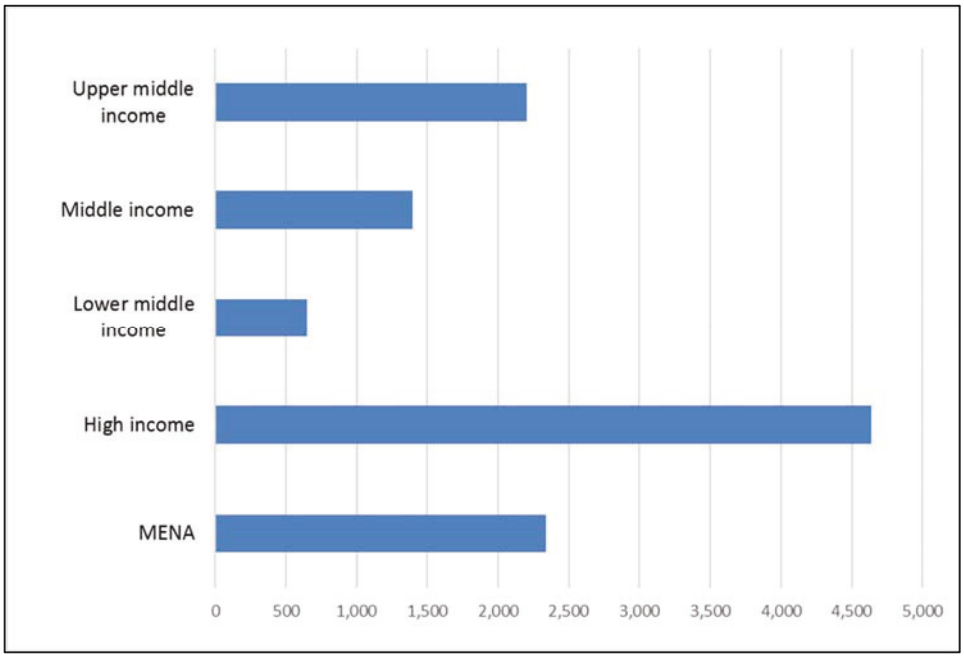
Source: World Bank, 2019

Energy

Countries in the MENA region rely heavily on oil and gas as the main means of meeting domestic energy demand. Figure 5.21 shows the strong relationship between energy use (kg of oil) and the level of economic development; as a country develops, the per-capita use of oil increases.

In the BAU, WSE and FSC scenarios, the use of fossil fuel is expected to increase slightly, which is consistent with the historical trend over the period 1990-2015 (Table 5.4). However, in the ESC and NSC scenarios, it is assumed that the demand for fossil fuels will decrease to be replaced by renewable resources. The rate of change varies between countries and depends on the renewable resources available in each. The rate of change in this research is calculated based on the reports prepared by various agencies (Connor & El-Khoury, 2013; IRENA, 2019; Meisen, 2007; World Energy Council, 2016).

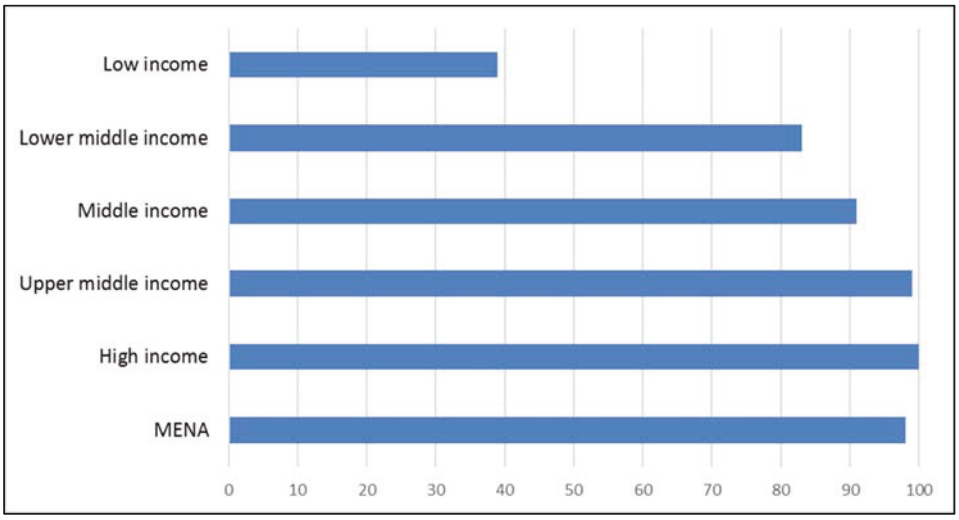
Figure 5.21: A comparative view of energy use (kg of oil per-capita) in 2015



Source: World Bank, 2019

About 98% of the population in the MENA region currently has access to electricity, which is slightly below than the access levels for upper-middle countries (Figure 5.22). However, the level of access in the region varies among the selected countries. In all the countries except for Morocco and Tunisia (whose populations have close to 100% access), the population has 100% access to electricity (World Bank, 2019). In all the scenarios in this research, however, it is assumed that access to electricity in Morocco and Tunisia will increase to 100% as their economies develop.

Figure 5.22: A comparative view of access to electricity (% of population) in 2014



Source: World Bank, 2019

The current electricity generation mix in MENA countries is dominated by fossil fuels (97%). In the BAU, WSC and FSC scenarios, fossil fuels are assumed to remain dominant in the electricity supply mix. However, in the ESC and NSC scenarios, it is assumed this mix will change. It is assumed that conventional fossil-fuel power plants will be partly replaced by renewable resources and alternative technologies. In other words, this study assumes that the share of fossil fuel power plants will gradually reduce over time and that the share of advanced technologies will gradually increase. In the ESC scenario, it is assumed that the share of nuclear and large-scale non-hydro-based renewable electricity will have increase by 2050. The increase in nuclear power generation is assumed to occur mainly in Iran and UAE, where the governments have developed nuclear power plants. In the NSC scenario, it is assumed that conventional fossil-fuel power plants will be replaced mainly with small-scale distributed renewable electricity generation technologies by 2050. The share of resources for generating electricity varies between different countries (Table 5.5). The potential for technological transformations in the electricity generation mix for the MENA region has already been discussed in various studies (GECF, 2017; IRENA, 2016).

Table 5.5: Electricity generation mix in the BAU, ESC and NSC scenarios

2050	Coal			Oil			Gas			Nuclear*			Solar			Wind			Hydro			Biomass/Goth		
	BAU	ESC	NSC	BAU	ESC	NSC	BAU	ESC	NSC	BAU	ESC	NSC	BAU	ESC	NSC	BAU	ESC	NSC	BAU	ESC	NSC	BAU	ESC	NSC
Egypt				21%	3%	1%	71%	49%	10%				0%	23%	66%	1%	15%	14%	7%	5%	5%		5%	4%
Iran	0%	1%	6%	14%	13%	1%	79%	71%	6%	1%	3%		0%	9%	74%	0%	1%	2%	5%	2%	6%	0%	0%	5%
Israel	36%	6%	6%	0%	1%	1%	61%	64%	40%				2%	27%	44%		0%	1%		2%	6%	0%	0%	3%
Kuwait				64%	16%		36%	85%	54%					14%	44%		1%						0%	2%
Morocco	57%	19%	5%	7%	2%	1%	19%	25%	6%				0%	23%	66%		23%	14%	8%	7%	1%		1%	8%
Oman				19%	10%	2%	81%	70%	12%					14%	62%		6%	21%					0%	3%
Qatar							100%	99%	49%					1%	51%								0%	0%
Saudi Arabia				44%	17%	10%	56%	54%	12%				0%	23%	57%		5%	5%					1%	16%
Tunisia				5%	3%	1%	92%	66%	9%				0%	16%	69%	2%	14%	14%	0%	1%	1%		0%	7%
UAE		2%		1%		1%	99%	50%	13%		8%		0%	38%	86%		1%			0%			1%	1%

Note: * only in Iran and the UAE
Source: GECF, 2017; IEA, 2015; IRENA, 2016; World Nuclear Associaton, 2019

End-use energy efficiency (or energy productivity) has improved worldwide except the MENA region (specifically the Middle East) (World Energy Council, 2013). In contrast to the rest of the world, the rapid development of energy-intensive industries in MENA has lowered the rate of energy productivity in the almost last 30 years (1990-2016) by 0.8%. This rate is much lower than the world average, as shown in Table 5.6, thus suggesting that there is considerable scope for energy efficiency improvements in the region. In the BAU, WEC and FEC scenarios, it is assumed that energy productivity in the selected MENA countries will continue the historical trend. In the other two scenarios, energy productivity is assumed to improve at different rates. The rate in the ESC scenario generally corresponds with the rates experienced by upper-middle income countries while the rate in the NSC scenario will be similar to that in high-income countries. Many studies

have emphasised the challenges related to the low energy efficiency in the MENA region and urge this rate to be improved (Menichettti, El Gharras & Karbuz, 2017; World Energy Council, 2013).

Table 5.6: Energy productivity growth

	Energy productivity (2011US$ per MJ)	**Energy productivity improvements[1] (% pa)**
High income	6.53	1.4
Upper-middle income	4.58	1.9
Middle income	4.67	2
Lower-middle-income	4.88	2
Low income	8.76	1.1
MENA	5.27	-0.8*

Note [1] Energy productivity improvements between 1990 and 2016.
* Negative shows a decrease in energy productivity growth
Source: World Bank, 2019

The MENA region currently contains approximately 52% and 42% of the world's oil and gas reserves, respectively. Several studies have focused on the role of the MENA region in producing oil and gas in 2050 (EIA, 2017a; Frei et al., 2013; OPEC, 2017). The Middle East will be the key source of energy because it will produce more than half of the oil and gas needed in the world. Overall, oil production in MENA is assumed to increase by approximately 2% per year in the BAU, WSC and FSC scenarios, which is consistent with the historical trend of the region (OPEC, 2017). In the ESC and NSC scenarios, a 1.2% annual growth rate is assumed (OPEC, 2017).

Natural gas production in MENA has grown by nearly 7% annually since 1990 (EIA, 2017b). Iran and Saudi Arabia contributed to most of this growth and Israel and Morocco the least. Gas production in the region is projected to grow at an annual average rate of around 2% in the BAU, WSC and FSC scenarios (Frei et al., 2013). In the ESC and NSC scenarios, a 2.5% annual growth rate is assumed.

Food

Crop selection for the alternative scenarios is shown in Table 5.4. This selection is based on the water-intensiveness of agricultural production in arid and semi-arid areas, as shown in Table 5.7. For example, in a moderate climate, grass needs only 4mm of water per day to grow while in the arid and semi-arid areas it needs to10mm per day (Bacon, 2017). Some of the selected crops, such as tomatoes and potatoes, need more water to grow in arid areas than in a temperate climate. For

the BAU and ESC and WSC scenarios, the selection of crops is based on the predominant resource-use patterns.

In the FSC scenario, the historical pattern will continue but an increase in the share of wastewater and agricultural drainage technologies for the food sector will be considered. Agricultural drainage technology will be applied only to Egypt where it is already in place.

The NSC scenario considered an increase in the share of less resource-intensive crops by assuming water-intensive crops could be partly replaced with similar (i.e., grains) but less water-intensive crops (Table 5.7). Such a switch of crops would be based on the historical cropping patterns in the selected countries in MENA region. For example, water-intensive sorghum would be partly replaced by less water-intensive barley and maize. This replacement has the potential to reduce the use of water by one-half for each ton of grain produced. Similar assumptions are made for other agricultural product, taking into consideration the agriculture production profiles for the region in the past (Table 5.4).

Table 5.7: Water intensity of agricultural production

Water intensity (m3 per ton)			
Grains food		**Vegtable & Fruit**	
Millet	4,478	Nuts and products	9,063
Sorghum	3,048	Dates	2,277
Oat	1,788	Bananas	790
Barley	1,423	Potatoes	287
Maize	1,222	Tomatoes	214
Vegetable oil		**Beverages**	
Sesameseed Oil	21,793	Coffee	15,897
Olive Oil	14,726	Tea	8,856
Groundnut Oil	7,529	**Meat**	
Sunflowerseed Oil	6,792	Bovine Meat	15,415
Rape and Mustard Oil	4,301	Mutton & Goat Meat	8,763
Soyabean Oil	4,190	Pig meat	5,988
Cottonseed Oil	3,957	Poultry Meat	4,325
Maize Germ Oil	2,575		

Source: Mekonnen & Hoekstra, 2011; Mekonnen & Hoekstra, 2012

Agriculture productivities for different income group for the 27 years (1990-2017) is displayed in Table 5.8. Agricultural yield in MENA is lower than in other regions, which reflects both the high percentage of arable land used for low-yield crops and the low productivity of desert pastures (OECD & FAO, 2018). In the BAU, ESC and WSC scenarios, agricultural productivity for the selected countries in the MENA region is assumed to increase at the historical average rate of 1.4% per year. In the FSC and NSC scenarios, productivity is assumed to increase at a higher

average rate of 1.9% per year. In the FSC scenario, it is assumed that improvements in agricultural productivity will be achieved by increased use of energy-intensive fertilisers and pesticides, while productivity improvements in the NSC scenario are based on applying mainly capital-intensive genetic modification techniques.

Table 5.8: Agricultural productivity growth

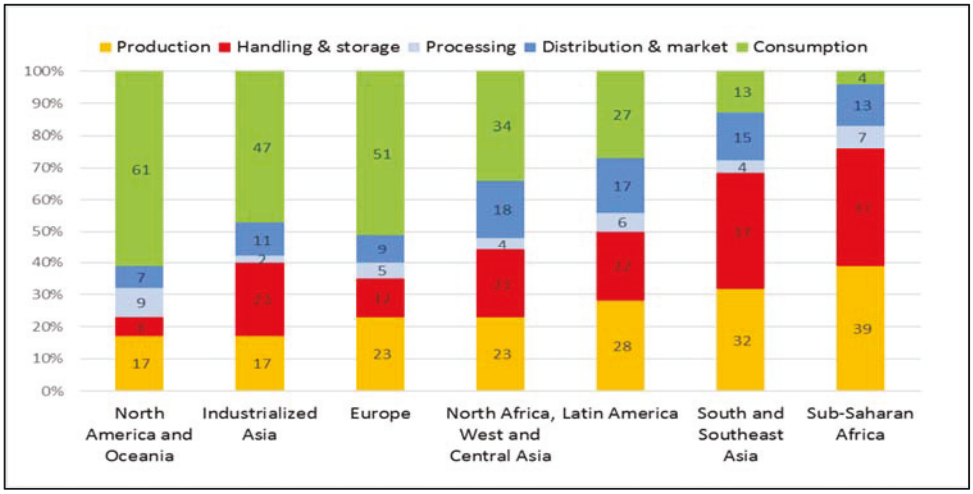
Agricultural yield (% pa)	
High income	1.7
Upper-middle income	2.1
Middle income	1.8
Lower-middle income	1.5
Low income	1.6
MENA	1.4

Source: World Bank, 2019

Based on World Bank estimations, the quality of transport infrastructure in the MENA is similar to the upper-middle income group. However, a significant percentage of food is lost and wasted in the supply chain stages (Figure 5.23). For example, in North Africa and in West and Central Asia[17], more than 40% of the food is lost and wasted in the two stages closest to the farm, namely, production and storage. In this area more than 66% of food is lost due to lack of infrastructure (Lipinski et al., 2013). In the BAU, ESC, WSC and FSC scenarios, this index is assumed to improve at historical rates for each country (on average 0.1% per year). In the NSC scenario, transport infrastructure is assumed to improve by additional investment and a higher growth rate is therefore applied to the index value in each country. It is estimated that by 2050, the value for this index will be 3.0 for the lower-middle and upper-middle income countries in this research (Egypt, Tunisia, Morocco and Iran). This value is projected to be 4.0 for the remainging countries, which are classified as high income (Figure 5.24).

[17] North Africa and West and Central Asia consist of Algeria, Egypt, Iraq, Israel, Jordan, Kazakhstan, Kuwait, Kyrgyzstan, Lebanon, Libya, Mongolia, Morocco, Oman, Saudi Arabia, Syria, Tajikistan, Tunisia, Turkey, the UAE, Uzbekistan and Yemen

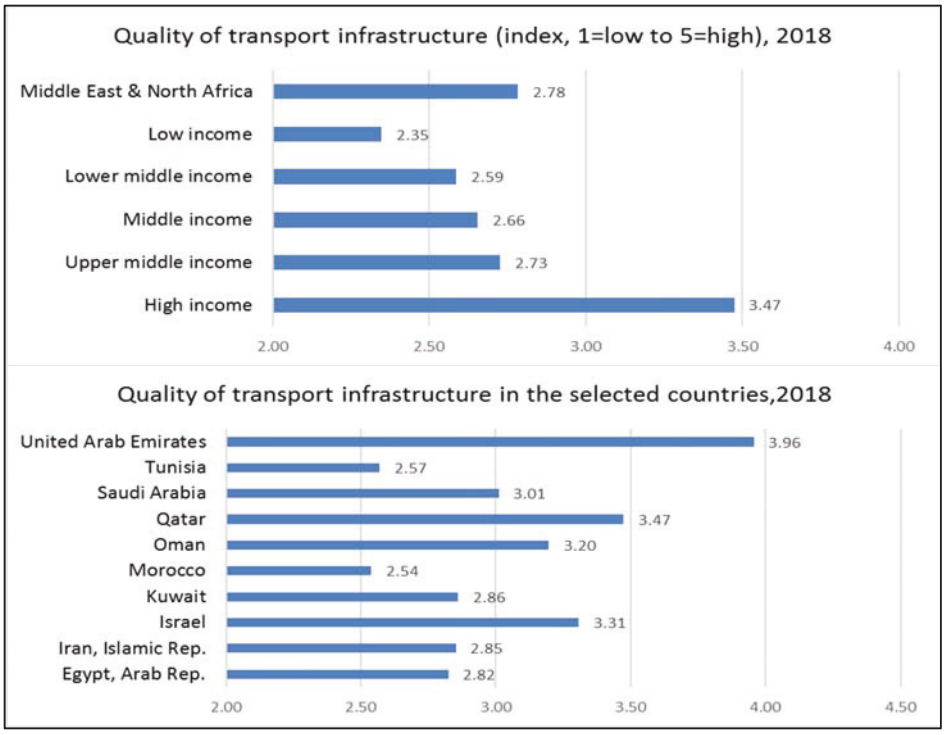
Figure 5.23: Lost and wasted food in different regions, 2009



Note: MENA countries except Iran are categorised as part of North Africa, West and Central Asia. In this figure, Iran is considered part of South and Southeast Asia.

Source: Lipinski et al., 2013

Figure 5.24: Logistic performance index



Source: World Bank, 2019

Water

The water supply assumptions are similar to those for electricity generation mix. In the BAU, ESC and FSC scenarios, water supply technologies are assumed to change slightly over the next three decades. In the WSC and NSC scenarios, existing technologies are assumed to improve significantly to reduce pressure on surface water and groundwater supply. The reduction in surface water and groundwater supply is assumed to be replaced by energy-intensive seawater and advanced-treatment wastewater. Table 5.9 shows the water supply mix for the countries in this research. In the WSC scenario in all the countries, the main replacement technology is assumed to be seawater desalination, while in the NSC scenario, advanced wastewater technology is the replacement. Reused agricultural drainage water will be used only if the country has developed the technology already. The potential of the advanced technologies discussed in this research in MENA has also been considered by the World Bank (Jagannathan, Mohamed & Kremer, 2009).

Table 5.9: Water supply mix in the BAU, WSC and NSC scenarios

2050	Surface water			Groundwater			Desalination			Treated wastewater			Reused agricultural		
	BAU	WEC	NSC	BAU	WEC	NSC	BAU	WEC	NSC	BAU	WEC	NSC	BAU	WEC	NSC
Egypt	0.82	0.72	0.62	0.12	0.09	0.08	0.01	0.05	0.09	0.01	0.09	0.15	0.04	0.05	0.06
Iran	0.46	0.43	0.42	0.47	0.40	0.28	0.05	0.15	0.12	0.02	0.02	0.18	-	-	-
Israel	0.19	0.17	0.17	0.30	0.15	0.15	0.14	0.31	0.20	0.37	0.37	0.48	-	-	-
Kuwait	0.01	0.01	0.01	0.45	0.12	0.12	0.46	0.72	0.60	0.08	0.15	0.27	-	-	-
Morocco	0.50	0.40	0.35	0.18	0.11	0.09	0.20	0.39	0.35	0.12	0.10	0.21	-	-	-
Oman	0.30	0.24	0.24	0.04	0.01	0.01	0.56	0.60	0.53	0.10	0.15	0.22	-	-	-
Qatar	0.16	0.15	0.15	0.13	0.06	0.06	0.61	0.67	0.61	0.10	0.12	0.18	-	-	-
Saudi Arabia	0.23	0.17	0.17	0.25	0.05	0.05	0.45	0.60	0.55	0.07	0.18	0.23	-	-	-
Tunisia	0.54	0.20	0.20	0.37	0.30	0.30	0.03	0.38	0.32	0.06	0.12	0.18	-	-	-
UAE	0.10	0.05	0.05	0.02	0.02	0.02	0.70	0.80	0.74	0.18	0.13	0.19	-	-	-

Source: (Negewo et al. 2011; Verdier 2011)

5.5 Policy perspective of the EWF security nexus in MENA implementations

The intention of the final stage of the integrated framework for this study is to prove that a EWF nexus could lead to effective policy development. Based on the scenario assessments (which discuss the impact of alternative scenarios available in this research in terms of economic and social outcomes, energy security, water security and food security), these assessments will be synthesised. This will assist in extending the analysis and capturing broader policy perspectives. Such policy perspectives could improve the outcomes of the trade-offs between policies, even though the policies might have different objectives (which sometimes conflict with one another) in the presented scenarios.

Further, this study will present some recommendations based on the assessments which may improve the consistency between EWF policies while reducing the negative potential of policy trade-offs.

5.6 Sources of data required in the model

The model applied in this research consists of two main parts: the first part involves building the IO model, expanding the IO table, re-basing the IO table (recalculating its coefficients by changing the base year from 2011 to 2015) and developing 'satellite' accounts for energy, water and employment to conduct analysis. The second part involves applying the framework to analysis the impacts of considered scenarios in this research. Two main sets of data are therefore needed for this study: one for the IO model and the other for the scenario analysis. Detailed information about the scenario analysis data was discussed in Section 5.4. In this section, the focus is on the data required for the IO model.

Data applied to the IO model

The IO table applied in this research is adapted from the GTAP 9 database (Aguiar, Narayanan & McDougall, 2016). The benefit of this dataset is that is has a consistent format (industry classification) for various countries. The standard GTAP IO table consists of 57 sectors, 8 factors of production (aggregated to 4 factors in this research) and 4 final sectors. The electricity sector has been disaggregated further into 8 subsectors (Peters, 2016). Table 5.10 shows the available sectors in the GTAP database and the available sub-sectors in the electricity sector. Energy 'satellite' accounts can also be developed from the GTAP database. Other accounts, such as employment to show the rate of employment in various sectors, can also be developed in the model for analysis. To develop an employment account that corresponds to the IO table, the information could be gathered from the World Bank and the International Labour Organization, both of whom publish data annually.

In this research, some of the sectors in Table 5.10 are extended further to their individual commodities by incorporating EWF data from different sources. For example, data from the UN Food and Agricultural Organization (FAO, 2018a) is used to disaggregate the agriculture and food sectors. The water sector in GTAP is disaggregated to present the water consumption and water supply technologies by applying the FAO AQUASTAT (FAO, 2016a) and Eora MIRO databases (Lenzen et al., 2013). It is worth mentioning, FAO provides the Food Balance Sheets for all the countries in this research, except Qatar. Therefore, for all selected countries, except Qatar, FAO's Food Balance sheets are used to breakdown the GTAP data, whereas the food sector for Qatar is only disaggregated at the level of GTAP Input-Output table.

Table 5.10: 57 sectors in GTAP9

No.	Code	Description	No.	Code	Description
1	Pdr	Paddy rice	34	nmm	Mineral products n.e.c.
2	wht	Wheat	35	i_s	Ferrous metals
3	gro	Cereal grains,Not elsewhere classified	36	nfm	Metals n.e.c.
4	v f	Vegetables, Fruit, Nuts	37	fmp	Metal products
5	osd	Oil seeds	38	mvh	Motor vehicles and parts
6	c b	Sugar cane, Sugar beet	39	otn	Transport equipment n.e.c.
7	pfb	Plant-based fibers	40	ele	Electronic equipment
8	ocr	Crops n.e.c.	41	ome	Machinery and equipment
9	ctl	Cattle, Sheep, Goats, Horses	42	omf	Manufactures n.e.c.
10	oap	Animal products n.e.c.	43	ely	Electricity
11	rmk	Raw milk		1	Nuclear
12	wol	Wool, Silk-worm cocoons		2	Gas
13	frs	Forestry		3	Oil
14	fsh	Fishing		4	Coal
15	coa	Coal		5	Hydro
16	oil	Oil		6	Wind
17	gas	Gas		7	Solar
18	omn	Minerals n.e.c.		8	Other renewables
19	cmt	Meat: Cattle, Sheep, Goats, Horse	44	gdt	Gas Distribution
20	omt	Meat products n.e.c.	45	wtr	Water
21	vol	Vegetable oils and fats	46	cns	Construction
22	mil	Dairy products	47	trd	Trade
23	pcr	Processed rice	48	otp	Transport n.e.c.
24	sgr	Sugar	49	wtp	Sea transport
25	ofd	Food products n.e.c.	50	atp	Air transport
26	b t	Beverages,Tobacco products	51	cmn	Communication
27	tex	Textiles	52	ofi	Financial services n.e.c.
28	wap	Wearing apparel	53	isr	Insurance
29	lea	Leather products	54	obs	Business services n.e.c.
30	Lum	Wood products	55	ros	Recreation and other services
31	PPP	Paper products, Publishing	56	osg	PubAdmin/De-fense/Health/Educat
32	p c	Petroleum, Coal products	57	dwe	Dwellings
33	crp	Chemical, Rubber, Plastic			

Further, to show the detailed technological levels of energy and water nexus in the IO model, this research also applies the assumption made in other studies. For example, a study done by Verdier in 2011 provides information about desalination and energy supply for future water demand (Verdier, 2011). Another study, Water in the West (2013) explores water intensities for different energy technologies and energy intensities for various water supply options (Water in the West, 2013). Similarly, for the water-food nexus in the model, studies done by Mekonnen and Hoekstra (2011, 2012) provide information about water intensities for crops and animal products.

Table 5.11: Sectors included in this research

Sectors				
Energy sectors (15)	**Food sectors (7)**	**Water sectors (6)**	**Other sectors (11)**	**Primary Factor**
Energy resource extraction	*Crops and crops products*	Surface water	*Non-food agriculture*	
Coal mining	Starchy food	Groundwater	Plant-based fiber products	Labor
Crude oil exploration	Fruit and vegetables	Desalination	Forestry	Capital
Natural gas production	*Livestock, meat and meat products*	Treated wastewater	*Industrial and Commercial services*	Land Natural resources
Uranium mining	Beef cattle	Reused treated wastewater	Textile industry	
Non-electric energy supply	Mutton and goats	Reused agricultural drainage water	Paper manufacturing	
Petroleum refining	Poultry		Heavy manufacturing	
Gas supply	Fish		Light manufacturing	**Final Demand**
Electricity supply	*Processed food manufacturing*		Intensive commercial services	
Nuclear power plant			*Transport and communication services*	Private consumption
Coal power plant			Land transport	Government expenditure
Gas power plant			Water transport	Investment
Oil power plant			Air transport	Exports
Hydroelectric power plant			Communication services	
Wind power plant				
Solar power plant				
Other Renewable power plants				
Electricity transmission & distribution				

Table 5.11 shows the list of sectors, commodities, primary production factors and final demand categories for the IO model.

To re-base the IO table and associated energy 'satellite' account from the GTAP9 database (where the latest information is available for 2011) to the year 2015 (when data for all countries was available), the model applies information published from various sources.

- The World Bank publishes annual data for different components of GDP, including private consumption, government expenditure, investment, exports and imports. All these categories of data (except imports) correspond to matrices B, C and E in Figure 5.4. The IO coefficients in these matrices can be updated with the information provided by the World Bank.
- Similarly, annually updated information from the International Energy Agency (IEA) and the US Energy Information Administration (EIA) have been used directly to update the energy accounts for 2015.

5.7 Summary and conclusion

In summary, the aims of this chapter were: i) to introduce the integrated framework based on an IO model with flexible functionality to examine the EWF nexus in the wider economy and ii) to identify the data required in the model and the methodology that can convert the raw data into a form that can be used for different assessments in this research. The main points of this chapter are summarised below:

- The integrated framework for this research consisted of four main steps:

  a) In the first module, the historical analysis was taken, to help better understand the EWF security challenges in the MENA region. The historical analysis spanned three periods of time: 1950-1970, which includes decolonisation, socio-economic improvement and state-building process in countries in the region; the 1980s, when countries started structural adjustment, Islamism became widespread and population growth in the region accelerated, and post-1990, which encompasses the transition to advanced developments, rights for women, higher levels of education and conflicts in the region.

  b) In the second module, the core methodology was developed. This methodology is based on an IO modelling approach, both for quantity and price. The basic IO model with fixed Leontief production function was replaced in this research with a flexible production function. This replacement allowed the IO coefficients to change as prices

change. The IO table was adapted from the GTAP database, the sectors of which were disaggregated further to meet the purpose of this research. The IO table was re-based to the year 2015 and other 'satellite' accounts were developed. In the third part of this methodology, the IO coefficients were adjusted to reflect technological change. As a result of new technology, new sectoral prices were estimated.

c) In the third module, the IO table was developed for the future alternative scenarios. In this research, five scenarios were created: Business-As-Usual (BAU), Energy-Oriented (ESC), Water-Oriented (WSC), Food-Oriented (FSC) and Nexus-Oriented (NSC). The results obtained from the ESC, WSC, FSC and NSC scenarios were compared with the baseline scenario (BAU) to assess the impact of technology change. The scenario analysis discusses the impact of the BAU, ESC, WSC, FSC and NSC scenarios in terms of economic and social outcomes, energy security, water security and food security for the selected countries in the MENA region.

d) In the final stage, the outcomes from all applied scenarios were examined to provide a complete policy perspective. In this module, the assessments recognise the trade-offs that may occur between policies that aim to achieve different and sometimes conflicting objectives in the various scenarios.

Chapter 6: Assessment of the impact of the scenarios (I)

In Chapter 5, the integrated framework to assess the impacts of the EWF nexus was developed. The purpose of the next two chapters is to use that framework to evaluate the impacts of the key attributes (shown in Figure 5.11), namely, economic and social attributes, as well as the energy security, water security and food security attributes in the 10 countries selected for this research. The assessment will be discussed based on the business-as-usual (BAU), energy-oriented (ESC), water-oriented (WSC), food-oriented (FSC) and nexus-oriented (NSC) scenarios. The method for applying the assessment was discussed in Sections 5.2 to 5.5 in detail.

Chapter 6 focuses on the economic and social impacts and energy security; Chapter 7 gives the results for water and food security. Both chapters discuss the short-term (2015-2030) and long-term (2030-2050) results.

Chapter 6 is organised as follows: in Section 6.1, the economic and social impacts are discussed based in terms of economic growth, trade balance, investment in key infrastructure and employment. In Section 6.2, the focus is on energy security, based on energy demand, energy intensity, energy diversity, energy import dependency and energy affordability. Section 6.3 summarises the major findings of this chapter.

6.1 Economic and social impacts

In this section, the impacts of different scenarios on economic and social key attributes are presented.

6.1.1 Economic growth

Table 6.1 provides a summary of the GDP of 10 countries in the MENA region for 2015, 2030 and 2050 according to the various scenarios.

Table 6.1: GDP of selected countries in MENA for various scenarios

	2015	2030					2050				
		BAU	ESC	WSC	FSC	NSC	BAU	ESC	WSC	FSC	NSC
	GDP ($US bn, 2010)										
Egypt	255	418	425	421	421	422	639	641	637	641	725
Iran	486	596	611	607	607	604	609	641	608	607	668
Israel	264	367	370	368	368	369	494	497	487	486	540
Kuwait	127	163	167	165	164	165	219	219	216	208	241
Morocco	105	148	150	149	149	150	202	207	205	204	213
Oman	75	112	114	116	113	115	156	160	154	152	172
Qatar	190	235	235	235	237	238	265	267	262	259	276
Saudi Arabia	659	857	870	872	865	899	1,152	1,162	1,151	1,150	1,268
Tunisia	47	66	66	66	66	69	94	91	91	90	104
UAE	424	553	556	558	556	569	693	704	690	688	768

Source: Appendix B, Section A, Table A2 and the World Bank (2019)

BAU scenario

In the **BAU scenario**, the GDP of the countries will grow at different rates in the 35 years to 2050. This economic growth will be driven mainly by increases in population. As shown in Table 6.2, the per-capita GDP income will increase more rapidly in the short term (2015-2030), (an average 0.9%) compared to the average annual growth of 0.8% in the longer term.

The largest economy in the region in 2015 belonged to Saudi Arabia and this will continue with a 1.7% average annual growth rate until 2050. It is expected that high-income countries in the region will experience moderate GDP growth over the period of 2015-2030. For example, the GDP of Oman, Israel and the UAE will improve by 1.2%, 0.9% and 0.8% respectively. In the long term (2030-2050), Israel can expect the fasted annual growth (0.9%) among the high-income countries. Qatar will experience the lowest annual growth (1%) among the high-income countries in the period 2015-2050 with 0.6% in short term (2015-2030) and 0.4% in the period 2030-2050.

Higher annual GDP growth over the 35 years to 2050 is expected for lower income countries, including Egypt (2.7%), Tunisia (2.0%) and Morocco (1.9%). Egypt will have the highest GDP growth rate of all countries in both the short and long term (4.3% and 1.2% respectively) and it will be the third largest economy in the MENA after the UAE by 2050.

Iran, the only upper income country in this research, will experience the lowest GDP growth rate over the period 2015-2050. Its GDP annual growth rate will be 0.1%, the main reason being that Iran will have the lowest population growth by 2050 (Table 6.2) (United Nations, 2019a). This means that Iran will drop from the second largest economy in 2030 to the fourth largest by 2050.

Table 6.2: Growth in population and GDP per-capita between 2015 and 2050

	2015	2030	2050	%Δ 2015-2030	%Δ 2030-2050	2015	2030	2050	*Growth rate 2015-2030*	*Growth rate 2030-2050*
	Population (million)					*GDP per-capita (constant 2010US$)*				
Egypt	93.8	119.7	153.4	28	28	2,710	3,492	4,163	0.7%	1.2%
Iran	78.4	88.9	93.6	13	5	6,120	6,701	6,508	0.3%	0.1%
Israel	8.2	10.5	13.2	27	26	31,483	35,077	37,490	0.3%	0.9%
Kuwait	3.8	4.9	5.6	29	16	32,824	33,507	38,858	0.1%	0.8%
Morocco	34.3	40.9	45.7	19	12	3,017	3,627	4,426	0.5%	0.9%
Oman	4.0	5.0	5.6	26	12	18,396	22,427	28,170	0.6%	1.0%
Qatar	2.4	3.2	3.8	36	17	77,719	72,573	70,346	-0.2%	0.4%
Saudi Arabia	30.8	39.5	45.1	28	14	20,968	21,717	25,579	0.1%	0.8%
Tunisia	11.1	12.8	13.9	15	8	4,183	5,171	6,768	0.6%	1.0%
UAE	9.1	11.1	13.2	22	19	46,118	50,019	52,668	0.2%	0.6%

Source: Appendix B, Section A, Tables A1, A2 and A3 and United Nations, 2019a.

ESC, WSC and FSC scenarios

While the GDP for all countries would increase in the ESC, WSC and FSC scenarios by 2050, their rates of growth compared with the BAU scenario by 2050 will differ.

The **ESC scenario** will result in a slight increase (0.03% on average) in the overall GDP growth rate of all the countries compared with the BAU scenario. However, the impact vary will from one country to another−some will have positive economic growth, others, negative (Figure 6.1). Of the 10 countries in this research, the GDP for Iran, Israel, Egypt, Morocco, Oman, Saudi Arabia, the UAE and Qatar in the ESC scenario will be larger under the ESC scenario than in the BAU scenario. More specifically:

- Significant income growth of 5.3% (US$32 billion) is expected for Iran by 2050 than in the BAU scenario. Larger increases are also expected for Oman (2.6%), Morocco (2.3%). In this scenario, all countries except Tunisia and Kuwait will show economic benefit by 2050.

- In the short term, however, most of the countries can expect only a moderate increase in their GDP, the highest of these being Iran (2.5%), Kuwait (2.4%) and Oman (2.2%) compared with the BAU scenario. Tunisia is the only country likely to expect a decline in its GDP in the short run (2030) compared with the BAU scenario.

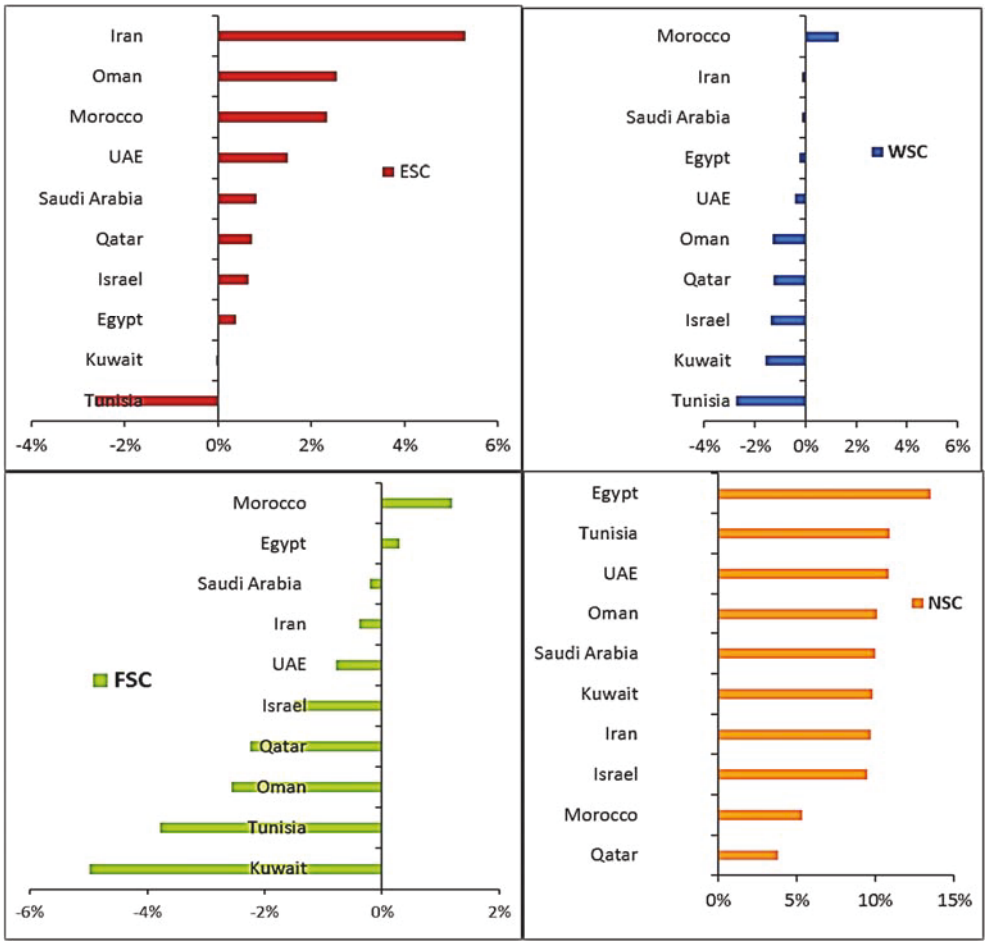
In the **WSC** and **FSC scenarios**, the GDP of the countries would worsen by 2050, Morocco would be the only country experiencing a positive impact (an increase of approximately 1.3%/US$3 billion) in both the WSC and FSC scenarios compared to the BAU scenario (Table 6.1). Egypt could also expect a slight increase (0.3%/ US$2 billion) in its GDP compared to the BAU scenario by 2050.

- In the short term, all countries except Tunisia can expect positive impacts on their GDPs from the WSC and FSC scenarios. Between 2015 and 2030, the WSC scenario will give Oman a significant boost to its GDP of 4.3% (US$5 billion) above the BAU scenario (Table 6.1) and the rest of the countries would experience a moderate increase. In the FSC scenario, all countries except Tunisia could expect a slight improvement in their GDP in the short term. Iran's GDP would increase by 1.9% (US$11 billion), Qatar's by 1.2% (US$3billion) and Oman's by 1.1% (US$1 billion) compared with the BAU by 2030. In the case of Saudi Arabia, Egypt, UAE, Morocco, Israel and Kuwait, the growth rate would increase by approximately 1% in the FSC scenario by 2030.

- However, the impact of the WSC and FSC would show the reverse in the long term (2030-2050). Most of the countries except Morocco would experience negative impacts from in both these scenarios.

In all three scenarios, two of the 10 countries show consistent behaviour in terms of their GDP: Tunisia shows a moderate reduction in its GDP by 2050 and Morocco an increase.

Figure 6.1: Change in Gross Domestic Product (GDP) in 2050 compared with the BAU



Source: see Appendix B, Section A, Tables A1, A2 & A3

NSC scenario

In contrast to the ESC, WSC and FSC scenarios, the **NSC scenario** would improve the GDP of all the countries significantly by 2050.

- Significant economic gains would be experienced by Saudi Arabia, Oman, the UAE, Egypt and Tunisia by 2050, ranging from 10% to 14% compared to the BAU scenario. Higher economic growth in Egypt could result in its GDP in 2050 being US$725 billion, as compared with US$638.7 billion in the BAU scenario (Table 6.1).

- It is forecast that the rest of the countries would experience significant impact from the NSC scenario by 2050 but their annual rate of growth would be approximately 3.8% to 10%. In this group, Qatar would experience the lowest rate of growth (3.8%) and Kuwait the highest (9.8%) by 2050.

- In the short term (2015-2030), all countries could expect to improve their GDP by an average of 2.2% annually but in the longer term (2030-2050) the annual growth would be approximately three times that (9.4%) (Table 6.1).

- Overall, if the NSC scenario was implemented in all the selected countries in the region, the GDP of the MENA could expect a US$451 billion improvement compared with the BAU scenario by 2050. Based on this scenario, Saudi Arabia would have the largest economy in MENA with US$1267.9 trillion, followed by the UAE (US$768.5 billion) and Egypt (US$725.1 billion) by 2050.

6.1.2 Trade balance

BAU scenario

In the BAU scenario, the trade (export-import) of goods and services will improve for all the selected countries except for Israel. The trade results for the individual countries are summarised below:

- In 2015 four out of the 10 countries in this research, namely Egypt, Israel, Morocco and Tunisia, were facing a trade deficit. In this group, Israel spent the lowest amount of its GDP (6%) on importing goods and services, which would decline further to 4% by 2050. Egypt and Morocco spent around 20% of their income on imports, while Tunisia spent 44% of its GDP on imports goods and services. This share is expected to decrease to 20% for Tunisia and 9% for Morocco by 2050 in the BAU scenario. All these countries could expect the same trend in the short term by 2030, except for Egypt, whose deficit would fall a further 1% (Table 6.3).

- The majority of the countries, specifically Iran, Kuwait, Oman, Qatar, Saudi Arabia and the UAE, are considered to be in trade surplus. Of these, Qatar and the UAE derive the highest share of their GDP (39%) from exports, a percentage that contributed US$74.8 billion of national income to Qatar and US$164.9 billion to the UAE in 2015. However, it is expected that the trade surplus for Qatar, UAE, Oman and Kuwait will decline over the period 2015-2050 as the source of economic growth shifts to the domestic market (particularly household consumption and investment) and the contribution of net exports

to the GDP will fall. In Saudi Arabia, the proportion of GDP provided by exports is likely to remain unchanged in the future (see Table 6.3).

Table 6.3: Trade balance of selected countries in MENA for various scenarios

	2015	2030					2050				
		BAU	ESC	WSC	FSC	NSC	BAU	ESC	WSC	FSC	NSC
	Trade balance (net exports) US$ billion										
Egypt	-49	-83	-82	-81	-79	-81	-114	-108	-129	-121	-111
Iran	2	5	4	4	14	3	-1	3	0	2	9
Israel	-17	-16	-17	-17	-17	-16	-9	-11	-11	-11	-7
Kuwait	33	40	40	40	40	41	51	48	46	50	56
Morocco	-21	-22	-20	-20	-18	-24	-19	-14	-14	-7	-13
Oman	20	27	24	24	24	26	26	22	22	21	30
Qatar	75	82	83	83	83	81	75	79	76	76	80
Saudi Arabia	80	99	102	103	103	102	134	134	138	139	139
Tunisia	-21	-22	-20	-20	-18	-24	-19	-14	-14	-7	-13
UAE	165	197	191	194	193	195	219	205	211	208	224

Source: See Appendix B, Section A, Table A4

- The trade surplus position for Iran is likely to change in the years to come. In 2015, net exports contribute to 0.4% to the share of the GDP and bring US$2.1 billion of income to the country. However, by 2050, Iran would become a trade deficit country in the BAU scenario and 0.2% (US$1billion) of its income would be transferred to other countries. Iran currently earning US$85 billion of income from exporting energy and spending about US$75 billion on importing food, industrial goods and transport services. In 2050 however, it is likely that Iran earns US$105 billion from exporting energy while spending about US$106.5 billion on importing the same goods and services.

- In contrast, Iran would expect a further surplus in the short term with 0.8 % share of GDP, which will bring US$5 billion of income into the country in 2030 (Table 6.3).

ESC, WSC and FSC scenarios

In these three scenarios, the impact on the trade balance would differ from country to country in this research (Figure 6.2). Some countries would follow the same trend in the ESC, WSC and FSC scenarios. For example, the Qatar and Morocco trade balance would improve while the UAE and Oman would experience a reduction compared with the BAU scenario.

In the **ESC scenario,** five out of the 10 countries would experience a decline in their trade positions, with a noticeable increase in their net imports (compared with BAU scenario) by 2050.

- Among the lower income countries, the trade balance would be impacted positively. Egypt, Morocco and Tunisia would experience fewer imports by approximately US$5.1

billion in this scenario, reflected by a decline in the share of GDP from importing good and services to 17%, 7% and 15% respectively by 2050. Iran as an upper income country would also experience an improvement in its trade balance by US$3.5 billion, which would give the country a trade surplus by 2050.

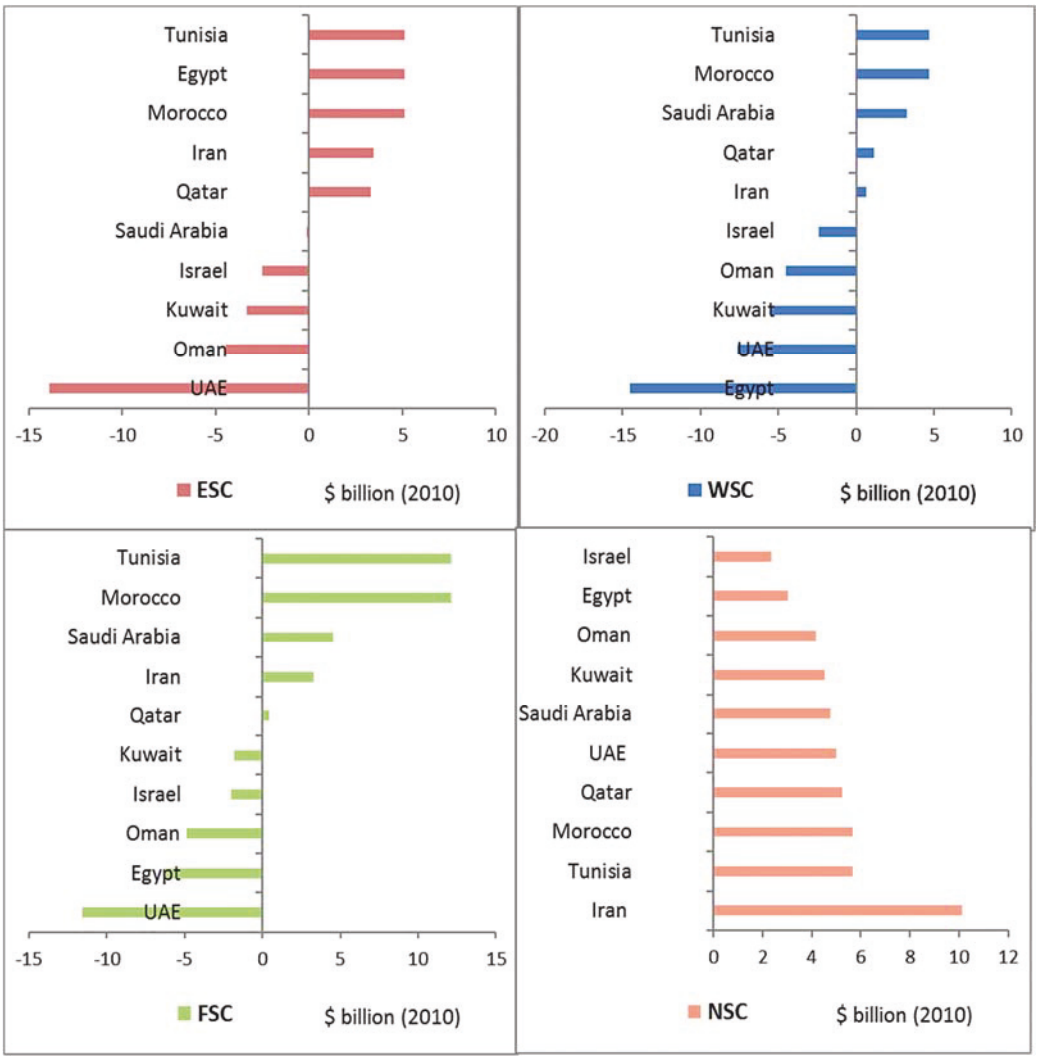
- Among the high-income countries, the UAE, Israel, Oman, Kuwait and Saudi Arabia are likely to experience a reduction in their trade balance compared with the BAU scenario, ranging in value from US$0.1 billion for Saudi Arabia to US$13.9 billion for the UAE. The most common reason for this reduction in the oil exporting countries would be a slight decrease in their net exports of energy and an increase in their net imports of food and industrial goods. For example, in the ESC scenario, Oman and the UAE would export 1% more energy but their food imports, particularly crops, would increase by 23% in Oman and 5% in the UAE. In addition, the UAE would experience a significant upsurge of 10% in its imports of industrial goods and Oman an upsurge of 7% by 2050 (Figure 6.2).

- In the short term (2015-2030), UAE, Oman and Israel could expect the same trend as the long term. However, Saudi Arabia and Kuwait would experience a better trade balance with US$3.1billion (12% of GDP) and US$0.6 billion (24% of GDP) further income in the ESC scenario, respectively, compared with the BAU by 2030 (Table 6.3).

- In contrast to the long term (2030-2050), Iran could expect a negative impact on its trade balance by 2030 through increased imports of goods and services by US$0.9 billion (1% of GDP) compared with 0.8% of GDP in the BAU scenario. An increase in the import of industrial goods would be the main reason for this reduction.

- Other countries in this research could expect the same trend as those mentioned above in both short and long terms in this scenario.

Figure 6.2: Change in trade balance in 2050 compared with the BAU



Source: See Appendix B, Section A, Table A4

In the **WSC** and **FSC scenarios**, while Egypt, the UAE, Oman, Israel and Kuwait could experience negative impacts, the other countries could expect improvement in their trade balance positions by 2050. In the long term, countries could expect the following results in the WSC and FSC scenarios (Figure 6.2):

- Both the three trade-surplus countries of the UAE, Kuwait and Oman and the trade deficit countries of Egypt and Israel could expect a decline in their trade balance in long term. Except Egypt and the UAE, the countries in this category would find their trade balances affect only moderately in both scenarios. In the WSC scenario, Egypt would experience a further trade deficit fall by US$14.5 billion due to the additional imports of food and industrial goods and the UAE would be similarly affected in the FSC scenario which would fall by a further US$11.6 billion.

- In the **WSC and FSC scenarios**, the largest impact in terms of GDP losses is likely to be felt by Oman, where the trade balance is expected to decrease compared to the BAU scenario. Its GDP will fall by US$4.5 billion in the WSC and by US$4.9 billion in the FSC by 2050, in both cases, an amount equivalent to 3% of Oman's GDP. In terms of Kuwait and Israel, the loss in net exports by 2050 will be moderate: US$1.8 billion in Kuwait and US$2 billion in Israel in FSC scenario.

- Analysis shows that the **WSC scenario** is likely to produce better outcomes for Qatar, Iran, Morocco, Saudi Arabia and Tunisia. Tunisia's and Morocco's trade positions, for example, would improve significantly, by US$4.7 billion, which is equivalent to 4% and 2% of their respective GDPs. Decreases in energy imports by Tunisia and in agricultural goods (particularly processed food) by Morocco would be the main reason for this decline. In terms of Qatar, with an extra US$1.1 billion GDP, and Saudi Arabia, with an extra US$3.2 billion GDP, the changes in their trade balance would be moderate due to increases in their energy exports.

- In the **FSC scenario**, Tunisia, Morocco, Saudi Arabia, Iran and Qatar are likely to experience an increased surplus by 2050. The greatest impact in terms of GDP gain would be in Tunisia and Morocco, both of whose trade deficits would decrease further compared to the BAU scenario by US$12.1 billion. These amounts are roughly equivalent to 8% and 3% of their respective GDPs. While both countries would experience significant improvement in their net exports, the reasons for that vary: for Tunisia the main cause would be the decline in imported energy (oil and gas) while in Morocco the decline would be attributable to increased food exports, particularly crops and processed food. Iran and Saudi Arabia would experience US$3.3 billion and US$4.5 billion improvements respectively in their trade positions by 2050.

In the short term (2015-2030), however, the trend among the countries is slightly different (Table 6.3).

- In the **WSC scenario**, countries experiencing a trade surplus, such as Iran, Oman, and the UAE, and Israel as a trade deficit country, would expect a moderate reduction in their trade by 2030. The highest loss in terms of GDP would occur in Oman (3%) and the UAE (2%), countries that could reduce their net exports by US$2.7 billion and US$2.8 billion respectively. The main reason for this loss compared to the BAU

scenario would be further food imports. The rest of the countries in this scenario would experience an improvement in their trade balance positions. For example, Tunisia would expect the highest impact on its GDP with 2% improvement, equivalent to US$1.5 billion.

- In the **FSC scenario**, analysis shows that most countries except the UAE, Oman and Israel would experience an increase in their trade balance. Iran, Egypt and Saudi Arabia could expect significant improvements in their net exports by 2030, specifically US$9.1 billion, US$4.7 billion and US$4.5 billion respectively.

NSC scenario

In the **NSC scenario,** all the countries would improve their trade balance considerably. In general, the common reason for improvement in trade would be an increase in the export of energy (particularly oil and gas) and reduced imports of industrial goods and commercial services. The long-term trade impacts for the individual countries are summarised below:

- Due to the size of its economy, Iran is expected to experience an additional US$10 billion of net export in its GDP, compared with its deficit of US$1billion in the BAU scenario. This will enable the country to maintain its trade surplus status in the NSC scenario. While the country could expect to export more oil and gas than in the other scenarios, its dependence on commercial and transport services imports would decline significantly compared with the BAU scenario.

- Tunisia and Morocco are the two countries that could expect significant improvements in their trade deficit by 2050. Morocco's trade balance, for example, would improve against the BAU scenario by US$5.7 billion, mainly due to decreases in its importation of energy (coal and oil), industrial goods and commercial and transportation services.

- With the exception of Tunisia and Egypt, all the countries in this research would experience improved trade balances in the NSC scenario compared with the other scenarios. Tunisia in the FSC scenario could see its trade deficit decline significantly by around US$6 billion compared to the NSC while Egypt would probably be US$3.4 billion better off from export revenue in the ESC scenario than in the NSC scenario.

In the short run however, the situation for most of the countries in this research is the reverse (Table 6.3).

- Six (6) out of 10 countries are likely to face further decline in their trade positions in the NSC scenario by 2030. These countries include Iran, the UAE, Tunisia, Morocco, Oman and Qatar. Israel would experience the same trade position as in the BAU scenario, while Kuwait, Egypt and Saudi Arabia are likely to experience improved trade balances in the NSC scenario compared with the BAU.

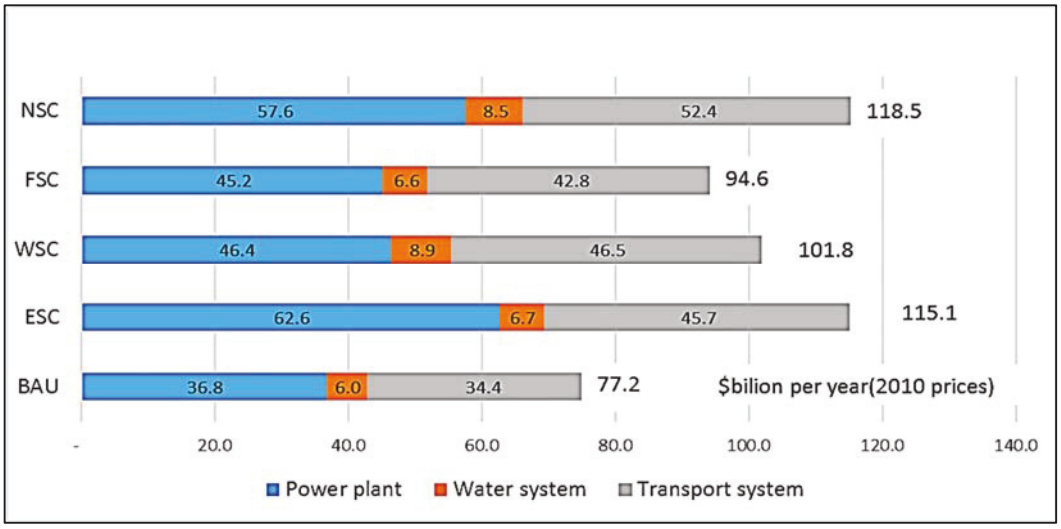
- In the NSC scenario, all the selected countries in the MENA region would experience a greater decline (by US$3 billion together) in their trade position by 2030 from the BAU scenario than they would in the ESC, WSC and FSC scenarios. On average, the FSC scenario would give the selected countries a better outcome with additional US$20 billion (together) in export revenue by 2030. In addition to the export of oil and gas (as seen in other scenarios), The main reason for the significant impact on trade balance in FSC scenario is reduction in importing food and commercial and transport services by 2030.

6.1.3 Investment in key infrastructure

Increase in infrastructure investment is an important driver for economic growth. Overall, across all the countries in this research, in the **BAU scenario**, it is estimated that approximately US$77.2 billion per year (or nearly US$2.7 trillion over the period 2015-2050) will be invested in electricity, water and transport infrastructure (Figure 6.3)[18]. Much of the investment (US$36.8 billion) would be needed to develop new power plants. About US$34.4 billion would be required for transportation systems, mainly land transport, such as roads, railways and pipelines. However, investment in water system (mainly desalination systems) would be US$6.0 billion. The analysis of investment in this research shows that the investment trend varies across the countries in this research.

[18] The value of annual infrastructure investment estimated in this research is within the same range as reported by the World Bank (2012)

Figure 6.3: investment requirements for key infrastructure, 2015-2050 compared with the BAU scenario



Source: See Appendix B, Section A, Tables A5 to A7

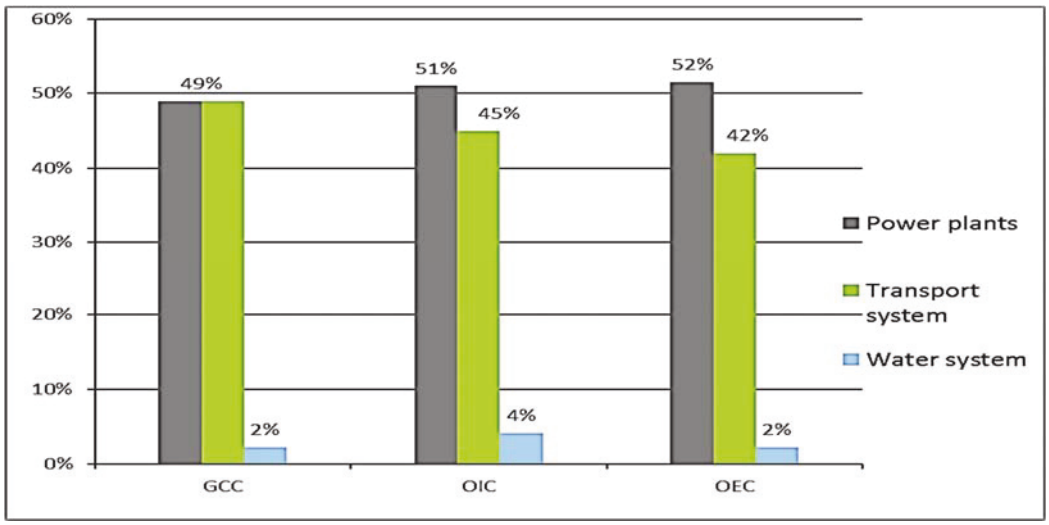
- Power plant infrastructure is expected to be the main recipient of investment funds over the 35 years in all of the countries in this research (Figure 6.4). For example, the investment needed for new power plants in Egypt, Morocco and Tunisia as oil importer countries (OIC) is likely to exceed 50% of total investment requirements. Significant power plant infrastructure investment is also needed in Iran as a developing oil exporting country (OEC).

- Many countries are also expected to invest in improving transport infrastructure (Figure 6.4). An average transportation system would require 45% of total investment for all the countries in this research. The GCC, which includes Kuwait, Oman, Qatar, Saudi Arabia and the UAE, in particular, would require more than the average, almost 50% of its total investment in this type of infrastructure, equal to the investment in power plants.

- In relation to water systems, overall, most countries in this research would spend less than 5% of their investment funds on improving water infrastructure while they do not have sufficient water resources (see Section 7.1.1 in Chapter 7). In Figure 6.4, the highest investment on water systems belongs to the OIC countries (Israel, Egypt, Morocco and Tunisia) which are likely to spend 4% of total investment in developing water infrastructure. This is equivalent to approximately US$540 million (Israel), US$670 million (Egypt), US$220 million (Morocco) and US$101 million (Tunisia) annually.

- Saudi Arabia will require a significant amount of money over the 35 years from 2015 to 2050 to develop new power plants, water and transportation infrastructure. Annual investment in such infrastructure is expected to be US$35.7billion, which is about one-third of the total investment in all countries in this research. Saudi's government will invest most of these funds in developing power plants and transport infrastructure.

Figure 6.4: Required investment for key infrastructure in BAU, 2015-2050



	2015-2030					2030-2050				
	BAU	ESC	WSC	FSC	NSC	BAU	ESC	WSC	FSC	NSC
	Investment in key infrastructure (US$bn, 2010)									
Egypt	68	109	86	90	98	199	375	252	307	390
Iran	168	239	205	152	194	319	428	403	282	447
Israel	60	87	78	68	77	154	315	274	213	335
Kuwait	43	82	74	60	54	112	240	175	167	265
Morocco	24	55	44	37	37	63	137	112	111	89
Oman	29	37	36	35	35	80	100	97	95	110
Qatar	61	59	69	70	136	136	145	194	187	169
Saudi Arabia	171	214	213	208	233	476	685	677	665	692
Tunisia	11	15	11	12	19	29	32	26	29	47
UAE	144	143	152	119	174	354	531	386	402	547

Source: See Appendix B, Section A, Tables A5 to A7 and Freund & Ianchovichina (2012)[19].

ESC, WSC and FSC scenarios

The impact of these three scenarios was different in terms of investment for most of the countries (Figure 6.5). In all of these scenarios for most countries, the investment in key infrastructure would be improved compared with BAU scenario by 2050.

[19] Gulf Cooperation Council (GCC): Kuwait, Oman, Qatar, Saudi Arabia and the UAE
Oil Importing Countries (OIC): Israel, Egypt, Morocco and Tunisia
Developing oil exporting countries (OEC): Iran

In the **energy-oriented scenario (ESC)**, the results show a significant increase in investment in power plants, in order to support the transition from inefficient fossil fuel power plants to advanced large-scale technologies, such as efficient fossil-fuelled, large scale renewable power plants and nuclear power plants. The infrastructure investment plan is likely to vary significantly among the countries in the different scenarios.

- While all the countries in this research would need to improve the infrastructure of their power plant systems, Israel and the UAE would spend a significant amount of investment among the selected countries by 2050 (see Figure 6.5). The UAE, in particular, would require an extra US$4.1 billion per year (on top of the US$6.8 billion required in the BAU scenario) over the 35 years to build new power plants. For new large renewable power plants, there would be a need for further additional investment in the power sector. Israel would need to invest an extra US$4.7 billion annually, and its total investment in power plants by 2050 would be 0.2% of GDP in the ESC scenario. The UAE's investment in power plants in the long term (2030-2050) would be 61% of total investment and that of Israel would be 70% of total investment (see Figure 6.4).

- In some of the selected countries, investment in power plants would increase marginally in the ESC scenario compared to the BAU scenario, while in others it would decrease. The countries with a marginal increase in their investment comprise Oman and Tunisia. It is expected that Oman and Tunisia additionally increase their investment by about US$4 billion and US$1billion, respectively on top of the investment in the BAU scenario in the ESC scenario over the period of 2015 to 2050. Oman and Tunisia would spend further on power investment (particularly large-scale renewable power plants) by 2030 while the investment is likely to drop slightly compared to the BAU over the long term. However, in Qatar, the investment would decrease marginally by US$183 million annually less than the investment in the BAU scenario. This is mainly due to the lower investment in the thermal power plants in the ESC scenario.

- Since water is the main issue of the all countries in the region, water systems would require significant investment. Kuwait, Israel and the UAE in particular would spend funds improving and developing their desalination systems. Kuwait's annual investment to improve its desalination plants annually would double from US$228.6 million in the BAU scenario to US$457 million in the ESC scenario by 2050. Less than 30% of this sum would be invested in the first 15 years (2015-2030); the rest would be spent between 2030 and 2050.

- In the ESC scenario, investment in transportation systems is likely to increase in all countries except Morocco in both the short and long term compared to the BAU scenario. Morocco's investment in its transportation system would fall by US$105 million per year through to 2050 compared with the BAU scenario (see Figure 6.5).

In the **WSC** scenario, most of the countries would spend more to improve their water systems, their main challenge in this research, and that extra investment would be used to build new seawater desalination systems (see Figure 6.5).

- Iran would invest the most in its water system, an extra US$1.4 billion yearly (on top of the US$2 billion required in the BAU scenario) over the 35 years (see Figure 6.5). In the short term, the annual investment would be US$2.3 billion, more than half of the long term (2030-2050) annual investment.

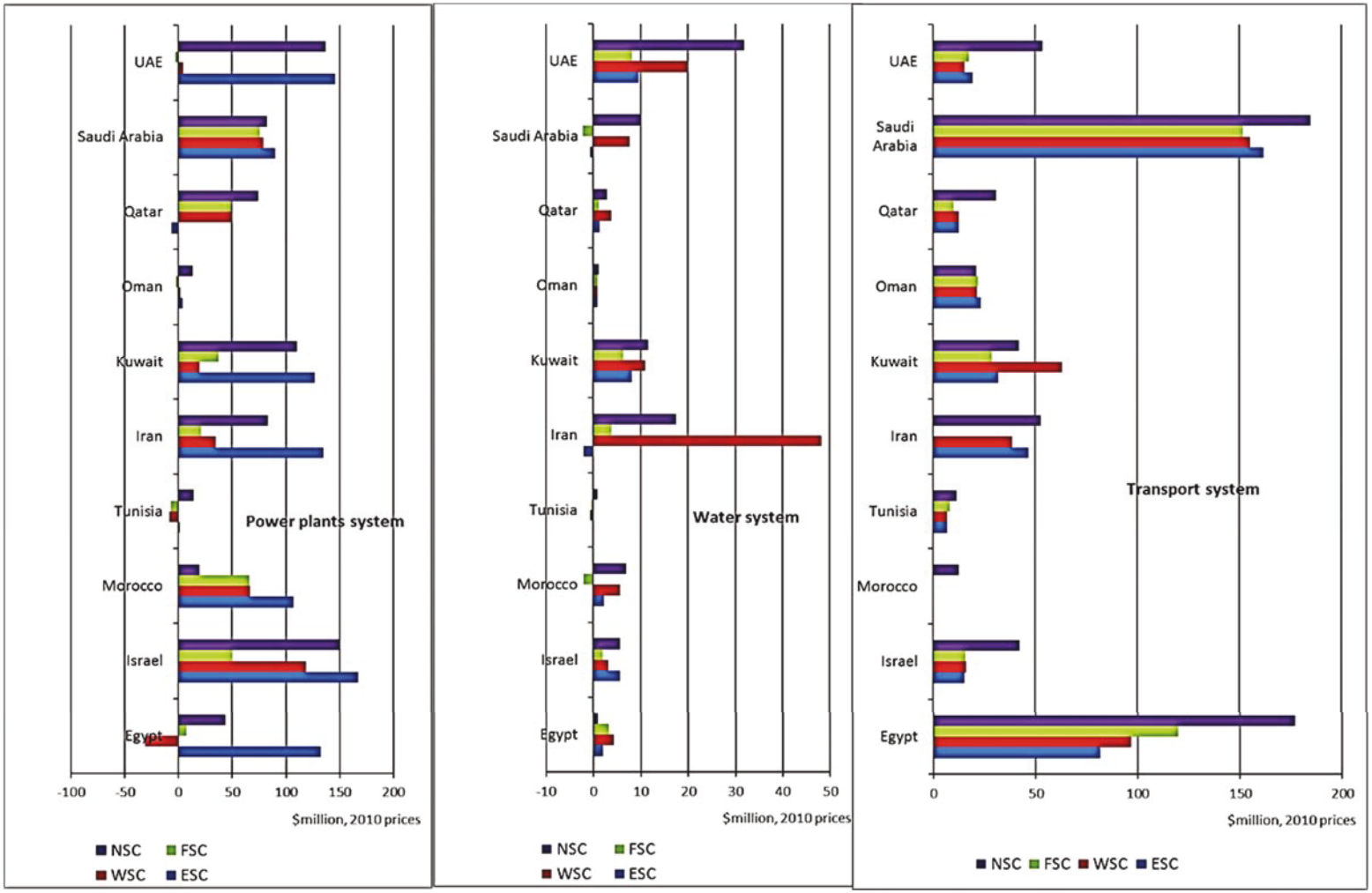
- Among high-income countries, Saudi Arabia and the UAE would make a significant investment in their water systems, particularly seawater desalination and relatively in treated wastewater. Saudi Arabia and the UAE would spend annually an additional US$218 million and US$571 million (on top of the investment in the BAU scenario), respectively, over the 35 years to 2050.

- Tunisia is the only country that would invest less (US$612 million) on its water system in the WSC scenario compared to BAU over the 35 years to 2050.

- Power plant systems in all countries also would receive extra investment in this scenario, mainly to support new water technology systems. For example, Saudi Arabia would need to spend an extra US$2.3 billion annually compared with the BAU scenario on renewable power plants to support the electricity required for seawater desalination and treated wastewater systems. Similarly, Morocco and Israel would spend approximately two times more on their power plant systems compared with the BAU scenario, an additional US$1.8 billion and US$3.4 billion, respectively, by 2050.

- Countries such as Egypt and Tunisia are likely to spend less on their power plants system both in the short term and the long term. For instance, Egypt would spend US$3.7 billion annually, US$885 million less per year compared with the BAU over the 35 years to 2050.

Figure 6.5: Additional investment requirements for the MENA countries (compared with BAU)



Source: Appendix B, Section A, Tables A5 to A7 and Freund & Ianchovichina (2012)

In the **FSC** scenario, the focus for investment in all countries except Morocco and Iran would be on their transportation systems compared with the BAU scenario, while investment in power plants and water systems would also increase. The extra investment in transportation would improve food accessibility, which is one of the challenges for the countries in this research. As in the other two scenarios, the level of investment would vary across the countries. For example:

- Egypt and Saudi Arabia, in total, would spend most of their investment on transportation systems in the FSC scenario (on the top of the investment required in the BAU scenario). Egypt's annual spend would be US$6.7 billion, totalling US$234 billion for its transportation system, particularly land transportation, over the 35 years to 2050. This is equivalent to 1.6% of the country's GDP in 2030 and 1% of the GDP in 2050. In the case of Saudi Arabia, the investment would increase by 51%, an extra US$151.5 billion on top of the US$299 billion required in the BAU scenario.

- Iran and Morocco are the two countries whose investment in their transportation systems would drop in the FSC scenario. Iran's investment on transportation system would decline by US$2.2 billion yearly. The rate of change of investment in this sector is slower in the short term as compared to the long term. In the case of Morocco, the decline in investment would be US$81 million yearly.

- The investment in power plants and water systems in this scenario would improve at a medium rate in most of the countries. Kuwait and the UAE would spend significantly on its water system to improve the agricultural system in the countries, an extra US$181 million and US$233 million per year, respectively, over 35 years, but this is less than their investment in water in the ESC and WSC scenarios. For the power plant system, Morocco and Saudi Arabia would devote an annual investment of US$3 billion (compared with US$1.2 billion yearly in the BAU scenario) and US$11 billion (compared with US$8.8 billion yearly in the BAU scenario), respectively, by 2050.

NSC scenario

The **NSC** scenario results show significantly increased investment in transportation systems, particularly land transportation, in order to improve food accessibility in both the short and long terms. The growth rate of investment in the long term (2030-2050) would be faster than that in the short term (2015-2030) due to investment in new infrastructure and maintenance. However, in this scenario compared to the other scenarios, more overall investment would be required across all the selected countries. In this scenario, overall funds for water systems would increase

compared to the WSC scenario, the extra investment going to improve treated wastewater systems in all the countries. While the investment would generally be significant in this scenario, individual countries would have different infrastructure investment landscapes. For example:

- Compared with the BAU, ESC, WSC and FSC scenarios, investment in transport systems in the NSC scenario is expected to be larger for most of the countries (except for Kuwait and Oman) in this research (see Figure 6.5). Kuwait and Oman are likely to experience the highest investment in the transport system in ESC scenario and WSC scenario, respectively, as compared to the NSC scenario. For example, Kuwait would spend an annual investment of US$3.9 billion in its transport systems in WSC scenario as compared with US$3.3 billion yearly in the NSC scenario by 2050. The countries that would experience the most substantial investment in transport systems include Egypt and Saudi Arabia as compared to the other scenarios. For instance, Egypt would require an additional US$1.6 billion per year in this scenario compared with the FSC scenario to improve its transportation system.

- Most of the investment in transportation systems across the countries would be spent on land transportation such as roads, railways and pipelines. All countries would need to spend more than half of their total investment on land transportation alone.

- Investment in power plants in this scenario is likely to be less than in the ESC scenario for most countries in this research (see Figure 6.5). For example, Morocco would require approximately US$1.8 billion per year for the 35 years 2050 to build new electricity generation plants in NSC scenario, compared with an annual investment of US$4.2 billion in the ESC scenario. Most of the investment in NSC scenario would be needed to develop small-scale renewable power plants.

In addition to the above analysis, this study has used a GDP-investment index in order to show the importance of infrastructure investment on the aggregate output of economy. This indicator measures the sensitivity impact of the investment on GDP. Based on the results of this analysis, infrastructure investment could significantly influence the economic growth of all the countries in this research. The results of this research could demonstrate the following points:

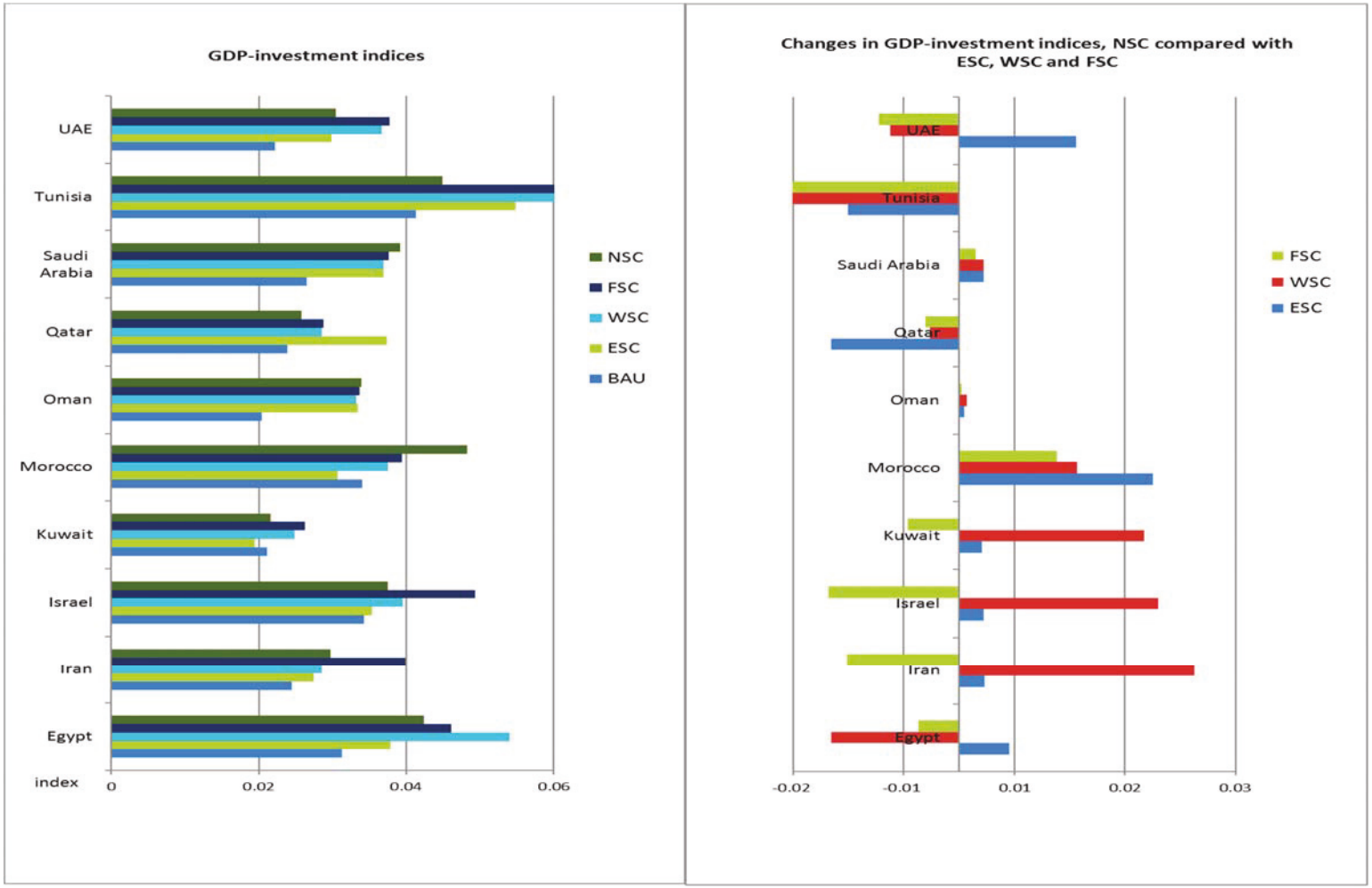
- The GDP-investment indices for all scenarios are likely to be more than those in the BAU scenario for all countries in this research (see Figure 6.6). The countries that could experience the most significant improvement in the GDP-investment index in the ESC scenario

compared with the BAU scenario are Qatar and Oman. These countries are energy exporters and improvements in their inefficient thermal power plants could bring large benefits to their economies. In the WSC scenario, the countries with the significant improvement in the GDP-investment index include Egypt, Oman, Tunisia and the UAE. Oman and the UAE rely heavily on seawater desalination to meet their water needs and extra investment in improving their desalination systems and developing their treated wastewater systems could be beneficial for their economies. In the FSC scenario, Iran, Oman, the UAE and Tunisia would be affected significantly positive, thanks to improvements in their transportation systems, which in turn could improve food accessibility and decrease the losses in the food system.

- The GDP-investment indices show different results in the NSC scenario from those in the ESC, WSC and FSC scenarios. The results reveal that the difference of GDP-investment between ESC and NSC scenarios in all countries except Qatar and Tunisia would have marginally higher GDP-investment index. In the comparison between NSC and WSC, the countries that would experience a larger GDP-investment index in the NSC scenario would be Iran, Israel, Kuwait, Morocco, Oman and Saudi Arabia. Countries including Morocco, Oman and Saudi Arabia would expect greater GDP-investment index in the NSC scenario compared to the FSC scenario. In contrast, Qatar and Tunisia are likely to experience higher economic benefits from investment in the ESC, WSC and FSC scenarios as compared with the same amount of investment in the NSC scenario.

- This suggests that investment in key infrastructure in the countries listed in each group could lead to higher GDP in the NSC scenario compared with the same degree of investment in the ESC, WSC and FSC scenarios.

Figure 6.6: GDP-Investment indices



Source: See Appendix B, Section A, Table A8

6.1.4 Employment

Table 6.4 provides a summary of employment rates for the different scenarios.

Table 6.4: Total employment in the selected countries (million persons)

		BAU	ESC	WSC	FSC	NSC	BAU	ESC	WSC	FSC	NSC
	Total employment (Mn person)										
Egypt	28,226	48,021	44,983	45,463	47,280	47,001	76,287	67,400	69,192	74,865	74,436
Iran	20,914	25,224	25,270	25,290	25,576	26,086	25,873	25,811	25,788	26,508	26,430
Israel	3,728	5,139	5,114	5,118	5,115	5,181	6,871	6,989	7,006	6,997	7,333
Kuwait	1,581	2,130	2,086	2,091	2,105	2,198	3,022	2,904	2,909	2,963	3,181
Morocco	11,542	16,132	15,895	15,929	16,024	16,073	21,385	20,823	20,833	21,269	21,617
Oman	1,323	1,985	1,988	1,990	1,986	2,078	2,815	2,792	2,818	2,807	3,106
Qatar	1,269	1,594	1,595	1,593	1,612	1,627	1,848	1,845	1,847	1,895	1,933
Saudi Arabia	11,236	15,679	15,164	15,223	15,226	15,738	22,839	21,306	21,500	21,514	23,072
Tunisia	3,349	4,752	4,664	4,665	4,650	5,098	6,794	6,524	6,527	6,509	7,175
UAE	6,102	8,183	8,278	8,192	8,125	8,588	10,659	10,371	10,624	10,457	11,767

Source: See Appendix B, Section A, Tables A9

BAU scenario

Economic growth in the **BAU** scenario is accompanied by the employment growth in the countries in this research. The overall combined economy of these countries will be double over the 35 years to 2050, creating 179 million jobs (a 99% increase compared with 2015), which could impact the whole MENA region. On average and in all these countries, new jobs are expected to be created by 2050 as follows: agriculture (28%), industrial (15%), commercial and services (38%), transport (7%), energy (11%) and water (1%). As these results show, most of these jobs will be created in commercial and services sectors, as these are the sectors that will continue to play the major role in the economy for most of the countries in this research. More specifically, the analysis shows:

- Approximately 43% of the new jobs in these countries will be created in Egypt, which by 2050 will be the third largest economy and the most populated country. The country, with an annual growth rate of 2.9%, would experience the highest growth in employment among the countries by 2050. Egypt's total population is expected to grow by 1.8% per year, from 94 million in 2015 to 153 million in 2050 (see Table 6.2). Most of the new jobs created there (39%) will be in the agriculture sector both in the short term (39%) and the long term (44%). This is due to the large contribution of the agriculture sector to the overall economy of the country. While the energy sector accounted for less than 8% of

total employment in Egypt in 2015, it is likely to experience large growth in terms of job creation, at a rate of 2.5% per year.

- Oman, Tunisia and Saudi Arabia would also experience a moderate increases in employment in the BAU scenario with total employment expected to grow by 2.2% for Oman and 2.0% for Tunisia and Saudi Arabia. Growth in the commercial and service sectors will be the common driver of job creation in Oman and Saudi Arabia while in Tunisia, the industrial sector will play a vital role in job creation by 2050.

- Other countries are likely to experience a slight increase in employment over the 35 years to 2050. Total employment in the UAE and Morocco from different income groups, for example, could increase by 1.7% and 1.9%, respectively. Most of the new jobs in Morocco is likely to create in the agriculture sector (40%), whereas the commercial and service sectors (45%) will be the main factor for new job opportunities in the UAE.

- Iran as an upper-middle income country with an annual growth rate of 1.2% will have by 2050 the lowest growth in employment among the countries in this research in the BAU scenario.

- Overall, in the short term (to 2030), countries can expect faster growth in terms of job creation compared with the long term. For example, Egypt would grow by 1.5% annually by 2030 but this rate of growth would drop to 1.3% per year between 2030 and 2050.

ESC, WSC and FSC scenarios

The employment growth impacts for all three scenarios could be negative (compared with BAU) in most of the countries by 2050.

In the **energy-oriented (ESC)** scenario, the employment growth impacts could be considerable and negative for all countries except Israel (Figure 6.7). This is due to the fall in the number of jobs created by the agricultural sector, which is generally more labour intensive than other sectors. Any additional jobs created in the energy, industrial and commercial services sectors will not be sufficient to cover the jobs lost in the agriculture sector.

- The negative employment growth impacts will be negligible for Iran (0.2%), Qatar (0.2%), and Oman (0.8%) by 2050. The number in brackets shows the percentage by which the employment will be lower in those countries in comparison with the employment rate in the BAU scenario. Morocco, the UAE and Kuwait are likely to

experience moderate negative impact, ranging from 2.6% for Morocco to 3.9% for Kuwait. The most considerable negative impact could be expected for Egypt (11.7%), Saudi Arabia (6.7%) and Tunisia (4%). The jobs lost in the agriculture sector could be expected to be replaced by other sectors in the ESC scenario. For example, in Egypt, more than 14 million jobs would be lost in the agriculture sector but only 6.3 million jobs would be created in other sectors.

- In the short term, Iran, Oman, Qatar and the UAE would expect minor improvement in terms of job creation, whereas the rest of the countries are likely to expect a negative impact in the ESC scenario compared to the BAU. For instance, Egypt and Saudi Arabia would expect 3 million and 515,000 fewer jobs, respectively, by 2030 compared with the BAU scenario (see Table 6.4).

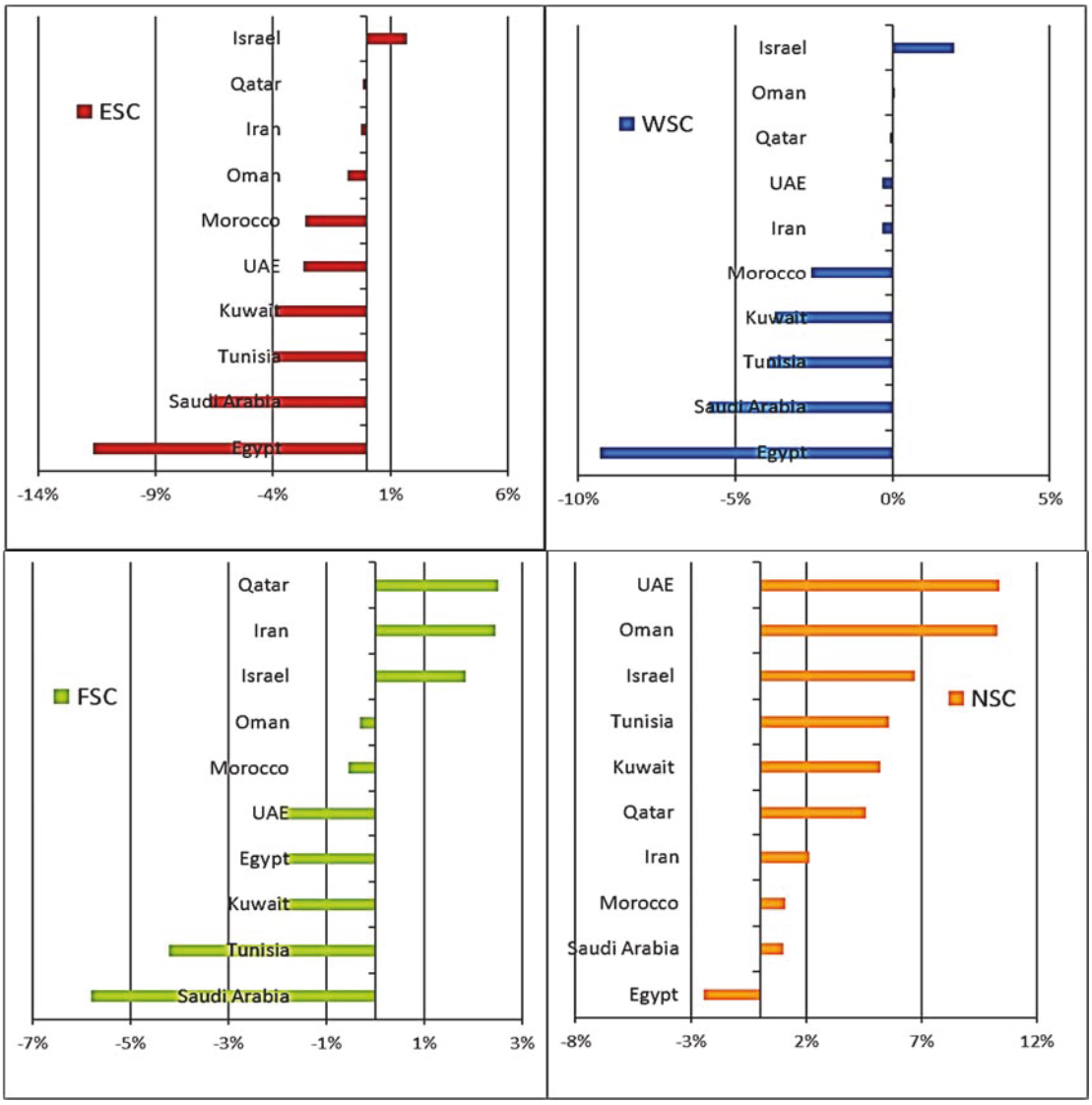
In the **water-oriented** scenario **(WSC)**, as with the ESC scenario, all countries except Oman and Israel would experience a negative impact compared to the BAU scenario.

- Israel would experience a moderate (2%) improvement in employment, mainly due to new jobs in the agriculture, industry and water sectors. In actual terms, 135,000 new jobs could be created in Israel by 2050. In Oman, the improvement in new job opportunities (0.1%) would be negligible and few new job opportunities (2500) would be created in this scenario as compared to the BAU scenario in the long term.

- The rest of the countries would face a decline in employment growth. While this could be negligible to moderate for Qatar (0.1%), Iran (0.3%), UAE (0.3%) and Morocco (2.6%), it would be considerable for Egypt (9.3%) and Saudi Arabia (5.9%). As in the ESC scenario, the significant losses in jobs would be due to the decline in the agriculture sector. In this scenario, Egypt would lose more than 13 million jobs in this sector.

- Between 2015 and 2030, Iran and the UAE, like Oman, are likely to show a negligible improvement in employment, ranging from 0.3% extra jobs for Iran and Oman to 0.1% in the UAE. Egypt and Saudi Arabia could expect the largest negative impacts in the short term, as they would in the ESC scenario (see Table 6.4).

Figure 6.7: Change in employment in 2050 compared with the BAU scenario



Source: See Appendix B, Section A, Table A9

In the **food-oriented** scenario **(FSC),** the negative impact on employment could be less than in the two other scenarios (ESC and WSC). For example:

- Iran (2.5%), Qatar (2.5%) and Israel (1.8%) could experience moderate growth in employment compared with the BAU scenario. The improved employment in Qatar and Israel would be due to the increase in jobs in the agriculture and industry sectors while in Iran the new jobs would be created in the energy sector.

- In contrast, the rest of the countries could expect falls in the creation of new jobs compared with BAU scenario, but with less employment impacts. Oman, Morocco, Egypt, the UAE and Kuwait are likely to experience negligible to slight negative impacts, ranging from 0.3% for Oman to 2% for Kuwait. Tunisia (4.2%) and Saudi Arabia (5.8%) could expect the largest negative impacts in the FSC scenario as compared to the BAU scenario (see Figure 6.7).

- Improvements in employment compared with the ESC and WSC scenarios would be due to improvements in the transport sector, which could create more jobs than the industry and energy sectors. However, these jobs would not compensate for the jobs lost in the agriculture sector. For example, Egypt would lose 7.5 million jobs in the agriculture sector, more than half those lost in the ESC and WSC scenarios. However, the transport sector would create only around 2 million extra jobs in FSC scenario. In the ESC and WSC scenarios, the sector could create 1.1 million and 1.3 million new jobs, respectively.

- In the short term, Iran (1.4%), Qatar (1.1%) and Oman (0.04%) are likely to show a slight improvement in employment, whereas the rest of the countries would experience moderate negative impact in the FSC scenario as compared to the BAU scenario (see Table 6.4).

The analysis in all three scenarios demonstrates that there is no direct correlation between employment and economic growth. In Saudi Arabia, Egypt and the UAE, although the GDP would be higher in all the three scenarios compared with the BAU scenario, employment in these countries would, in fact, be lower than the employment in the BAU scenario. For example, the Egyptian economy in the ESC scenario is likely to be 1.4% more than in the BAU scenario, but employment would be 12% lower (8.8 million fewer jobs) compared with the BAU scenario. The switch from a labour-intensive agriculture sector to a capital-intensive industrial sector is the main reason for these results.

NSC scenario

The overall employment level for the majority of the countries is likely to increase in the **NSC** scenario by 2050. Total employment in this scenario for all the countries would increase by 2.4% (828 million jobs) in the short term and by 4.5% (1660 million jobs) in the long term as compared to the BAU scenario. While jobs could be lost in the agriculture sector, new jobs would be created in other sectors of the economy. However, the impact of the scenario could vary among the countries.

- Unlike the other three scenarios, where employment was affected negatively in most of the countries, the employment impact in the NSC scenario by 2050 is likely to be positive for nine of the ten countries (except Egypt) in this research (see Figure 6.7). Significant new job opportunities will arise in Oman (10.3%), the UAE (10.4%), followed by considerable improvement for Israel (6.7%), Tunisia (5.6%), Kuwait (5.2%) and Qatar (4.6%). Iran (2.2%), Morocco (1.1%) and Saudi Arabia (1%) would experience a slight positive improvement in their employment condition in the NSC scenario (as compared to the BAU scenario) by 2050. A common trend observed in all the countries with significant impact is a shift in employment from energy and agriculture to the other sectors of the economy. For example, in the case of Oman and UAE, the transport and commercial and service sectors account for more than 50% of total new jobs created in the economy.

- In this scenario, Egypt could be the only country to experience a moderate negative impact on employment by 2050. The negative impact could, however, be 2.4% (1.8 million) fewer jobs than in the BAU scenario. Although additional job opportunities will arise in the transport and commercial and service sectors, they will not compensate for the lost job opportunities in the agriculture sector. Around 14 million jobs would be lost in agriculture sector, and just 12.8 million new jobs would be created by all the other sectors of the economy.

- In the short term, Morocco, like, Egypt, could also face a slight negative impact in terms of job creation. It is expected that employment opportunities would drop by 0.4% (59,000) in the 15 years to 2030 as compared with the BAU scenario. Significant positive impact would be experienced by Tunisia (7.3%), the UAE (4.9%) and Oman (4.7%) in terms of additional job opportunities by 2030 (see Table 6.4).

In this scenario, analysis shows no direct correlation between employment and economic growth. While the GDP in the NSC scenario in 2050 for all countries would be higher, in Egypt employment could be less. Egypt could expect the highest economic growth (13.5%/US$86.4 billion) in the NSC scenario among the countries in this research by 2050. However, it would be the only country to experience job losses (-2.4%/1.9 million) compared with the BAU scenario.

6.2 Energy security

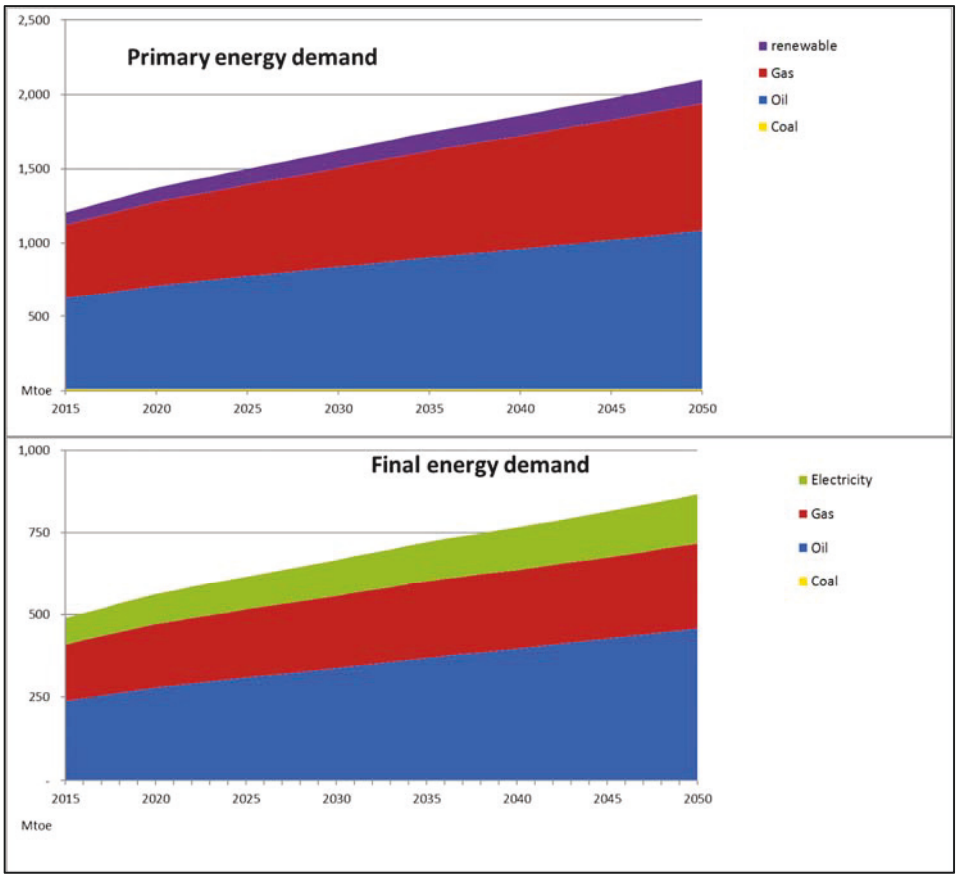
This section provides an assessment of the impact of the different scenarios on energy security for the countries in this research. The attributes used to assess energy security include energy demand, energy intensity, energy conversion efficiency, energy import dependency and energy affordability.

6.2.1 Energy demand

BAU scenario

Based on historical trends, most of the countries in this research put significant pressure on energy resources because energy is the main driver of their rich economies. For example, in the **BAU** scenario**,** the total primary energy in the countries is expected to increase, on average, by 1.6% per year, from 1187 Mtoe in 2015 to 2102 Mtoe in 2050 (see Figure 6.7).

Figure 6.8: Total energy demand for all countries in the BAU scenario



Source: See Appendix B, Section B, Tables B1 & B2

The impact on energy demand is likely to vary across countries. For example:

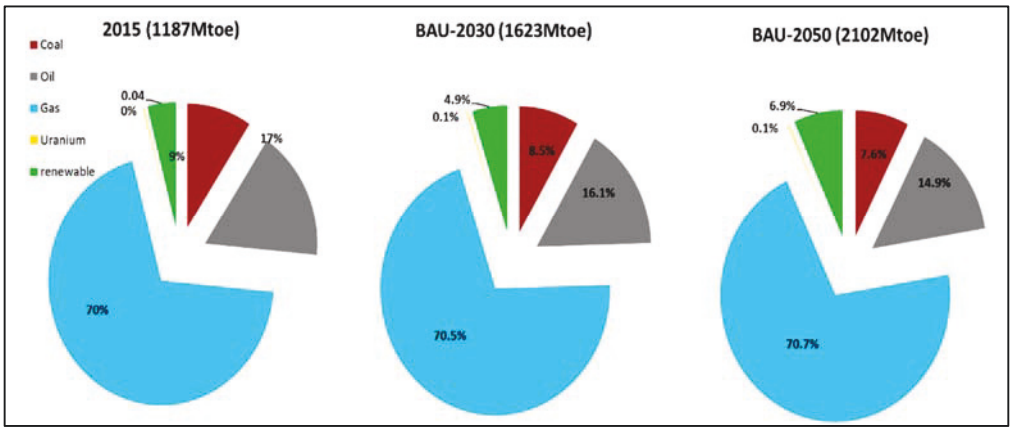
- In 2015, the 10 countries in this research accounted for 83% of the MENA region's total primary energy demand (EIA, 2015), three of them, namely Saudi Arabia, Iran and the UAE alone accounting for 30%, 26% and 11% respectively. By 2050, Saudi Arabia will be the major energy consumer among the countries, accounting for more than 35% of the total primary energy demand of the countries in this research. In contrast, the share of Iran and the UAE would reduce to 18% and 9% respectively by 2050.

- Countries with moderate growth in energy include Egypt, Oman, Saudi Arabia and Tunisia, where the primary energy demand is expected to grow by more than 2% per year over the study period. As noted in Section 6.1.1, these countries are expected to experience moderate change in their economic growth in the period to 2050, and therefore, they would need additional energy to support their economic growth. In contrast, primary energy demand in the rest of the countries (Iran, Israel, Kuwait, Morocco, Qatar and UAE) is expected to increase by less than 2% per year over the period of 2015-2050, due mainly to moderate growth in their GDPs. However, all the countries (except Kuwait and Tunisia) could expect a faster rate of primary energy demand between 2015 and 2030 compared with between 2030 and 2050.

The major changes across the countries are as follows:

- Overall, oil and gas will be the main source of energy to meeting primary energy requirements (see Figure 6.9). Apart from Israel and Morocco, which use 30% and 45% coal respectively to meet their energy demands in the long term, all the countries rely mainly on gas and oil to provide essential energy services, for both the residential and industrial sectors. Although the demand for both oil and gas will increase in the years to 2050, it is expected that the share of gas will increase more than oil share in total across all countries in the BAU scenario.

Figure 6.9: Primary energy mix overall in the selected countries in MENA in the BAU scenario



Source: See Appendix B, Section B, Table B3

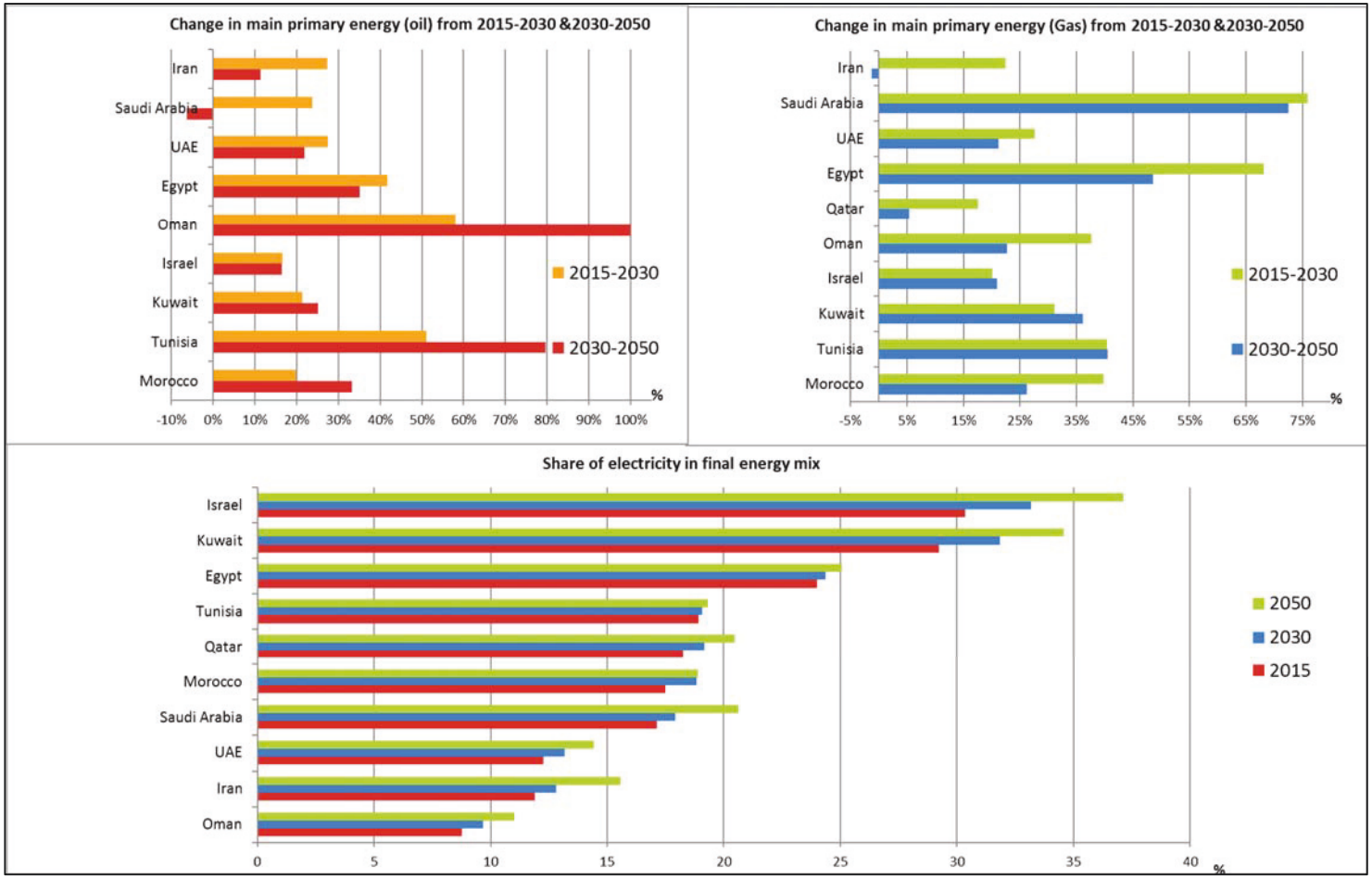
- Electricity demand accounts on average for 19% of the final energy demand. The share of electricity was between 10% and 30% in all countries except Oman in 2015 (see Figure 6.10). Electricity in Oman constituted the lowest share of total final energy demand in 2015 compare with the other countries in this research. The importance of electricity is likely to increase further in all countries in the BAU scenario. In particular, the share would go beyond 30% of total energy demand in Israel and Kuwait.

- The only country, in this scenario, which switch from traditional fossil fuels to more advanced technology would be Iran, which will continue to use nuclear energy to meet its final energy demand. However, the share of nuclear power is minor (1%) and Iran will continue to rely heavily on oil and gas as the main source of primary energy in the years to 2050.

ESC, WSC and FSC scenarios

In this section, it is expected that total primary energy demand will decrease in the ESC and WSC scenarios by 2050 but increase slightly in the FSC scenario compared with the BAU. Total primary energy demand across these countries would increase by an average of 1.5% in the ESC, 1.6% in the WSC and by 1.8% in the FSC scenarios per year (compared with 1.7% per year in the BAU scenario), reaching 1867 Mtoe, 1997 Mtoe and 2116 Mtoe respectively by 2050 (as compared with 2015) (see Figure 6.11). This is equivalent to a reduction of 11% (235 Mtoe) in the ESC scenario and 8% (162 Mtoe) in the WSC scenario and negligible additional demand in the FSC scenario, compared with the BAU scenario (2102 Mtoe). Energy efficiency improvement (through higher productivity) would be the main driver for the reduced demand, most of which would happen after 2030 (see Figure 6.11).

Figure 6.10: Share of electricity in the selected countries in MENA, BAU scenario



Source: See Appendix B, Section B, Tables B3 & B4

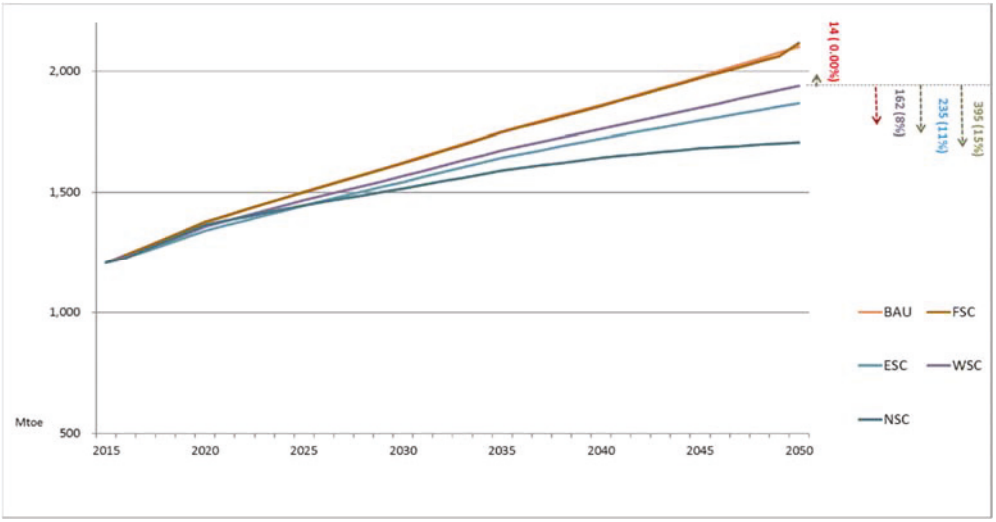
In the **energy-oriented scenario (ESC),** the primary energy demand in 2050 is likely to be less than in the BAU scenario, for all countries in this research (see Figure 6.12).

- The country that is likely to experience a substantial reduction (more than 20% compared with the BAU scenario) in primary energy demand is Tunisia (see Figure 6.12). Countries with significant reductions ranging between 10% and 20% in primary energy demand are Egypt, Israel, Kuwait, Oman, Saudi Arabia and the UAE. Among the countries in this group, Tunisia and Egypt are net energy importers and they classified as low-middle income countries.

- The rest of the countries are likely to experience a considerable reduction in primary energy demand in the ESC scenario (see Figure 6.12). For example, Qatar as high-income and Morocco as a low-middle income countries could expect reductions of between 5% and 10% in their primary energy demand. Iran, the only upper-middle income country, would experience the lowest change in energy demand compared with BAU scenario by 2050.

- The reduction in primary energy demand in the short term would be almost half of the reduction in the long term. On average, it is expected that the primary energy demand will fall by 7% (compared with BAU) across the countries by 2030 and by 14% (compared with the BAU) between 2030 and 2050. The main driver for the faster reduction in primary demand could be significant improvement in energy efficiency in the long term (see Section 6.2.3 in this chapter).

Figure 6.11: Total primary energy demand in all the countries, in all the scenarios



Source: See Appendix B, Section B, Table B1

The **water-oriented scenario (WSC)** would follow the same trend as the ESC scenario in that all countries could expect a decrease in their primary energy demand. Tunisia and Israel would experience significant reductions in their primary energy demand of 18% (4.4 Mtoe) and 10% (6.2 Mtoe) per year respectively compared with the BAU. Kuwait, Oman and the UAE are likely to experience the slight change of 1% in this scenario. The rest of the countries could expect the moderate change.

- The only country that could demand slight lees primary energy (compared with the ESC scenario) in this scenario is Iran by 2050. In the ESC scenario, the reduction in primary energy demand for the country is likely to be 2% while in the WSC scenario the reduction would increase to 4%. The rest of the countries would expect to increase the demand for primary energy in this scenario (compared with the ESC scenario) due to developing new desalination plants, which could overcome the water shortage in these countries.

- Similar to the ESC scenario, the reduction in demand for energy in this scenario will be much less as compared to the BAU scenario by 2030. On average, it is expected that the primary energy demand will fall moderately (by 2%) (Compared with BAU) across the countries by 2030 and considerable (by 5.3%) (compared with the BAU) between 2030 and 2050.Tunisia and Israel would experience a considerable reduction (6%) in this scenario in the short term but countries such as the UAE and Oman would expect more energy demand in this scenario as compared with the BAU scenario. The primary energy demand in Kuwait, Qatar and Egypt are likely to be negligible as compared to the BAU scenario (see Appendix B, Section B, Table B1).

- In the **food-oriented scenario (FSC)**, primary energy demand would be overall more than in the BAU, ESC and WSC scenarios. In contrast to the other two scenarios (WSC and ESC), not all countries would experience a reduction. Iran, Morocco and Oman (see Figure 6.12) would expect increase in their total primary energy demand by 2050. The growth in primary energy demand for Iran would be substantial (27%), rising from 386 Mtoe in the BAU scenario to 490 Mtoe in the FSC scenario. The additional primary energy demand in Morocco by 2050 would be 9% (5.2 Mtoe) compared with the BAU scenario. Increasing demand in electricity for pumping groundwater to meet the demand for water in this scenario could be the main driver behind the increased primary energy demand in all countries by 2050.

- The only country that could expect a significant reduction in its primary energy demand in this scenario is Tunisia. However, this demand would still be much higher than its

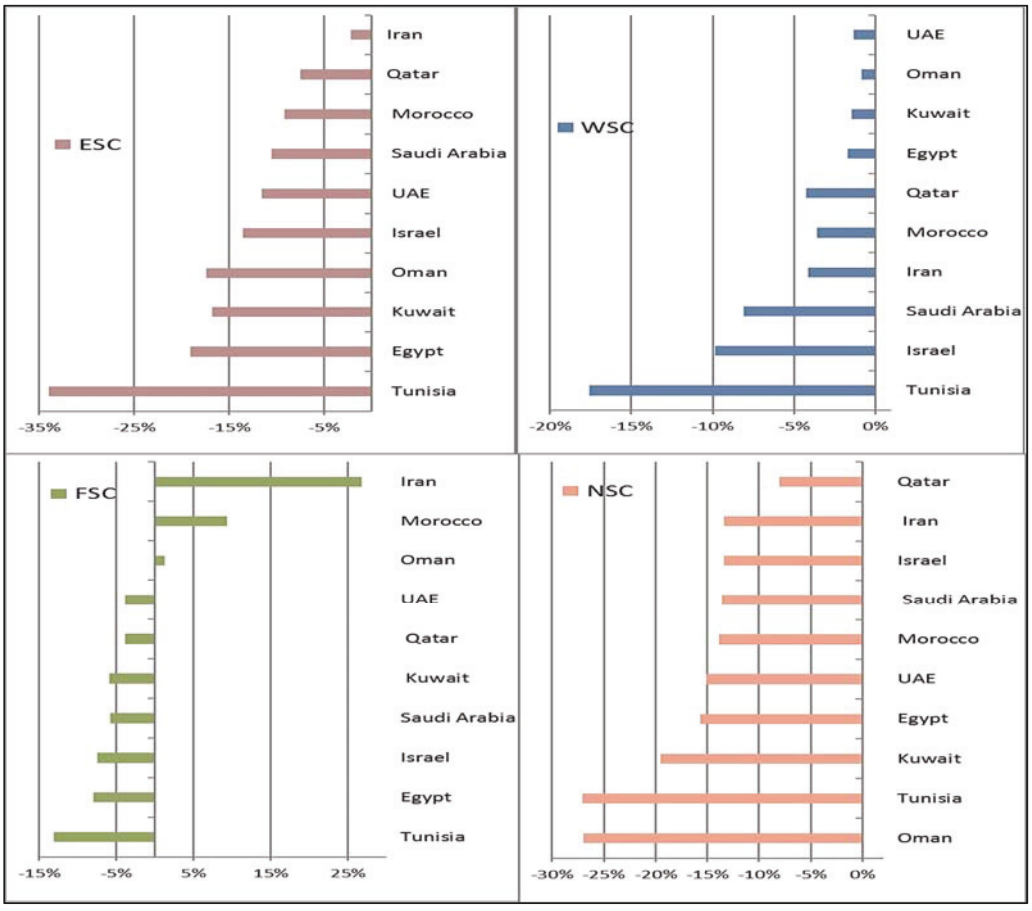
demand in the ESC and WSC scenarios. Tunisia in the FSC scenario would have a 13% reduction (3.3Mtoe) while the reduction in the ESC and WSC scenarios would be 34% (8.4 Mtoe) and 18% (4.4 Mtoe) respectively.

- The rest of the countries could expect a moderate reduction in this scenario by 2050.

- When comparing the short term and the long term, all countries would have the same trend as in the ESC and WSC scenarios but energy demand in the FSC scenario would be higher than in the BAU scenario, even, in the short term.

Of all these countries, only two would experience an increase in the use of modern energy. Iran and the UAE are likely to use uranium as one of the sources of primary energy to meet their electricity demand. Iran has the technology currently (2015) and the UAE is planning to develop the same technology by 2020. However, it is expected that oil and gas will remain the main source of energy in the countries of the study due to the political situation of the region.

Figure 6.12: Change in primary energy demand in 2050 compared with the BAU scenario



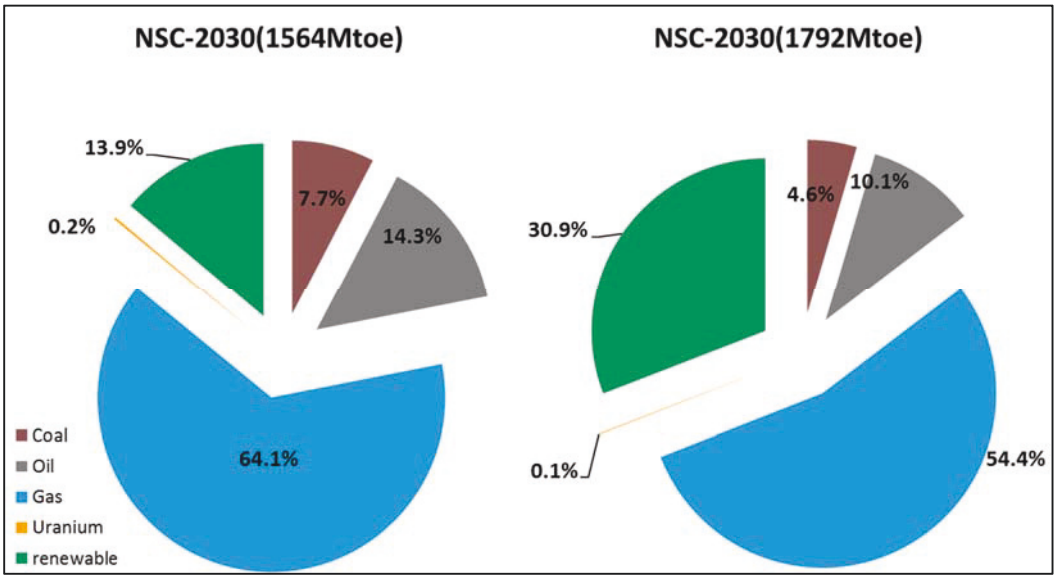
Source: See Appendix B, Section B, Table B1

NSC scenario

In the **NSC scenario,** the total primary energy demand in all the countries would rise by 1.0% per year (compared with 1.7% per year in the BAU scenario), reaching 1792 Mtoe in 2050 (see Figure 6.9 and Figure 6.13). This is equivalent to a further reduction against the ESC scenario of 2% (75 Mtoe). Most of this reduction would come from the reduced use of conventional fossil fuels (mainly oil and gas), which would vary from country to country in this research (see Figure 6.12)

- Compared with the ESC, WSC and FSC scenarios, use of primary energy in the NSC scenario is likely to be lower for the majority of the countries considered in this research (see Figure 6.12). For example, Iran's total energy demand is expected to be 335 Mtoe, which is around 11% (43 Mtoe), 10% (36 Mtoe) and 32% (155 Mtoe) lower than that in the ESC, WSC and FSC scenarios respectively by 2050.

Figure 6.13: Primary energy mix overall in the selected countries in MENA, NSC scenario



Source: See Appendix B, Section B, Table B1

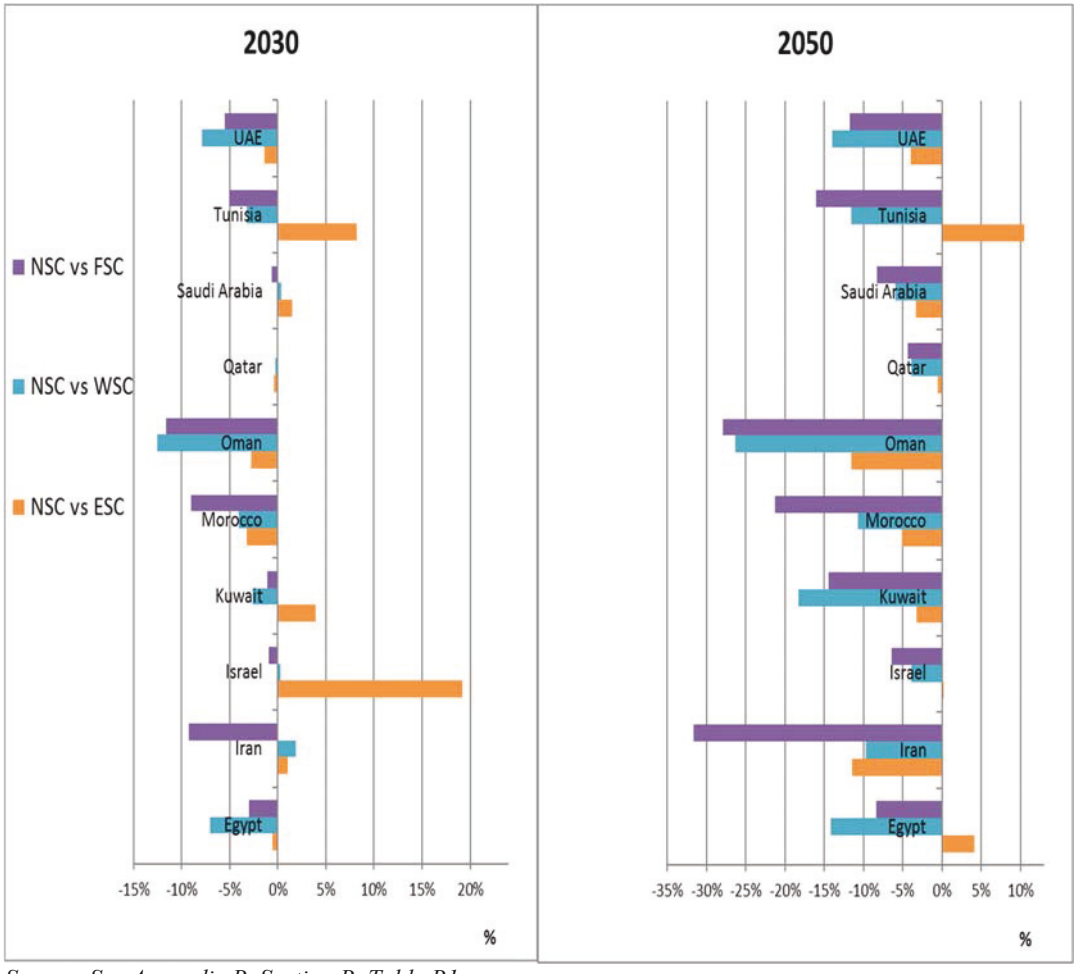
- In contrast, primary energy demand for Egypt and Tunisia (in ESC) is estimated to be lower than in the NSC scenario by 2050 (Figure 6.14). Egypt's total primary energy demand, for example, is expected to be 258 Mtoe in the NSC scenario in 2050, almost 4% (10 Mtoe) higher than in the ESC scenario.

- The model reveals that the NSC scenario would be relatively less effective in reducing energy demand in the short term as compared to the long term. The average reduction in primary energy demand in the NSC scenario will be 4% (59 Mtoe less than BAU

scenario) by 2030, whereas in the long term, such a reduction will be 15% (310 Mtoe less than in the BAU scenario) by 2050. Iran is probably the only country that is likely to show a slight increase in primary energy demand in the short term compared to the long term in the NSC scenario. In the short term, most countries would expect less primary energy demand in the NSC scenario compared to the ESC and WSC scenarios. However, countries including Iran, Israel and Saudi Arabia would expect less energy demand in both the ESC and WSC scenarios (compared to the NSC scenario). For all countries, energy demand would be less in the NSC scenario compared with the FSC scenario in both the short term and the long term (Figure 6.14).

- In the NSC scenario, as in the ESC, WSC and FSC scenarios, the demand for renewable energy will increase while demand for fossil fuels (coal, gas and oil) is likely to fall in all 10 countries (see Appendix B, Section B, Table B1).

Figure 6.14: change in primary energy demand (compared with the NSC)

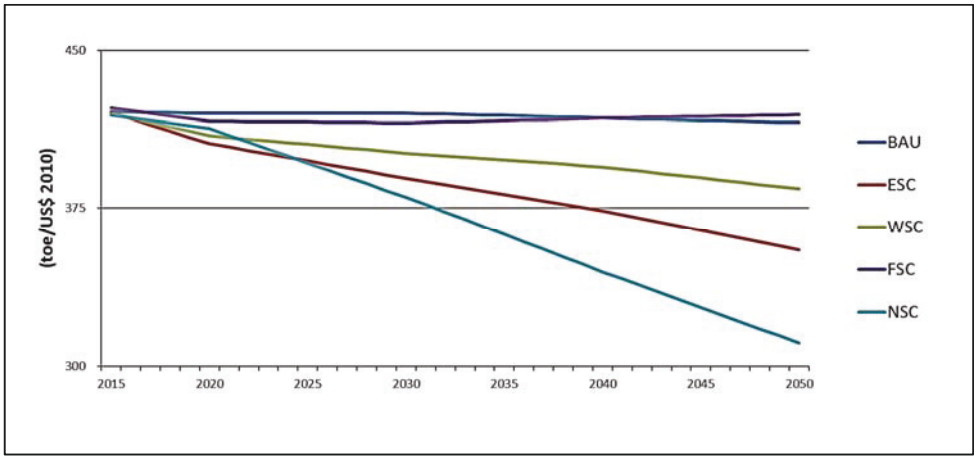


Source: See Appendix B, Section B, Table B1

6.2.2 Energy intensity

In the **BAU scenario,** the average energy intensity of the selected countries in MENA region is expected to decline slightly by 1% (or 0.03% per year) over the 35 years to 2050, from 421 toe per US$ in 2015 to 416 toe per US$ in 2050 (see Figure 6.15). This rate is expected to decline in other scenarios by 16% (or 0.5% per year, to 355 toe per US$) in the ESC scenario, by 5% (or 0.1% per year, to 400 toe per US$) in the WSC and by 25% (or 0.7% per year, to 316 toe per US$) in NSC. However, in FSC scenario, 0.1% (or 0.002% per year, to 424 toe per US$) increase is expected by 2050 (Figure 6.15).

Figure 6.15: Average energy intensity trend across the countries in various scenarios



Source: See Appendix B, Section B, Table B5

- Currently, there are contrasts in energy intensities across the 10 countries (Figure 6.16). Saudi Arabia, Iran, Kuwait, Oman and Egypt have higher energy intensities than the other countries in this research (greater than 500 toe per US$), Qatar and the UAE have energy intensities ranging between 300 and 400 toe per US$ and the rest of the countries (Israel, Morocco and Tunisia) have energy intensities that are lower than 300 toe per US$.

- In the **BAU** scenario, energy intensity is expected to decline slightly for all the countries except Saudi Arabia and Tunisia, which are likely to experience a 31% (0.9% per year) and 3% (0.08% per year) increase respectively over the 35 years. The greatest reduction−28% from 178 Mtoe in 2015 to 128 Mtoe in 2050−would be experienced by Israel (see Figure 6.16). This could be due to a reduction in the use of coal and greater use of renewables.

- A modest reduction in energy intensities is expected for Iran, Oman, Egypt and Kuwait, all of which have higher energy intensities than the other countries in this research. The reduction for these countries would be 2%, 4%, 6% and 7% respectively by 2050 in the BAU scenario.

- In the short term, energy intensities of most of the countries including Egypt, Iran, Kuwait, Morocco, Oman and the UAE would decline slightly ranging from 1.2% (Iran) to 2.9% (Kuwait). Similar as the long term, by 2030, Tunisia and Saudi Arabia would expect increase in their energy intensities while Israel would expect significant reduction.

ESC, WSC and FSC scenarios

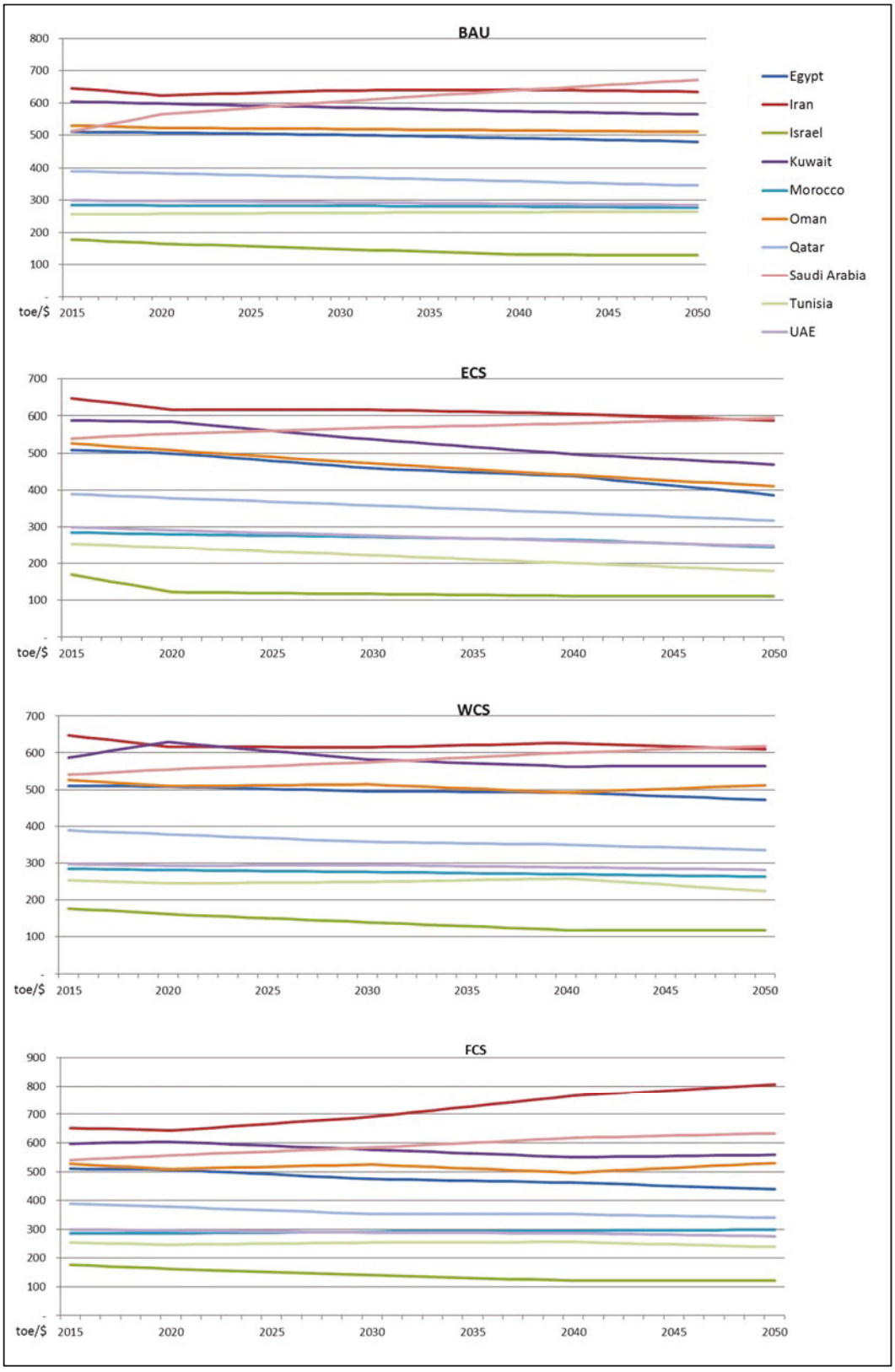
In these three scenarios, the 10 countries in this research act differently in terms of their energy intensity.

In the **energy-oriented scenario (ESC)**, the energy intensities for most of the countries decline faster than in the BAU scenario. Analysis suggest that the energy intensities of all the countries will converge to a narrower band (ranging between 110 and 595 toe per US$) by 2050 compared with the BAU scenario (where they have a range of 128 and 671 toe per US$) (see Figure 6.16).

- All countries are likely to experience some reduction in energy intensities in this scenario, both short and long term. Tunisia would expect substantial reduction of 32% (85 toe per US$. Egypt (19%), Israel (14%), Kuwait (17%), Morocco (11%), Saudi Arabia (11%), the UAE (13%) and Oman (19%) are likely to have significant reduction in their energy intensities. Iran and Qatar would decline the least by 7% (or 45 toe per US$) and 8% (or 28 toe per US$) compared to the BAU scenario by 2050 (see Figure 6.17).

- In the ESC scenario, Israel is the only country with faster reduction in its energy intensities in the short term (by 21%) as compared to the long term (14%). The rest of the country would experience slower decline by 2030 and faster drop in their energy intensities in the long term in ESC scenario.

Figure 6.16: Energy intensity in the countries in the BAU, ESC, WSC and FSC *scenarios*



Source: See Appendix B, Section B, Table B5

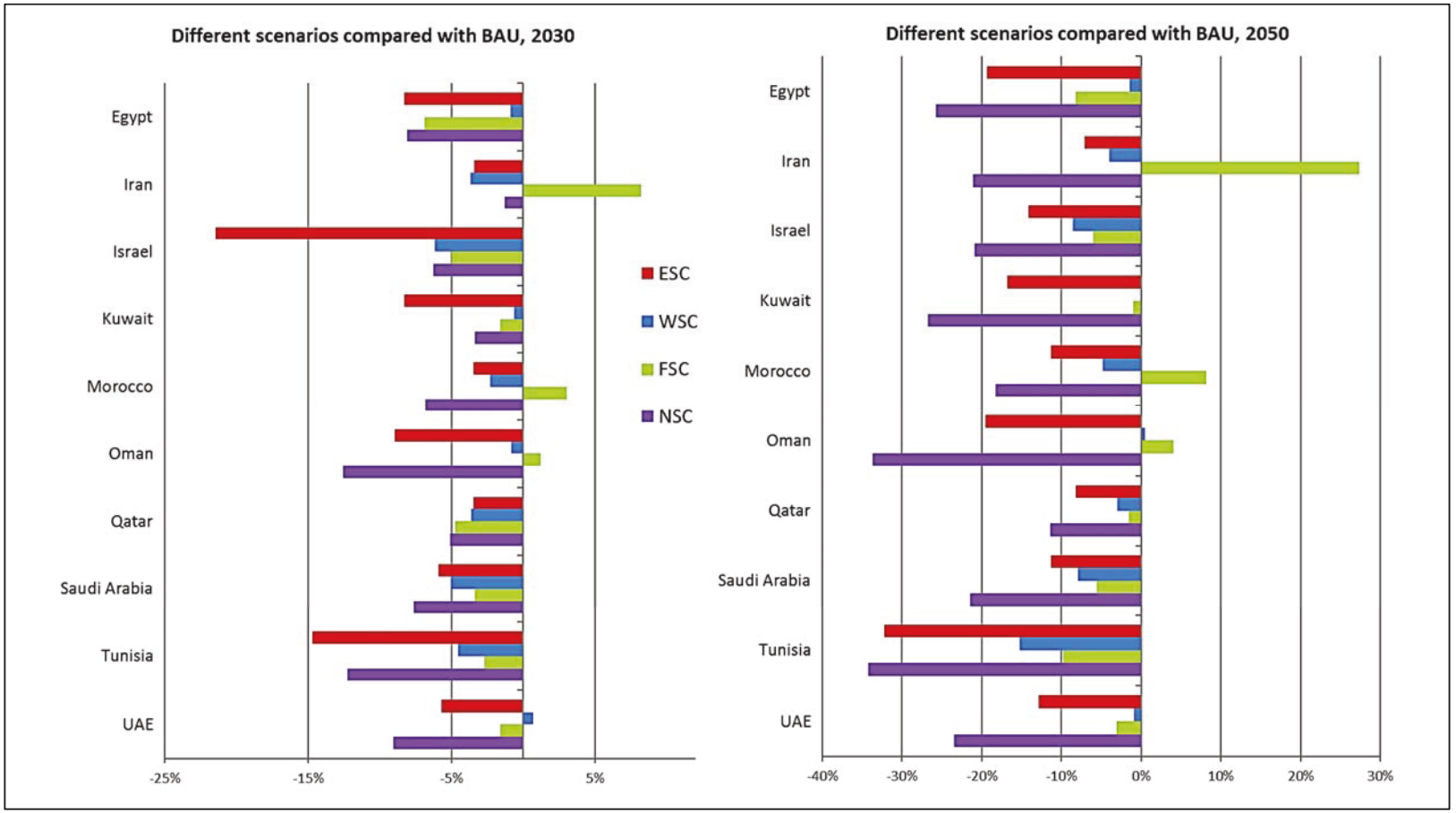
In the **water-oriented scenario (WSC)**, same trend as that in the ESC scenario would be followed by most of the countries, which they could expect a reduction in their energy intensities compared with the BAU scenario. However, in this scenario the reduction in energy intensity would be slower for all of the countries compared with ESC scenario both in the short term and the long term. For example, in the WSC scenario, Tunisia's energy intensity is expected to decline by 15%, from 264 toe per US$ in the BAU scenario to 224 toe per US$ in the WSC scenario in 2050. This decline is less than in the ESC scenario, where energy intensity will decline by 32% to 179 toe per US$ as compared to the BAU in 2050 (see Figure 6.17). This would be due to an increase in primary demand for a seawater desalination system in WSC scenario.

- While most countries are likely to experience some reduction in energy intensities in this scenario, the Kuwait and Oman energy intensities are expected to be 0.1% and 0.5% higher respectively than in the BAU scenario (see Figure 6.17). For example, in the WSC scenario, Oman's energy intensity is expected to decline by 3% from 530 toe per US$ in 2015 to 512 toe per US$ in 2050 (see Figure 6.16). However, this decline would be less than in the BAU scenario, where energy intensity will decline by 4% to 510 toe per US$ by 2050.

- In the short term, while most countries could expect a slower reduction in their energy intensities (than they would in the long term) compared to the ESC scenario, some countries are likely to experience a larger reduction. These include Iran and Qatar, which would expect an additional reduction of 0.3% and 0.2% respectively compared with their energy intensities in the ESC scenario by 2030.

- By 2030, the UAE's energy intensity in this scenario is likely to be 1% higher than in the BAU scenario, from 293 toe per US$ in the BAU to 295 toe per US$ in the WSC scenario. However, by 2050 its energy intensity is likely to experience 1% reduction compare to the BAU scenario, from 284 toe per US$ in the BAU to 282 toe per US$ in the WSC scenario (see Figure 6.17).

Figure 6.17: Change in energy intensity various scenarios compared with BAU scenario



Source: See Appendix B, Section B, Table B5

In the **food-oriented scenario (FSC)**, Iran, Oman and Morocco would face an increase in their energy intensities by 2050 than in the BAU scenario, but the other countries, namely Egypt, Israel, Kuwait, Qatar, Saudi Arabia, Tunisia and the UAE, could expect a further reduction in their energy intensities by 2050 compared with the BAU scenario (see Figure 6.17).

- The energy intensity in Iran, Oman and Morocco is likely to grow by 27.3% (173 Mtoe), 4% (20 Mtoe) and 8.1% (22Mtoe) respectively in the FSC scenario compared with the BAU scenario by 2050. This is consistent with what was observed in the primary energy demand for the three countries in the FSC scenario. The same trend applies to the period to 2030.

- With all other countries, although some reduction in energy intensities is observed, the rate of reduction in FSC scenario is slower than the other two (ESC and WSC) scenarios. In this scenario, the only country that could expect a considerable reduction in energy intensity would be Tunisia with 10% (26 Mtoe). Egypt and Israel would expect a moderate decline and one that would be less than in the ESC scenario. For example, Egypt's energy intensity is expected to decline by 13.7%, from 510 toe per US$ in 2015 to 440 toe per US$ in 2050 in the FSC scenario. This decline is almost half the reduction in the ESC scenario where energy intensity will decline by 24.3% (124 toe per US$) as compared to 2015.

NSC scenario

In the **NSC scenario**, energy intensities in most countries would decline even faster than in the ESC scenario[20] (see Figure 6.18).

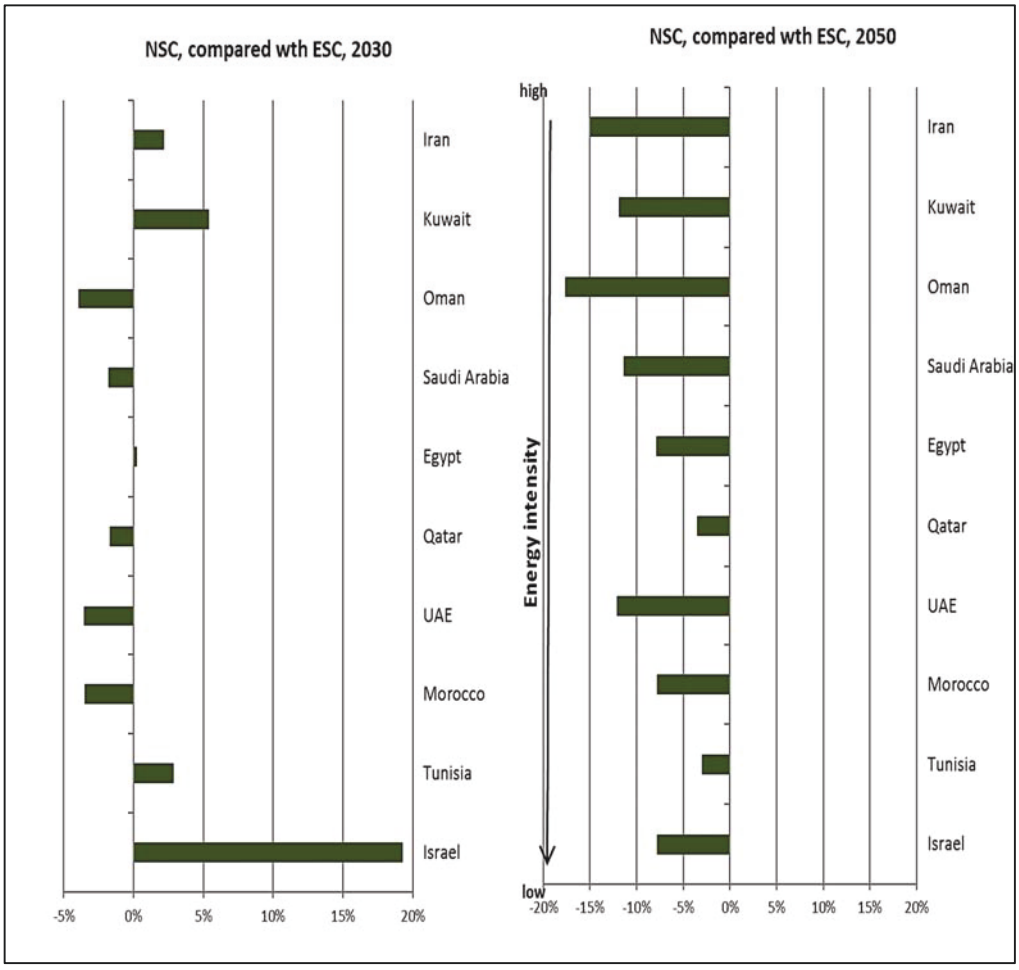
- The decline in all countries except Morocco and Qatar is more than 20% compared with the BAU scenario. Oman's energy intensity, for example, is expected to decline by 34%, from 530 toe per US$ in 2015 to 338 toe per US$ in 2050. These declines for Oman would be 4% (to 510 toe per US$), 19.5% (to 410 toe per US$) and 0.2% (to 512 toe per US$) in the BAU, ESC and WSC scenarios respectively by 2050.

- Qatar and Morocco would be the only countries with 11% and 18% reduction compared with the BAU scenario, however, a rate of change is faster than the other scenarios.

[20] In this research, NSC will be compared with the closest scenario for each sector. For example, in energy sector, the change in NSC scenario will be discussed against ESC scenario. In water sector, the comparison will be between NSC and WSC and in food sector, NSC scenario compared with FSC scenario.

- By 2030, all countries in this research would face a reduction in their energy intensity in the NSC scenario. However, in comparision to the ESC scenario, the the rate of change in energy intensity for the countries is different. Iran, Egypt, Israel, Kuwait and Tunisia would expect lesser energy intensity in the ESC scenario compared to the NSC scenario (see Figure 6.18). Israel, for example, would experience further reduction in its energy intensity, by 19.3% (22.5 Mtoe), in the ESC scenario compared to the NSC scenario by 2030.

Figure 6.18: Change in energy intensity between NSC and ESC scenarios in 2030 and 2050

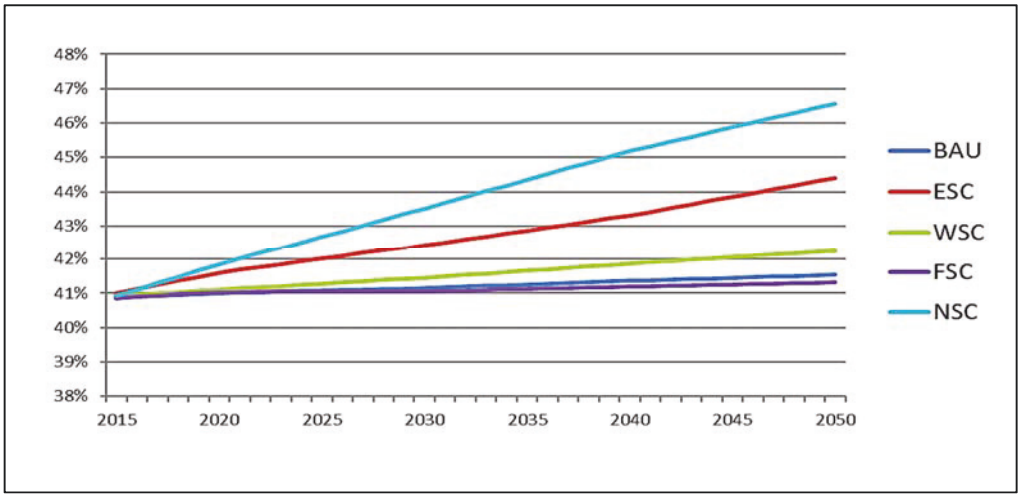


Source: See Appendix B, Section B, Table B5

6.2.3 Energy conversion efficiency

The overall energy conversion efficiency in the countries in the study is relatively poor. Approximately 40% of energy is lost before it reaches the point of final consumption. In the BAU scenario, energy efficiency is expected to marginally increase, from 40% in 2015 to 41.5% in 2050 (see Figure 6.19). In the ESC scenario, the energy efficiency improvement is likely be moderate while in the WSC and FSC scenarios, the change is minor. The NSC scenario produces the most significant improvement in energy efficiency compared with the other scenarios.

Figure 6.19: Average Trends in energy conversion efficiency in the countries of the MENA region



Source: See Appendix B, Section B, Table B6

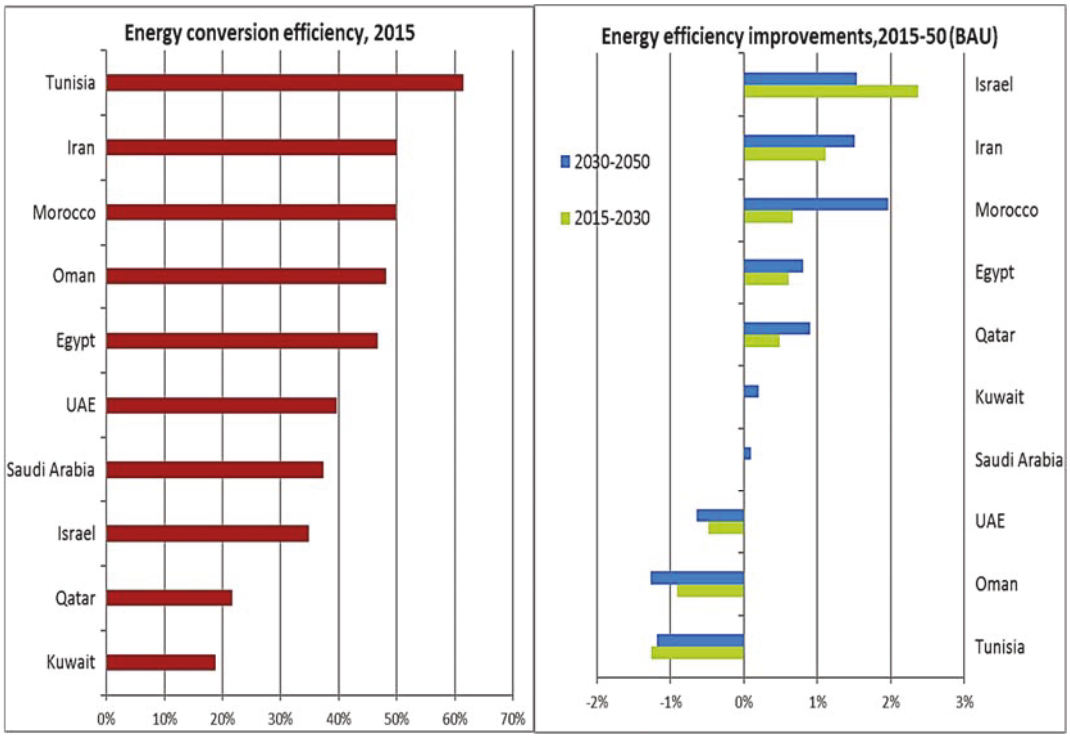
- There are considerable contrasts in the current energy convesion efficiencies across the selected countries for this study (see Figure 6.20). Tunisia is the only country that has a relatively high conversion efficiency–more than 60% of primary energy is converted into forms suitable for final consumption. In contrast, the rest of the countries (even those with abundant energy resources) have relatively low efficiency, that is, less than 50% of the total energy is available for final consumption.

- In the **BAU scenario**, the energy conversion efficiency of two of the six energy-aboundant countries, Oman and the UAE, would decline. For example, Oman's energy efficiency is expected to decline from 48.2% in 2015 to 46.1% in 2050.

- The largest reduction, however, would happen in Tunisia, an energy-scarce country, where the energy efficiency would fall from 61.6% in 2015 to 59.1% in 2050.

- In contrast, the energy efficiency of the two other energy-scarce countries, Egypt and Israel, would improve over the 35 years. Israel, for example, is likely to increase its energy efficiency significantly from 34.8% in 2015 to 38.8% in 2050.

Figure 6.20: Energy conversion efficiency in the MENA countries



Source: See Appendix B, Section B, Table B6

- Between 2015 and 2030, most of the energy-abundant countries would face a slight decline in their energy efficiency. These include Kuwait, Oman, Saudi Arabia and the UAE. Kuwait and Saudi Arabia could expect slight improvements in their energy efficiency of 1% and 0.2% respectively compared with the BAU in 2030.

- Tunisia would face the highest decline (2%) in its energy efficiency, from 61.5% in 2015 to 60.3% in 2030.

- The rest of the countries could expect minor improvements in their energy efficiency, apart from Israel, which would show a modest (2.4%) improvement from 34.8% in 2015 to 37.2% in 2030.

ESC, WSC and FSC scenarios

In the **energy-oriented scenario (ESC),** energy conversion for all countries except Qatar would improve by comparison with the BAU scenario (see Figure 6.21).

- Qatar as one of the least energy-efficient countries could become even less energy efficient by approximately 0.9%, from 21.7% in 2015 to 20.9% in 2050.

- The countries that are likely to experience significant improvement in energy conversion efficiency in the ESC scenario compared with the BAU scenario are Tunisia, Egypt and Iran. Iran's energy efficiency, for example, would increase to 56.6% (from 50% in 2015) by 2050 in the ESC scenario, which is 4% higher than its level in the BAU scenario.

- In the short term, Israel, Iran and Egypt would expect the highest improvement in their energy efficiency. For instance, Israel is likely to experience the moderate rate of energy efficiency, from 34.8% in 2015 to 39.8% in 2030, which is 2.6% higher than its level in the BAU scenario.

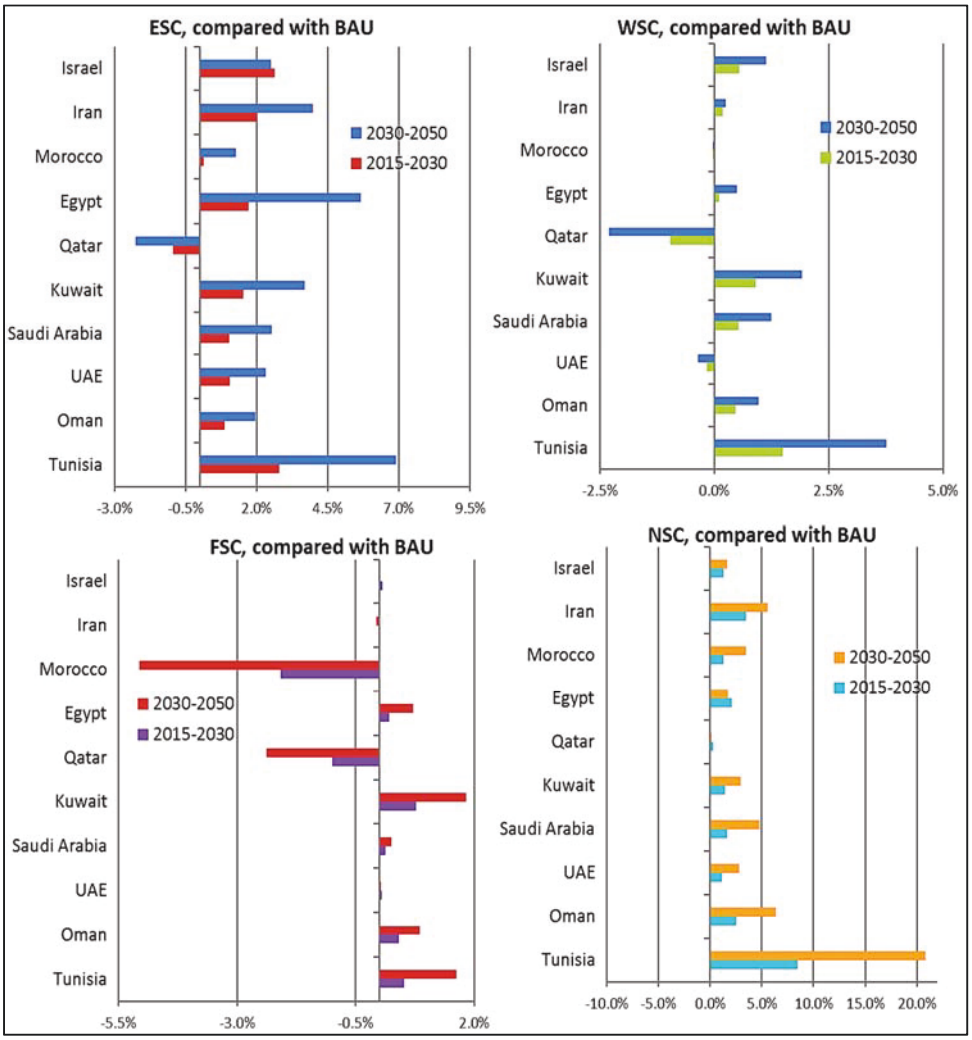
In the **water-oriented scenario (WSC)**, the energy conversion efficiencies for some countries would grow compared with the BAU scenario. However, the growth rate would be slower than the ESC scenario (see Figure 6.21).

- Countries that are likely to show a slight improvement in this scenario include Tunisia, Kuwait, Saudi Arabia, Israel and Oman. In these countries, the energy conversion efficiency could increase from 1% (for Oman) to 3.8% (for Tunisia).

- Egypt and Iran would expect marginal change in their energy conversion efficiencies compared to the BAU scenario. For example, in this scenario (WSC), Egypt's energy efficiency would increase to 48.6% by 2050, which is 0.5% higher than in the BAU scenario. This reduction of energy efficiency for Egypt is 5.7% in ESC scenario (as compared to the BAU).

- Morocco, Qatar and the UAE would expect reductions in their energy conversion efficiencies in this WSC scenario compared with the BAU scenario. Specifically, the reduction for Morocco would be negligible but that for Qatar and the UAE would decline to 20.8% and 38.2 respectively, 2.3% and 0.4% less than the levels in the BAU scenario (see Figure 6.21).

Figure 6.21: Change in energy conversion efficiency improvements, 2015-2050



Source: See Appendix B, Section B, Table B6

In the **food-oriented scenario (FSC)**, analysis suggests that the energy conversion efficiencies of Egypt, Kuwait, Oman, Saudi Arabia, Tunisia and the UAE would improve compared to the BAU scenario. However, the improvements in this scenario would be much less than those in the ESC and WSC scenarios (Figure 6.21).

- In this scenario, the energy conversion efficiency of no country would improve significantly. Indeed, any progress in energy efficiency would be less than 2%. The UAE, Saudi Arabia and Egypt could expect marginal improvement (less than 1%) in their energy conversion efficiencies in comparison to the BAU scenario. Tunisia and Kuwait are the only two countries that could experience a slight change in their energy efficiency,

with 1.6% and 1.8% increases respectively compared to the BAU scenario by 2050, reaching energy efficiencies of 60.7%, and 20.9%, respectively.

- Iran, Israel, Morocco and Qatar would expect declines in their energy efficiency compared with the BAU by 2050. However, in the short run, it is expected that Iran and Israel will have negligible improvement in their energy efficiency.

NSC scenario

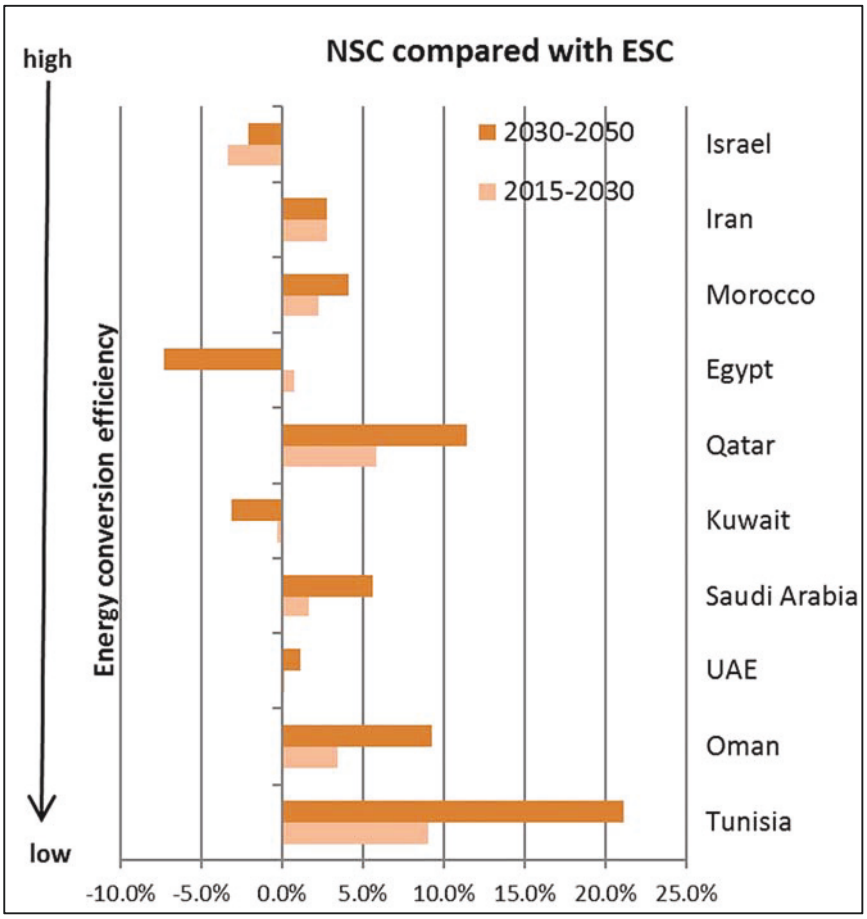
Energy efficiency improvement in the **NSC scenario** is expected to be much higher for most of the countries compared to the BAU and ESC scenarios in this research (see Figures 6.21 and 6.22). For example, energy efficiency in Tunisia would increase over the 35 years to 2050 to 79.9% in the NSC scenario compared with 59.1% in the BAU and 66% in the ESC scenarios.

- Overall, energy efficiency levels in the NSC scenario would be higher than the corresponding levels for BAU and ESC scenarios in Iran, Morocco, Qatar, Saudi Arabia, the UAE, Oman and Tunisia.

- Egypt, Israel and Kuwait would show even greater improvements in their energy efficiency levels compared with the BAU scenario. However, the rate of improvement for these countries in the ESC scenario would be faster than in the NSC scenario (Figure 6.22) by 2050.

- Analysis shows that in the short term, Kuwait and Israel would expect higher energy efficiency in the ESC scenario compared with the NSC scenario.

Figure 6.22: Change in energy conversion efficiency improvements NSC vs ESC



Source: See Appendix B, Section B, Table B6

6.2.4 Energy diversity

All the countries in this research rely on fossil fuels (particularly gas and oil) to meet their energy demands. Reduced dependency on fossil fuels will definitely diversify the energy mix. In the **BAU scenario,** considerable contrast in energy diversity can be observed across the 10 countries (see Figure 6.23).

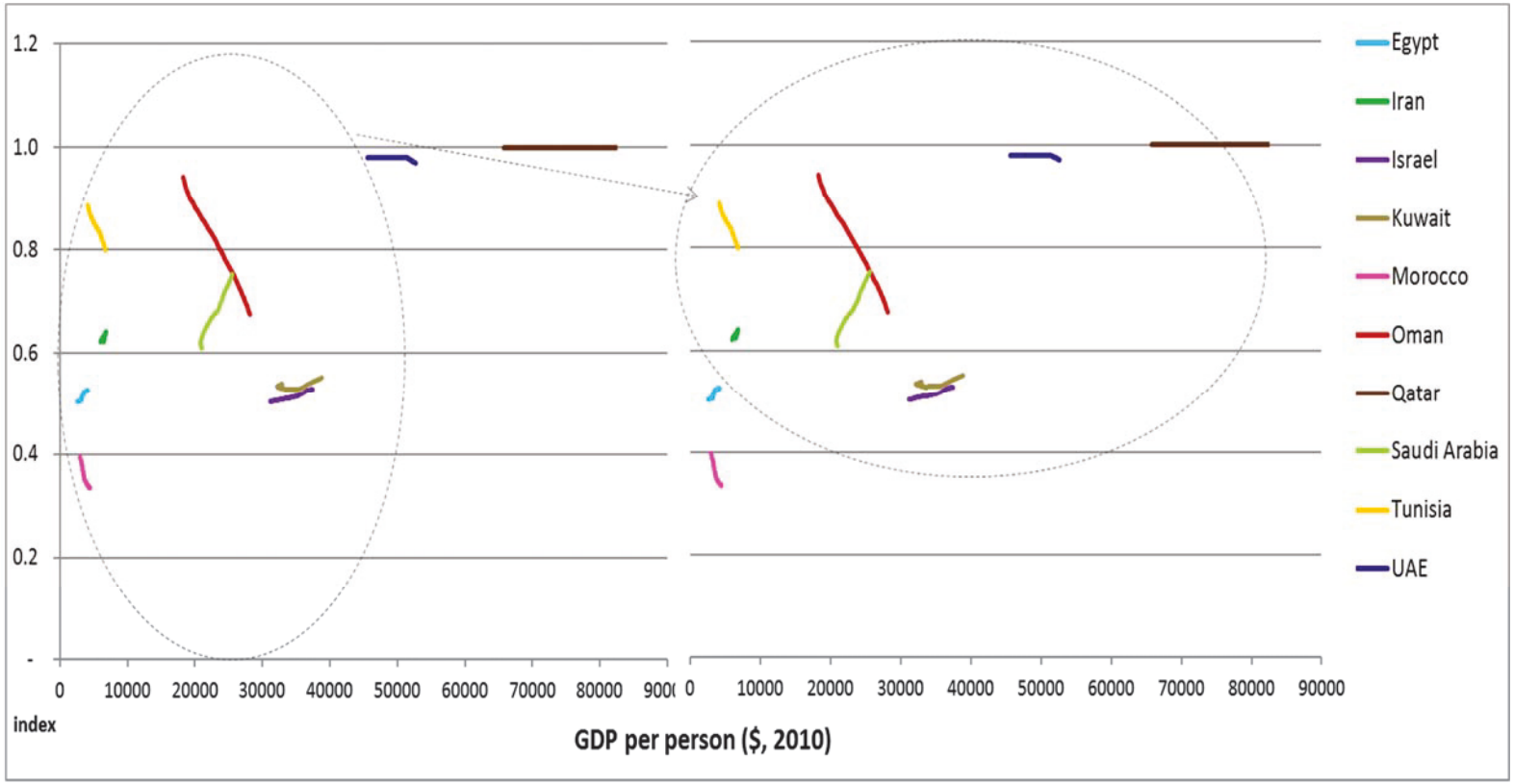
- In 2015, Morocco, is the only country with relatively high-energy diversity among the selected countries in this research; the Herfindahl index of the country is 0.39. Morocco relies on less gas and oil to meet its energy needs than the other countries. Its dependency on oil and gas is 6% and 20% respectively. Egypt and Israel rank jointly second among the selected countries in terms of their energy diversity; the Herfindahl index of both countries are 0.50.

- The rest of the countries are less energy diverse compare to Morocco, Egypt and Israel and their Herfindahl indices are all more than 0.50. Qatar's Herfindahl index is 0.99, the highest of all the countries due to its mainly reliance on gas (exceeding 95% of total primary energy demand requirements).

- In the **BAU scenario** and in the low-middle income countries, Egypt would become slightly less energy diverse by 2050, while Morocco and Tunisia would experience the reverse situation. For example, the Herfindahl index for Tunisia is expected to decrease from 0.88 in 2015 to 0.85 in 2030 and 0.80 in 2050, as the country reduces its reliance on gas and promotes the use of renewable energy (Figure 6.23). The Herfindahl index for Iran (upper-middle income) is expected to increase slightly from 0.62 in 2015 to 0.64 in 2030 and decline marginally to 0.63 in 2050, as Iran increases the use of oil slightly in its primary energy mix.

In contrast, energy diversity for high-income countries is expected to change differently (see Figure 6.23). Oman and UAE would likely experience improvement in their energy diversity in the BAU scenario by 2050. Oman, for example, could expect a significant improvement in its energy diversity index, from 0.93 in 2015 to 0.83 in 2030 and 0.68 in 2050. The main driver for this improvement would be the increase in the share of renewables from 3% in 2015 to 12% in 2050. Quite contrary, Saudi Arabia is expected to be less energy diverse by 2050. The energy diversity index would increase from 0.61 in 2015 to 0.65 in 2030 and 0.75 in 2050 implying the decline in energy diversity. This is mainly because Saudi Arabia keeps relying heavily on fossil fuels (oil and gas) to meet its demand. Other high-income countries, namely Israel and Kuwait, can expect slight increases in their energy diversity index (which implies a decline in energy diversity).

Figure 6.23: Energy diversity indices for the MENA countries, 2015-2050



Source: See Appendix B, Section B, Table B7

ESC, WSC and FSC scenarios

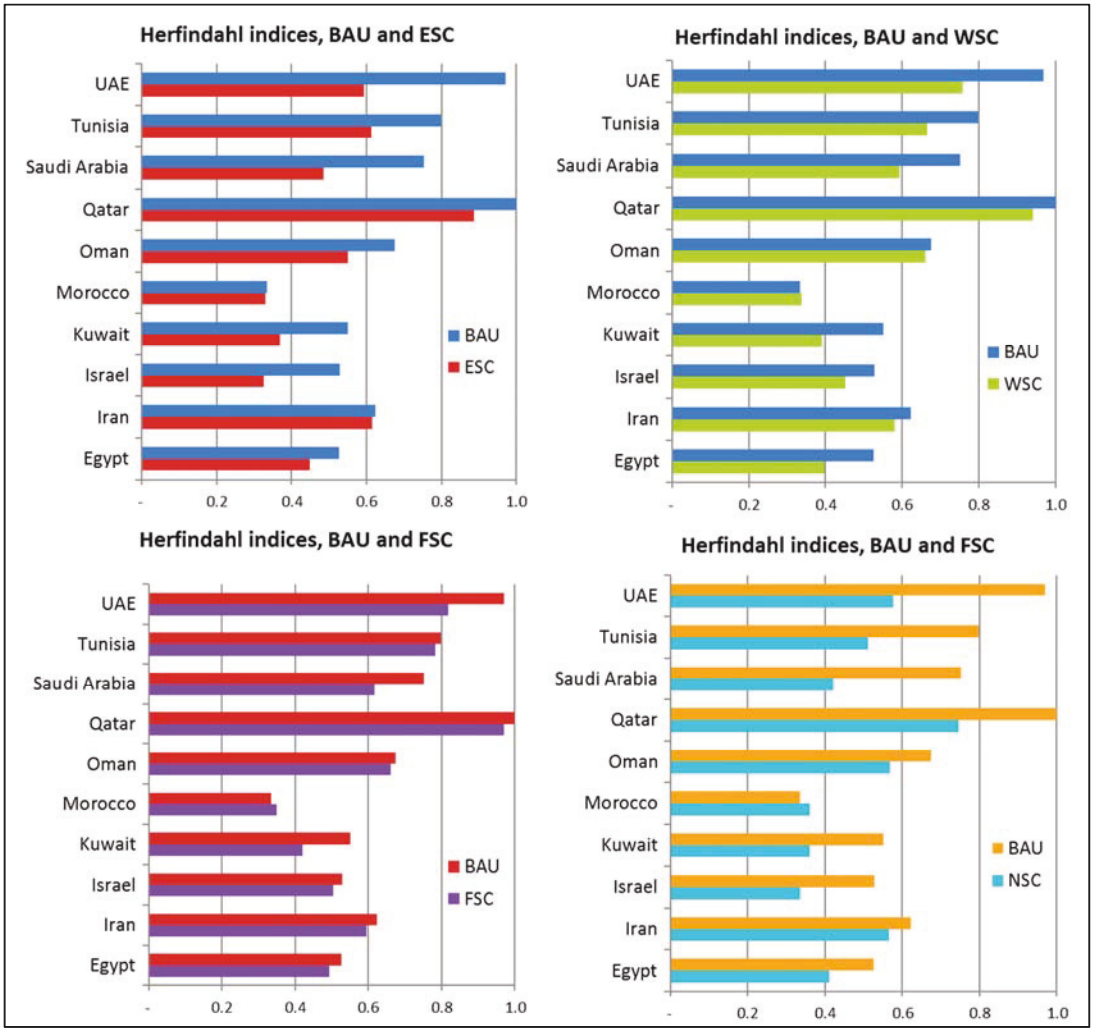
Most of the countries in this research are likely to become more energy diverse in all the scenarios in this section compared with BAU scenario (see Figure 6.24).

In the **energy-oriented scenario (ESC)**, for example, the UAE is likely to experience the largest improvement in energy diversity. The Herfindahl index will decrease from 0.98 in 2015 to 0.79 in 2030 and 0.59 in 2050 compare with the BAU scenario, (where it was 0.98 in 2030 and 0.97 in 2050). Morocco and Iran would expect the lowest change in their energy diversity in the ESC scenario compared with the other countries. Iran's energy diversity would drop by only 1% from 0.62% in the BAU scenario to 0.61 in the ESC scenario and Morocco would expect a marginal change in energy diversity by 2050 (see Figure 6.24).

Although countries would expect to be more energy diverse in the short term, the rate of change, on average is almost 50% less than in the long term. For example, the UAE could expect a 19% change in its energy diversity from 0.98 in the BAU scenario to 0.79 in the ESC scenario in the short term (2015-2030). In the long term (2030-2050), however, its rate of change in the energy diversity would improve by 39% (from 0.98 in the BAU scenario to 0.59 in the ESC scenario), two times faster than the change in the short term (see Appendix B, Section B, Table B7).

In the **water-oriented scenario (WSC),** most countries will face further reductions in their energy diversity index compared with the BAU scenario; however, the rate of change in energy diversity in the WSC scenario will be slower than in the ESC scenario. The UAE, Saudi Arabia and Kuwait could expect the greatest improvement in energy diversity, with the Herfindahl index reducing to 0.76 for the UAE, 0.75 for Saudi Arabia and 0.39 for Kuwait in this scenario compared with 0.98 for the UAE, 0.59 for Saudi Arabia and 0.55 for Kuwait in the BAU scenario. Morocco is the only country that is likely to become marginally less energy diverse. The Herfindahl index value for Morocco would decrease from 0.33 in the BAU scenario to 0.34 in 2050 in the WSC scenario, which implies an increase in energy diversity (see Figure 6.24).

Figure 6.24: Change in energy diversity in the MENA countries by 2050



Source: See Appendix B, Section B, Table B7

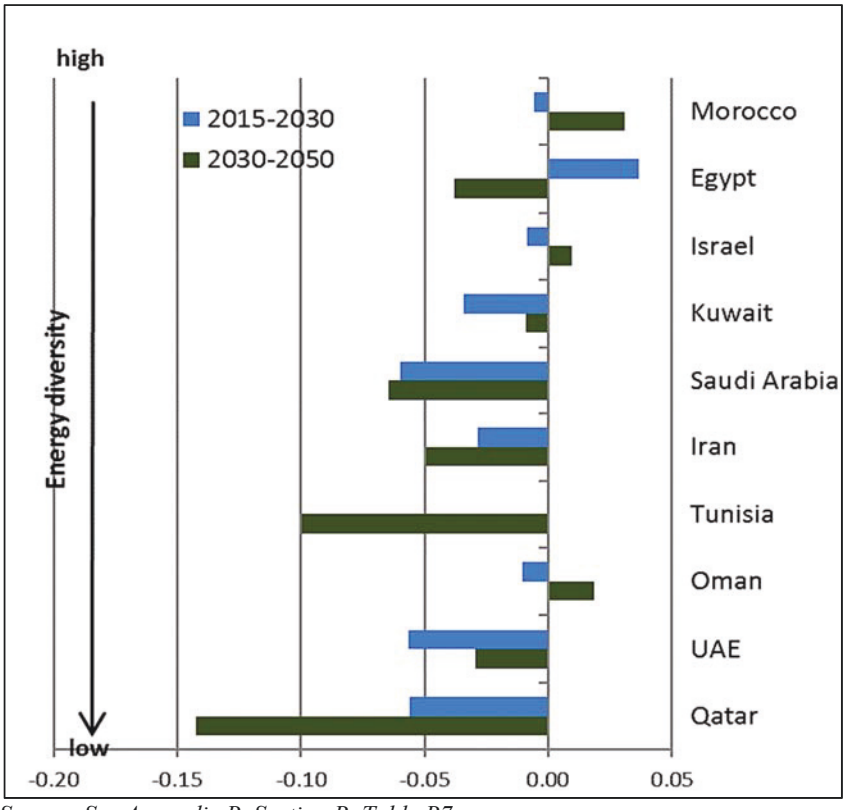
In the **food-oriented scenario (FSC),** all countries except Morocco would experience a reduction in energy diversity compared with the BAU scenario, the growth rate for energy diversity on average in the FSC being one-third of the ESC scenario. The UAE, Kuwait and Saudi Arabia could expect a significant improvement compared to the BAU scenario, possibly 15% for the UAE and 13% for Kuwait and Saudi Arabia. The change in the value of energy diversity for the rest of the countries would be below 3% in the FSC scenario compared to the BAU scenario. Morocco is the only country expected to have its Herfindahl index increase in the FSC scenario from 0.33 in the BAU scenario and to 0.35 in the FSC scenario, implying a decline in energy diversity by 2050 (Figure 6.24).

NSC scenario

In the **NSC scenario**, the change in energy diversity will be different across all the countries (Figures 6.24 and 6.25). Countries such as Tunisia, Qatar, Saudi Arabia and the UAE would expect substantial improvement in their Herfindahl indices in the NSC scenario by 2050. For example, Qatar will become more energy diverse, its Herfindahl index reducing to 0.75 in this scenario from 0.99 in the BAU scenario and to 0.89 in the ESC scenario. The significant improvement is likely to experience by Egypt, Israel Kuwait and Oman in the NSC scenario as compared to the BAU scenario by 2050. However, the improvement in the energy diversity for Oman and Israel would be less than the improvement in the ESC scenario. For instance, Oman's energy diversity will improve in the NSC scenario (0.57) compared with the BAU scenario (0.68) but less than in the ESC scenario (0.55).

Out of the selected countries in this research, Morocco is the only country that could experience a moderate increase in the value of its Herfindahl indices in the NSC scenario compared with the BAU scenario, implying a decline in energy diversity by 2050 (Figure 6.24). Morocco is likely to experience increase in its Herfindahl index in the NSC scenario from 0.33 in the BAU scenario and to 0.36 in the NSC scenario by 2050.

Figure 6.25: Changes in Herfindahl indices in NSC (compared with ESC)



Source: See Appendix B, Section B, Table B7

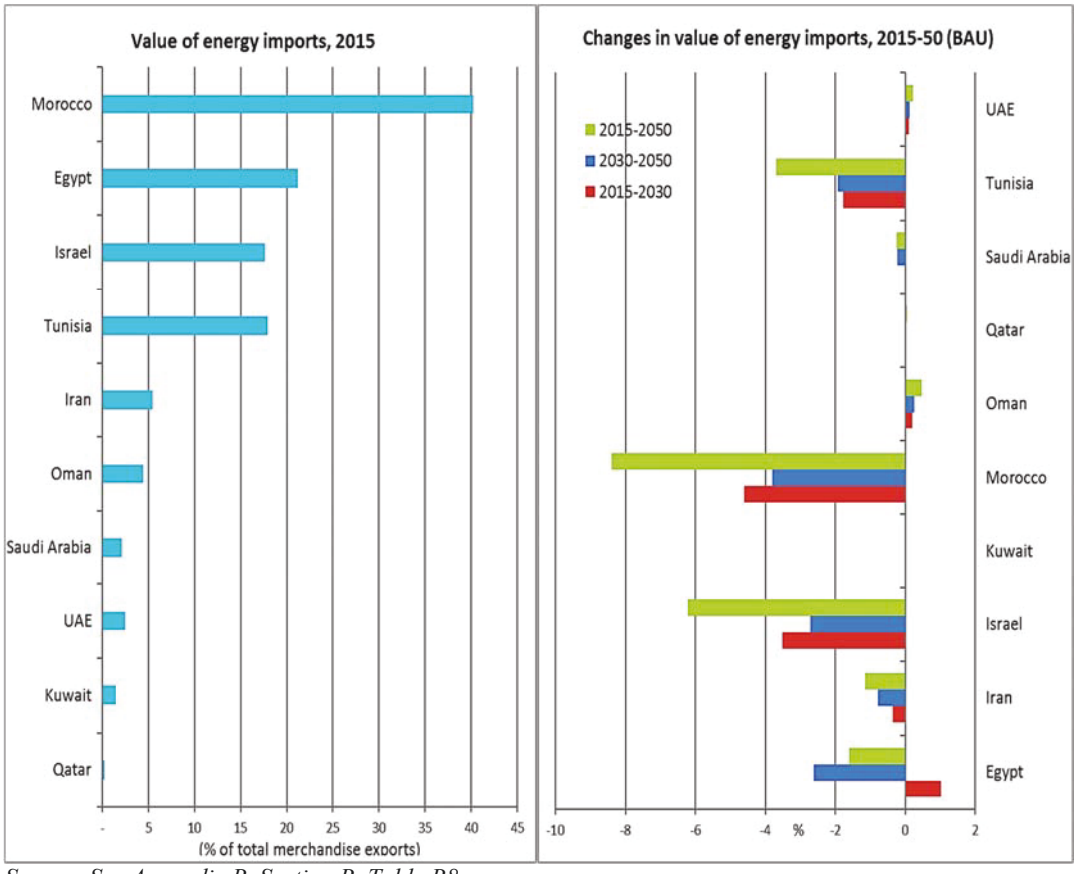
6.2.5 Energy import dependency

Energy import dependency in this research is expressed in terms of the monetary value of energy imports as a percentage of total exports. This shows the sensitivity of each country's balance of payments to energy imports. The smaller the value the more a country can manage its energy import value by expanding its export opportunities, which means an improvement in energy security. This definition has been used widely to assess energy security (Bolton 2018; Cabalu & Alfonso 2013) because it captures an economic dimension of energy dependency and vulnerability, which in turn can reflect the economic security of a country or region.

BAU scenario

In 2015, energy import dependency value varied among the countries in this research. Morocco spent a significant portion of its export income (40%) on energy imports. Egypt, Israel and Tunisia spend more than 15% of their export earnings on energy imports. In contrast, Iran, Oman, Saudi Arabia, the UAE, Kuwait and Qatar as energy-exporting countries spent less than 5% of their export earning on importing energy (see Figure 6.26).

Figure 6.26: Energy import dependency for the countries in this research



Source: See Appendix B, Section B, Table B8

- In the **BAU scenario**, the value of energy imports for most of the countries in this research in the 35 years to 2050 is expected to change. All the energy-importing countries, namely Egypt, Morocco, Tunisia and Israel, are expected to reduce their energy import dependency in the future. As an example, Morocco's energy imports (as a percentage of its total export) is expected decline from 41% in 2015 to 32% in 2050 (see Figure 6.26).

- The energy exporting countries of Kuwait, Qatar, the UAE and Oman are expected to spend (marginally) a greater portion of their export income on importing energy. Oman's energy imports, for example, will increase from 4% in 2015 to 5% in 2050. In contrast, Iran and Saudi Arabia are likely to reduce their energy imports expenditure slightly by 2050.

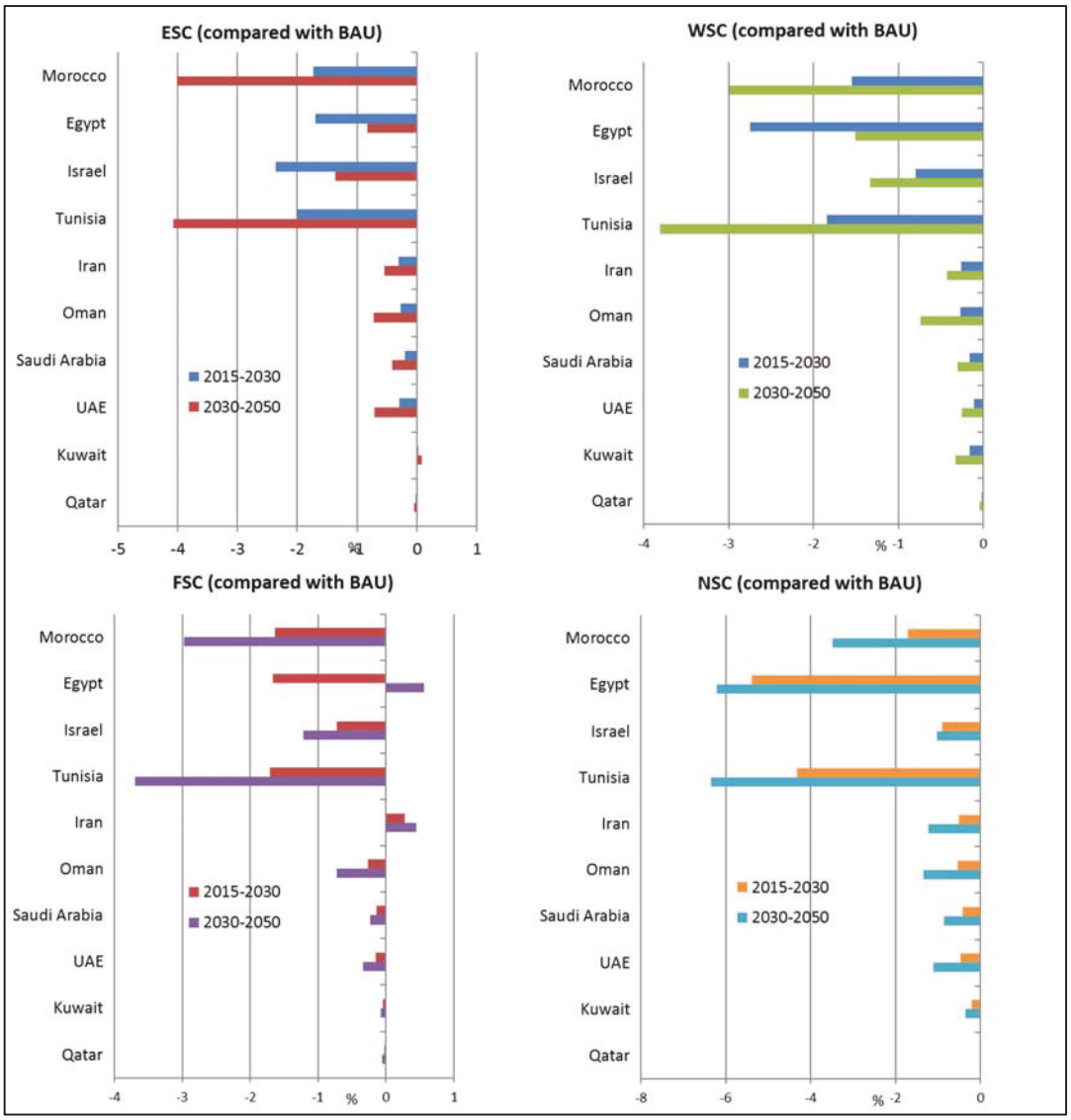
- In the short term, in the BAU scenario, countries would have the same trend in their energy import dependency except Egypt. Egypt's energy dependency will grow by 1% from 21% in 2015 to 22% in 2030, but in the long term its energy imports will decline by 2.6% (see Figure 6.26).

ESC, WSC and FSC scenarios

In the **energy-oriented (ESC)** and **water-oriented (WSC**) scenarios, most countries will become less dependent on energy import compared with the BAU scenario (see Figure 6.27). For example, Tunisia will reduce its expenditure on energy imports significantly, from 18% in 2015 to about 10% in 2050 in both the ESC and WSC scenarios; this compares favourably with its energy import dependency of 14% in the BAU scenario by 2050.

- While Kuwait's energy import dependency is expected to improve slightly in the WSC scenario, its dependency in the ESC scenario (2%) is likely to rise compared to the BAU scenario (1%).

Figure 6.27: Impact of alternative scenarios on energy imports (2015-2050)



Source: See Appendix B, Section B, Tables B8&B9

In the **food-oriented scenario (FSC)**, some countries will reduce their energy import expenditure compared to the BAU scenario. For example, Oman, an energy exporter, would drop its expenditure on energy imports from 4.5% in 2015 to 4.2% in 2050, compare with 4.9% in the BAU scenario in 2050. However, the reduction in the FSC scenario for Oman would be slightly less than the rate in the ESC and WSC scenarios by 2050 (see Figure 6.27).

In this scenario, Egypt and Iran would become more vulnerable to energy imports in the long term. For example, the value of Egypt's energy imports in this scenario would rise to 20.2% by 2050 compared with 19.6% in the BAU scenario and 18.8% in the ESC scenario. In the short

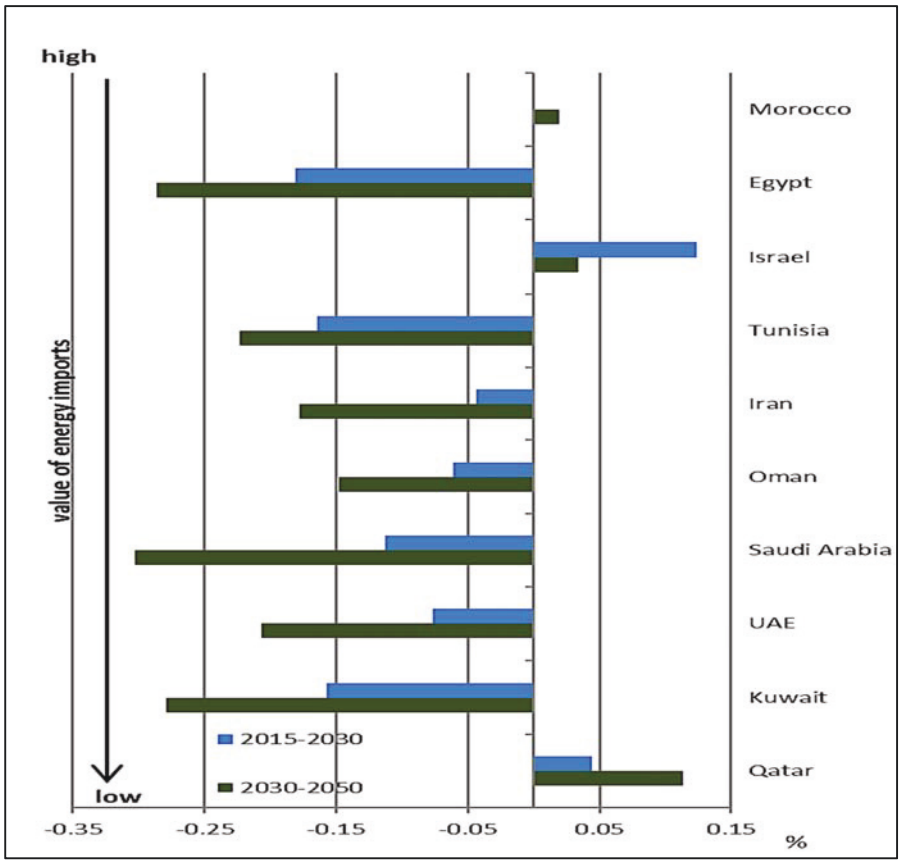
term, Iran is the only country that could experience a slight increase in the energy imports in the FSC scenario compared with the BAU scenario (Figure 6.26).

NSC scenario

In the **NSC scenario**, all the countries in this research become less vulnerable to energy imports compared with the BAU scenario (see Figure 6.27). A comparison between the NSC and ESC scenarios shows that most countries will also be less depending on importing energy than in the ESC scenario (see Figure 6.28). Egypt and Tunisia as energy-importing countries would expect to have 29% and 22% reduction on spending on energy imports but Morocco and Israel will spend approximately 0.03% more than in the ESC scenario in the long term. Among the energy-exporting countries, Qatar is the only one whose energy-importing dependency will increase slightly in the NSC scenario compared with the ESC scenario both in the short and long term.

While in the NSC scenario countries would spend less on importing energy in both the short and the long term, the rate of this change in energy import dependency will be slower during the short term as compared to the long term.

Figure 6.28: Changes in energy imports in the NSC scenario compared with the ESC scenario



Source: See Appendix B, Section B, Tables B8 & B9

6.2.6 Energy import affordability

Energy affordability in this research is measured in terms of the proportion of total income spent on the purchase of energy. In the BAU scenario, energy expenditure in all the countries would increase on average from 9% in 2015 to 9.4% in 2050. However, energy expenditure will decrease to 8.4% in the ESC scenario, to 8.7% in the WSC scenario, to 8.9% in the FSC scenario and to 7.3% in the NSC scenario.

- In 2015, energy affordability among the 10 countries in this research varied considerably. Most of the countries spent less than the 9% average of their total income on purchasing energy (see Figure 6.29), but Iran spent slightly higher than the average (9.8%) and Oman (15.3%), Saudi Arabia (15.7%) and Kuwait (17.6%) spent a significant percentage of their income on energy.

- In the 35 years to 2050, the share of energy expenditure in the **BAU scenario** will increase in most of the countries, the considerable increase, from 15.5% in 2015, to 23.4% in 2050, occurring in Saudi Arabia.

- Egypt, Israel, Kuwait, Oman and Qatar will spend less, ranging between 1.0% (Qatar) and 3.1% (Kuwait) of their income on energy in 2050, in the BAU scenario, compared with their energy expenditures in 2015 (see Figure 6.29). Other countries include Iran, Morocco, Tunisia and the UAE are likely to spend slightly more of their total income on purchasing energy in the long term.

- In the short term, energy expenditure would increase on average slightly (from 9% in 2015 to 9.1% in 2030). The increase on purchasing energy would be observed for Saudi Arabia, Iran, Morocco, Tunisia and the UAE.

- In the **ECS, WSC and FSC scenarios,** most countries will spend a smaller proportion of their income on energy compared with the BAU scenario (see Figure 6.29). For example, consumers in Saudi Arabia are expected to spend 17.5%, 18.4% and 18.7% of their incomes on energy in ESC, WSC and FSC scenarios compared with 23.4% of income in BAU scenario by 2050. In Oman, energy affordability will improve by 2.7% in the ESC scenario, by 2.4% in the WSC scenario and by 2.5% in the FSC scenario relative to the BAU scenario. On average, the ESC scenario would result in the lowest portion of income spent on energy of the three scenarios discussed here by 2050 (see Figure 6.29).

- Morocco is the only country that will spend more (an average of 4%) on energy in all three scenarios compared with the BAU scenario by 2050.

- In the short term (to 2030), the only scenario that would produce a fall in energy expenditure compared to the BAU scenario is the ESC scenario. The average share of energy expenditure among all the countries would be 9.1% in the BAU scenario, which is lower than the 9.5% in the WSC scenario and 9.2% in the FSC scenario. However, The ESC scenario will produce the lowest share of expenditure (9%) (see Figure 6.29).

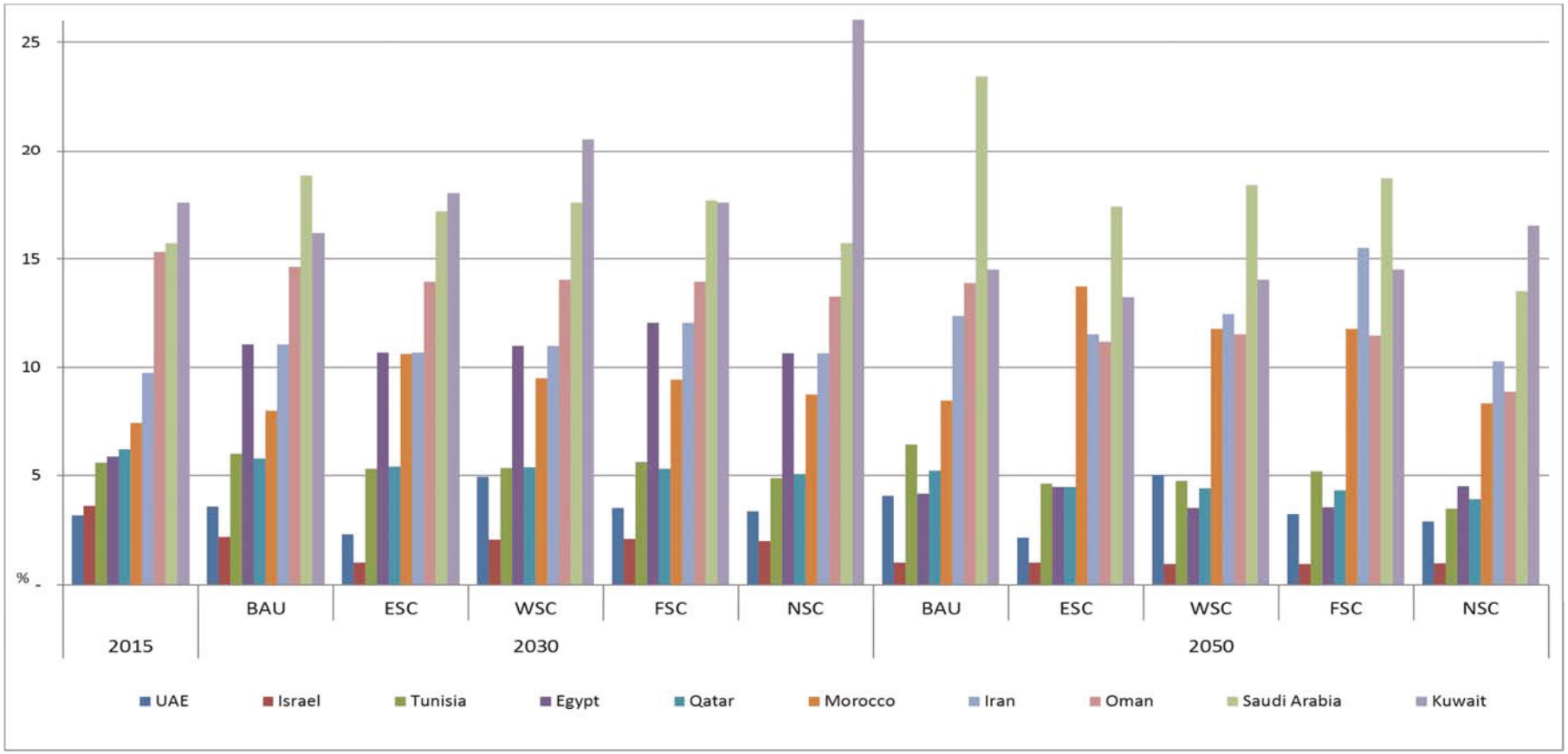
- In the short term, the change on purchasing energy would be varied among the countries in this research. Israel, Oman, Qatar, Saudi Arabia and Tunisia are likely to spend a smaller proportion of their income on energy compared with the BAU scenario in all three scenarios (ESC, WSC and FSC). In contrast, Kuwait (an average of 2.6%) and Morocco (an average of 1.8%) will spend more of their total income on purchasing energy in all three scenarios compared with the BAU scenario by 2030 (see Figure 6.29).

- Energy affordability for consumers in most of the countries will improve in the **NSC scenario** (see Figure 6.29). While the improvement is expected to be less than 3% compared with the BAU scenario in most of the countries, consumers in Oman and Saudi Arabia would benefit significantly in this scenario. Energy expenditure will decline by 5% in Oman and by around 10% in Saudi Arabia by 2050 in comparison with 2.7% (Oman) and 6% (Saudi Arabia) in the ESC scenario.

- In contrast, consumers in Egypt and Kuwait are likely to spend more of their incomes on energy in the NSC scenario compared to the BAU scenario, rising from 4.2% to 4.5% in Egypt and from 14.5% to 16.5% in Kuwait by 2050 (see Figure 6.29).

- In the short term (to 2030), the average share of energy expenditure among all the countries would be more in the NSC scenario (9.6%) as compared to the BAU scenario (9.1%). Kuwait and Morocco are the two countries, which spend further on purchasing energy as compared to the BAU scenario. While the residents of Morocco would spend slightly more of their incomes on energy (1%), the share of energy expenditure for Kuwaitis residents would increase significantly (12%) as compared to the BAU scenario by 2030 (see Figure 6.29).

Figure 6.29: Share of the energy expenditure in the countries in this research



Source: See Appendix B, Section B, Table B10

6.3 Summary and conclusion

Economic Outcomes

Gross Domestic Product (GDP)

If the current (BAU scenario) trends continues, the GDP in all the countries in this research over the 35 years to 2050 will have increased by an average of 1.8-fold, which is equivalent to an average annual growth of 1.7%. The per-capita income in all the countries will increase by 0.7% annually. While this increase in GDP and per-capita GDP will be applicable to all the countries, the most notable beneficiaries will be the low/middle-income countries of Egypt, Morocco and Tunisia, whose GDPs will more than double in the long term. Further, the per-capita income of the citizens of these countries would also improve by more than 1% annually. This pathway could promote the economic status of Egypt, Morocco and Tunisia from low/middle-income countries to upper/middle-income countries by mid-century. The other countries in this research would continue the same income level as 2015 situation in the BAU scenario by 2050.

In the short term, in the BAU scenario, most of the countries could expect moderate increases in their GDP. The highest annual GDP growth is expected for lower-income countries over the period of 2015-2030.

In the ESC, WSC and FSC scenarios, although the GDP would be nearly the same to that in the BAU scenario, the impact of change in the GDP across the countries would be slightly different. Tunisia is the only country expected to have a worse GDP in all the three scenarios (ESC, WSC and FSC) both in the short and long term. While most of the countries (except Kuwait and Tunisia) could expect slight improvement in their GDP in the ESC scenario, the GDP would worsen slightly for most of the countries in the WSC scenario (except Morocco) and in the FSC scenario (except Egypt and Morocco) by 2050.

In the short term, most of the countries can expect only a moderate increase in their GDP in ESC, WSC and FSC scenario. In the ESC scenario, Iran, Kuwait and Oman would expect the highest rate of growth compared with the BAU scenario. The WSC scenario will give Oman a significant boost to its GDP and in the FSC scenario, Iran, Qatar and Oman could expect a slight improvement in their GDP.

In the NSC scenario, the average GDP of all the countries is likely to be 9.4% (increase by US$451 billion) higher than in the BAU scenario. Significant economic gains (more than 10%) are likely to be experienced by Egypt, Oman, Saudi Arabia, Tunisia and the UAE, while Iran, Israel, Kuwait and Morocco are likely to experience considerable (5% to 10%) economic gains.

Trade balance

Four out of the 10 countries are currently in trade deficit, Egypt, Israel and Morocco heavily so and Tunisia relatively less so. Iran, Kuwait, Oman, Qatar, Saudi Arabia and UAE are currently trade-surplus countries.

By 2030, Egypt's trade deficit would be impacted the most between the selected countries, increasing from 19% of GDP in 2015 to approximately 20% of GDP in the **BAU scenario**. This will be due to the increase in demand for food, which will make Egypt more dependent on food imports to meet the domestic requirements of energy. Among the trade-surplus countries, only Iran will be unable to maintain its trade-surplus status to 2050, although it could expect a slight surplus in the short term, in the long term the country would face with trade deficit.

No appreciable impact on the overall regional trade balance is expected in the ESC, WSC and FSC scenarios, however, the impact on the trade balance would differ from country to country. In the **ESC scenario**, among the lower income countries, the trade balance would be impacted positively, whereas the high-income countries, the UAE, Israel, Oman, Kuwait and Saudi Arabia are likely to experience a reduction in their trade balance compared with the BAU scenario. In the short term, Saudi Arabia and Kuwait would experience a better trade balance, but Iran could expect a negative impact in ESC scenario as compared with the BAU scenario. Other countries in this research could expect the same trend in both short and long terms in this scenario.

In the **WSC** and **FSC scenarios**, while Egypt, the UAE, Oman, Israel and Kuwait could experience negative impacts, the other countries could expect improvement in their trade balance positions by 2050. Iran will be the only country among the trade-surplus counties that will be unable to maintain its balance and would become a trade deficit country only in the WSC scenario in the long term. Its deficit in this scenario would be due to increases in the import of processed food and industrial goods. Morocco will reduce its trade deficit in both scenarios, thanks to decreased imports of food, energy and industrial goods. However, the trade balances of Egypt and Tunisia are likely to be impacted negatively in the WSC and FSC scenarios.

By 2030, in the WSC scenario, countries experiencing a trade surplus, such as Iran, Oman, and the UAE, and Israel as a trade deficit country, would expect a moderate reduction in their trade balance. The rest of the countries in this scenario would experience an improvement in their trade balance positions. In the FSC scenario, analysis shows that most countries except the UAE, Oman and Israel (same as WSC scenario) would experience an increase in their trade balance. Iran, Egypt and Saudi Arabia could experience significant improvements in their trade balance in this scenario.

The trade balance of all countries would improve considerably in the NSC scenario, wherein no country would have a trade deficit. The main reasons for this improvement would be increases energy exports and reduced imports of industrial goods and commercial services. Due to the size of its economy, Iran would be the major contributor to improving MENA trade. However, countries that would experience the most significant gains would be Tunisia and Morocco (which would probably experience a reversal in their trade position compared with the BAU) and Iran (which would be able to maintain its trade-surplus status) by 2050.

In the short term, however, the situation is reverse for most of the countries. Iran, the UAE, Tunisia, Morocco, Oman and Qatar are likely to face further declines in their trade positions in the NSC scenario by 2030. Israel would experience the same trade position as in the BAU scenario and Kuwait, Egypt and Saudi Arabia are likely to improve their trade balance.

Investment in key infrastructure

In the **BAU scenario**, approximately US$77.2 billion per year (or nearly US$2.7 trillion) by the selected countries in MENA region over the period 2015-2050 will be invested in electricity, water and transport infrastructure. Much of this investment (US$36.8billion) will be needed to develop new power plants, US$34.4 billion for transport infrastructure, and the rest (US$6.0billion), for water infrastructure. Nearly one-third of total investment across the countries is likely to go to developing new electricity, water and transport infrastructure in Saudi Arabia. Power plant infrastructure is expected to be the main recipient of investment funds in all the countries. Kuwait, Oman, Qatar, Saudi Arabia and the UAE are also expected to require significant investment (around half of the total investment) in transport infrastructure. There would be little investment (less than 5%) in improving water infrastructure, despite the fact that all the countries will be in water stress in terms of water availability by 2050.

The **ESC scenario** would expect significantly higher in investment in power plants (US$25.8 billion higher annually) than the BAU scenario, in order to change electricity generation from fossil fuels only to renewables in the countries in this research. While all countries would require some additional investment to develop electricity systems, relatively large investment will be needed by Israel and the UAE as compared to the BAU scenario. The investment in power plant systems would increase significantly for countries including Egypt, Israel, Morocco, Iran, Kuwait, Saudi Arabia and the UAE while the change in the funds invested for power plants in Oman and Tunisia would be marginal. Qatar is the only country that would need less investment in power plants (particularly thermal power plants) in this scenario compared with the BAU scenario. Oman and Tunisia would need to spend more on power plants (particularly large-scale renewable power plants) by 2030 but their investment is likely to drop over the long term.

Water systems would receive significant investment, as water is the main issue for the region. Kuwait, Israel and the UAE will invest in improving and developing their desalination systems and Kuwait would need a considerable amount for improving seawater desalination plants annually. Compare to the BAU, investment in transportation systems is likely to increase in all countries except Morocco in the ESC scenario in both the short and the long term.

In the **WSC scenario**, and recognising that water is the main challenge for the region in the period 2015 to 2050, most of the countries in this research would spend to improve their water systems which is in total for all the counties US$3.0 billion annually more than in the BAU scenario. While all countries would require significant investments to develop alternatives, Iran would invest the most, with an extra US$1.4 billion yearly (on top of the US$2 billion required in the BAU scenario). As two of the most water-stressed countries in the world, Saudi Arabia and the UAE will also need large investment in this area by 2050. Most of this investment will be directed to developing seawater desalination systems by 2030. Tunisia is the only country that in this scenario will invest less (US$612 million drop in investment) on water system compared with the BAU scenario to 2050.

Overall, an additional US$9.57 billion (annually) of investment (compared with the BAU scenario) would be needed to develop power plants to 2050 in support of the required energy for the energy-intensive seawater desalination plants among the selected countries. This funding would be significantly invested in Israel, Morocco, Qatar and Saudi Arabia, most of it to develop seawater desalination and treated wastewater systems. Egypt and Tunisia are likely to spend less on power plant systems.

In the **FSC scenario**, transportation systems could expect significant investment (US$12.07 billion more than in the BAU scenario), in order to improve food accessibility in the countries. In Egypt and Saudi Arabia, most of the funds would be invested in land transportation systems. In fact, in this scenario, all the countries would spend more than 75% of their investment in transportation systems on developing land transport. Power plants and water systems in this scenario would improve moderately for most of the countries. Kuwait and the UAE would spend significantly on its water system to improve their agricultural system for irrigation. Morocco and Saudi Arabia could expect to devote significant extra investment in their power plant system.

The **NSC scenario** would see a significant increase in investment in transportation infrastructure, to increase accessibility to food in both the short and long term. The growth in investment will be greater in the long term (2030-2050) than in the short term (2015-2030) due to investment in new infrastructure and maintenance. An additional US$41.3biliion (compared with the BAU scenario)

would be needed to build new roads, railways and pipelines across the countries over the 35 years to 2050, the major recipient of this additional investment being Egypt and Saudi Arabia.

Investment in power plants in this scenario is likely to be less (US$5 billion) than in the ESC scenario for most countries in this research over the study period and most of this investment is likely to be concentrated on the development of small-scale renewable power plants.

In this scenario, overall funds for water systems would increase compared to the WSC scenario, the extra investment going to improve treated wastewater systems in all the countries by 2050.

Social Outcomes

Economic growth in the **BAU scenario** will be accompanied by the employment growth in these countries. The overall economy for these countries together will be twice the size in 2050 than it was in 2015, and this growth will create 179 million new jobs (a 99% increase compared with 2015), which could impact the whole MENA region. The number of employees would increase from 89 million in 2015 to 128 million in 2030 and 178 million in 2050. This is equivalent to an average growth in employment of 0.9% per year in the short term and 0.8% per year in the long term. More than 65% of these new jobs are expected to be created in the commercial and services and agriculture sectors, as these will continue to be the major sectors of the economy. The remaining new jobs are expected to be created in the water (1%), transport (7%), energy (11%) and industry (15%) sectors. More than two-fifths of new jobs across the countries will be created in Egypt alone, which would be the third largest economy and the most populated country in the region by 2050. Oman, Tunisia and Saudi Arabia would also experience large increases in employment. This will be due to strong growth in the commercial and service sectors in Oman and Saudi Arabia and in the industrial sector in Tunisia.

The employment impacts in the **ESC, WSC and FSC scenarios** will be mostly negative compared to the BAU scenario. In the ESC scenario, employment would be 3% (11.6 million) lower than in the BAU scenario by 2050, in the WSC scenario the rate will be 2.4% (9.3 million) lower and in the FSC scenario, the rate will be 1% (2.6 million). Overall, the increase in jobs, particularly in the industrial and commercial services sectors, in all three scenarios will not be sufficient to compensate for jobs lost in the agriculture sector in each scenario. In fact, the number of jobs will be negatively affected in all countries except Israel, where job creation will improve in all three scenarios by 2050. In the short term, however, Iran and Oman are likely to expect extra jobs in ESC, WSC and FSC scenarios.

By contrast, employment levels in all the countries in the **NSC scenario** are likely to increase by 2.4% (828 million jobs) in the short term and by 4.5% (1660 million jobs) in the long term as compared to the BAU scenario. While 6 million jobs are likely to be lost in the agriculture sector, 10 million new jobs will be created in other sectors of the economy. Significant new job opportunities are likely to arise in Oman (10.3%), the UAE (10.4%), Israel (6.7%), Tunisia (5.6%), Kuwait (5.2%) and Qatar (4.6%) and moderate extra opportunities in Iran (2.2%), with about a 1% improvement in Morocco and Saudi Arabia. In this scenario, Egypt would be the only country to experience a moderate negative impact on employment by 2050.

In the short term, that is, to 2030, Morocco, like Egypt, could face a slight drop in terms of job creation. However, a significant positive impact could be expected in Tunisia (7.3%), the UAE (4.9%) and Oman (4.7%) in terms of additional job opportunities.

Energy Security

Energy demand

To support the region's economy in the mid-century, in **the BAU scenario**, the primary energy demand will increase, from 1187Mtoe in 2015 to 1623Mtoe in 2030 and to 2102Mtoe in 2050. This is equivalent to a growth rate of 1.6% per year over the period 2015-2050.

Those with strong growth in energy demand include the lower/middle-income countries of Egypt and Tunisia and the high-income countries of Saudi Arabia and Oman, where the primary energy demand is expected to exceed by more than 2% per year for these countries over the study period. In contrast, primary energy demand in Israel, Kuwait, Qatar, Iran and the UAE is expected to increase by less than 2% per year. Saudi Arabia, Iran and the UAE, the three major economies in the region, currently account for 30%, 26% and 11% respectively of total primary energy demand in the region. By 2050, however, demand in Iran and UAE will decline to 18% and 9% respectively while the demand in Saudi Arabia would increase to 37%.

Apart from Israel (30%) and Morocco (45%) which use coal as one of the energy sources in their primary energy, the countries in this research rely on oil and gas to meet almost all their primary energy needs. Most of the oil and gas is used in the residential and industrial sectors. Although the demand for both oil and gas will increase in the years to 2050, it is expected that the demand for gas will increase more than for oil across all countries in the BAU scenario.

Electricity currently accounts for less than 20% of total final energy demand in most countries in this research. Egypt, Kuwait and Israel are the countries where the share of electricity in final energy demand is greater than 20%. The importance of electricity is, however, likely to increase

in all countries in the BAU scenario and Israel and Kuwait in particular are likely to see the share of electricity in their final energy mix exceeding 30%.

The only country likely to transition from traditional fossil fuels to more advance technology is Iran, which will continue using nuclear energy to meet its final energy demand. However, the share of nuclear power is expected to be minor (1%) and Iran will continue relying heavily on oil and gas as its main source of primary energy in the period of this study.

In the **ESC** and **WSC** scenarios, it is expected that the total primary energy demand will decrease but will increase slightly in the **FSC** scenario (compared with the BAU scenario) by 2050. Total primary energy demand across the countries would increase on average by 1.5% in the ESC scenario, by 1.6% in the WSC scenario and by 1.8% in the FSC scenarios per year (compared with 1.7% per year in the BAU scenario). Energy efficiency improvements through higher productivity would be the main driver of this reduced demand, and most of the reduction would happen after 2030.

In all the scenarios, Tunisia is likely to experience a significant reduction in demand by 34% (ESC), 18% (WSC) and 13% in FSC scenarios. The decline in energy demand is the most in Egypt, Kuwait and Oman will range from 15% to 20% in the ESC scenario by 2050. In the WSC scenario, Israel and Saudi Arabia are likely to experience the highest decline in energy demand of 9.8% and 8.1% respectively. The rest of the countries will produce different results in the ESC and WSC scenarios but on average, their reduction would be less than 10% in the ESC scenario and less than 5% in the WSC scenario by 2050.

In the ESC scenario, the short-term reduction in primary energy demand would be almost half of that in the long term. On average, it is expected that the primary energy demand will reduce by 7% compared with the BAU scenario across all countries between 2015 and 2030 while the average rate of reduction in demand would be 14% compared with the BAU scenario between 2030 and 2050. The main driver for this faster reduction in primary demand could be significant improvements in energy efficiency in the long term. Similar to the ESC scenario, the demand for energy in WSC scenario will be much higher by 2030. On average, it is expected that the primary energy demand will fall moderately (by 2%) (Compared with BAU) across the countries by 2030 and considerable (by 5.3%) (Compared with the BAU) between 2030 and 2050. In the WSC scenario, however, countries such as the UAE and Oman could expect more energy demand compared with the BAU scenario in 2030.

Most of the reduction in primary energy demand in the countries in these scenarios (ESC and WSC) would be due to use less fossil fuels, particularly oil (in ESC scenario) and coal (in WSC scenario), while the use of renewables would increase in all countries.

In the **FSC scenario,** overall primary energy demand would be more than in the BAU, ESC and WSC scenarios. In contrast to the ESC and WSC scenarios, not all countries would face a reduction in their demand. Iran, Morocco and Oman could expect an increase in total primary energy demand by 2050.

When comparing the short term and the long term, all countries would have the same trend as in the ESC and WSC scenarios but energy demand in the FSC scenario would be higher than in the BAU scenario, even, in the short term. Overall, the ESC scenario has the highest and the FSC scenario the lowest impact on reducing primary energy demand in both the short and long term, compared to the BAU scenario.

In the **NSC scenario**, total primary energy demand would increase by 1% per year (compared to 1.7% in the BAU scenario) by 2050, which is equivalent to a further reduction of 2% compared with the ESC scenario by 2050. Most of this reduction would come from reduced use of conventional fossil fuels, mainly oil and gas, and their replacement by renewable energy. Compared with the ESC scenario, primary energy demand in 2050 in this scenario is likely to be lower for all countries except Egypt and Tunisia. In the short term, the NSC scenario would be less effective in reducing energy demand than the long term. The average reduction in primary energy demand in the NSC scenario is 4% (59 Mtoe less than in the BAU scenario) by 2030 while in the long term; the decline is 15% (310 Mtoe less than in the BAU scenario) by 2050. In the short term, most countries (except Iran, Israel and Saudi Arabia) would expect less primary energy demand in the NSC scenario compared to the ESC and WSC scenarios. For all countries, energy demand would be less in the NSC scenario compared with the FSC scenario in both the short term and the long term

Energy intensity

In the **BAU scenario**, the average energy intensity of most of the selected countries (except Saudi Arabia and Tunisia) in the MENA region is expected to decline slightly, by 1% (or 0.02% per year), over the period 2015 to 2050. The most noticeable reduction will take place in what is currently the least energy-intensive country, Israel, whose energy intensity is forecast to be greater than 128 toe per US$ by 2050. In the short term, energy intensities of most of the countries including Egypt, Iran, Kuwait, Morocco, Oman and the UAE would decline slightly ranging from 1.2% (Iran) to 2.9% (Kuwait). Similar as the long term, by 2030, Tunisia and Saudi Arabia would expect increase in their energy intensities while Israel would expect significant reduction.

In the **ESC** and **WSC scenarios**, the average energy intensity of the region is expected to decline by 16% (or 0.4% per year, to 355 toe per US$) in the ESC scenario and by 5% (or 0.2% per year, to 400 toe per US$) in the WSC scenario over the period 2015-2050. Analysis suggest that the energy intensities across all the countries will come together as a narrower band in the ESC scenario compared with the BAU scenario by 2050. In the ESC scenario, Israel is the only country with faster reduction in its energy intensities in the short term while the rest of the country would experience slower decline in this period as compared to their energy intensities in the long term. In the WSC scenario, Kuwait and Oman energy intensities are expected to be greater than in the BAU scenario by 2050.

In the **FSC scenario**, the average energy intensity of the region is expected to increase by 0.1% over the period 2015-2050. Although some countries are expected to have reductions in their energy intensity, Iran, Oman and Morocco would expect to have higher energy intensity.

In the **NSC scenario**, the energy intensity of the region is expected to decline even faster than in the ESC scenario, at an average annual rate of 0.8% by 2050. The decline for all the countries except Morocco and Qatar is more than 20% compared with the BAU scenario by 2050. By 2030, all countries would face reduction in their energy intensities; however, the rate of change would be less than in the ESC scenario for some countries. Iran, Egypt, Israel, Kuwait and Tunisia would expect less energy intensity in the ESC compared with the NSC.

Energy conversion efficiency

The overall energy conversion efficiency in the countries of the study is relatively poor. Approximately 40% of energy is lost before it reaches the point of final consumption. In the **BAU scenario**, energy efficiency is likely to increase marginally from 40% in 2015 to 41.5% in 2050. While the improvement in energy efficiency is expected to occur in most countries such as Saudi Arabia, Kuwait, Qatar, Iran, Israel, Morocco and Egypt, other countries, including Oman, the UAE and Tunisia, are likely to observe a drop in their energy efficiency by 2050.

Between 2015 and 2030, Tunisia would face the highest decline in its energy efficiency and the rest of the countries would expect only slight improvement in their energy efficiency. Israel's energy efficiency with 2.4% increase would be the highest improvement in among the countries in this study in terms of energy efficiency by 2030.

In the **ESC, WSC and FSC scenarios,** overall, there is likely to be a modest improvement in energy efficiencies to the year 2050. These improvements will not, however, be uniform. For example, Qatar would be the only country whose energy efficiency would drop in all the three scenarios. Morocco and the UAE in the WSC scenario, and Iran, Morocco and Israel in the FSC scenario would expect drops in their energy efficiency compared to the BAU scenario by 2050.

In the **NSC scenario**, however, it is likely that energy efficiency improvements will be much higher for most of the countries by 2050 than in the BAU and ESC scenarios. Countries includes Iran, Morocco, Qatar, Saudi Arabia, the UAE, Oman and Tunisia would expect higher energy efficiency levels than both BAU and ESC scenarios by 2050. Few countries such as Egypt, Israel and Kuwait would have less improvement in their energy efficiency levels compared to the ESC scenario (although the rate of improvement would still be higher than in the BAU scenario) in the long term. In the short term, while most of the countries are expected to have higher energy efficiency in NSC scenario than in the ESC scenario, Kuwait and Israel are expected to have lower energy efficiency against ESC scenario.

Energy diversity

The region is currently overly dependent on fossil fuels, particularly gas and oil, to meet its energy needs. Reduced reliance on fossil fuels will definitely diversify the energy mix. In the **BAU scenario**, low-middle income countries apart from Egypt would become less energy diverse by 2050. In contrast, energy diversity for all high-income countries apart from Oman and the UAE would decline slightly both is the short and long term. The only upper income country in this research, Iran, would expect a slight increase in energy diversity in the short term while the country is likely to experience a marginal decline in energy diversity in the long term.

In the **ESC, WSC and FSC scenarios**, most countries are likely to become more energy diverse. Morocco as a low middle-income county would be the only country whose energy diversity would decline marginally in the WSC and FSC scenarios both in the short term and in the long term as the country would be more reliant on oil and gas. Although countries would expect to be more energy diverse in the short term, the rate of change is much slower than the long term in all these three scenarios. The rate of change for energy diversity, on average is almost 50% more in the long term (2030-2015) as compared to the short them (2015-2030).

The region's energy diversity in the **NSC scenario** is likely to be the same as in the ESC scenario. However, it is likely to vary across countries. In comparison with the BAU scenario, while most countries would become more energy diverse, Morocco is the only country likely to become less diverse in the short term and in the long term. Countries such as Tunisia, Qatar, Saudi Arabia and the UAE would expect substantial improvement in their energy diversity in the NSC scenario by 2050. The significant improvement is likely to experience by Egypt, Israel Kuwait and Oman in the NSC scenario as compared to the BAU scenario by 2050. In comparison to the ESC scenario, However, It is expected that, Israel, Morocco and Oman experience less energy diversity in the NSC scenario compared with the ESC scenario.

Energy-import dependency

On average, the countries in the region currently spend approximately 11% of their export earnings on energy imports, with the value ranging between 0.2% in Qatar and 41% in Morocco. In the **BAU scenario,** the rate of import dependency is also likely to vary across countries. By 2050, while most countries will experience reduced reliance on energy imports, some of the energy exporter countries include Kuwait, Oman, Qatar and the UAE are likely to experience increased reliance on importing energy. In the short term, Egypt can expect further dependency on energy with growth of 1% while in the long term the country would able to decrease its imported energy by 2.6%.

In the **ESC, WSC and FSC scenarios**, overall energy import dependency is likely to remain constant, approximately 8.2%. Most of the countries would expect improvement in their energy import dependency in these three scenarios compared to the BAU scenario. However, it is expected that countries such as Kuwait in the ESC scenario and Egypt, and Iran in the FSC scenario would become more energy dependent.

In the **NSC scenario**, the energy import dependency is expected to reduce to approximately 7%, with all countries in this research. A comparison between the NSC and ESC scenarios shows that most countries, namely, Egypt, Tunisia, Iran, Oman, Saudi Arabia, the UAE and Kuwait will be less depending on importing energy than in the ESC scenario. However, Morocco and Israel as energy-importing countries and Qatar as an energy-exporting country would become more dependent on importing energy as compared to the ESC scenario in both the short and the long term.

Energy affordability

In the **BAU scenario**, energy affordability is likely to become a matter of concern in the future, with average energy expenditure in the countries increasing from 9% in 2015 to 9.4% in 2050. In the 35 years to 2050, the considerable increase is expected to occur in Saudi Arabia. Egypt, Israel, Kuwait, Oman and Qatar will spend less on purchasing energy, while, other countries include Iran, Morocco, Tunisia and the UAE are likely to spend slightly more of their total income on purchasing energy in the BAU scenario both in the short term and in the long term.

In the **ECS, WSC and FSC scenarios,** most countries would spend a smaller proportion of their income on energy compared with the proportion in the BAU scenario. Morocco is the only country that will spend more on energy in all three scenarios (on average 4% more) compared with the proportion in the BAU scenario by 2050. In the short term, the change on purchasing energy would be varied among the countries in this research. Israel, Oman, Qatar, Saudi Arabia

and Tunisia are likely to spend a smaller proportion of their income on energy compared with the BAU scenario in all the three scenarios (ESC, WSC and FSC). In contrast, Kuwait and Morocco will spend more of their total income on purchasing energy in all three scenarios compared with the BAU scenario by 2030.

Energy affordability for consumers in most countries (except Egypt and Kuwait) is expected to improve (on average to 7.3%) in the **NSC scenario** compared with the ESC scenario in the long term. However, in the short term, the average share of energy expenditure among all the countries would less in the ESC scenario (9%) as compared to the NSC scenario (9.6%). While this improvement is expected for most of the countries in the short term and the long term, consumers in Saudi Arabia and Oman would benefit the most in this scenario.

Chapter 7: Assessment of the impact of scenarios (II)

In Chapter 6, the impact of the various scenarios on economic, societal and energy security in the MENA region were discussed in detail. This chapter will continue analysing the outcomes of the key attributes (shown in Figure 5.11) related to water and food security in the 10 countries selected for this research. As in the previous chapter, the assessment will be based on the Business as Usual (BAU), Energy (ESC), Water (WSC), Food (FSC) and Nexus (NSC) oriented scenarios.

For this purpose, this chapter is organised as follows: Section 7.1 explains water security and its key attributes, including water availability, water demand, water stress and water intensity. Section 7.2 presents food security and analyses the results for food accessibility, food import dependency and food affordability. Section 7.3 summarises the major findings discussed in this chapter.

7.1 Water security

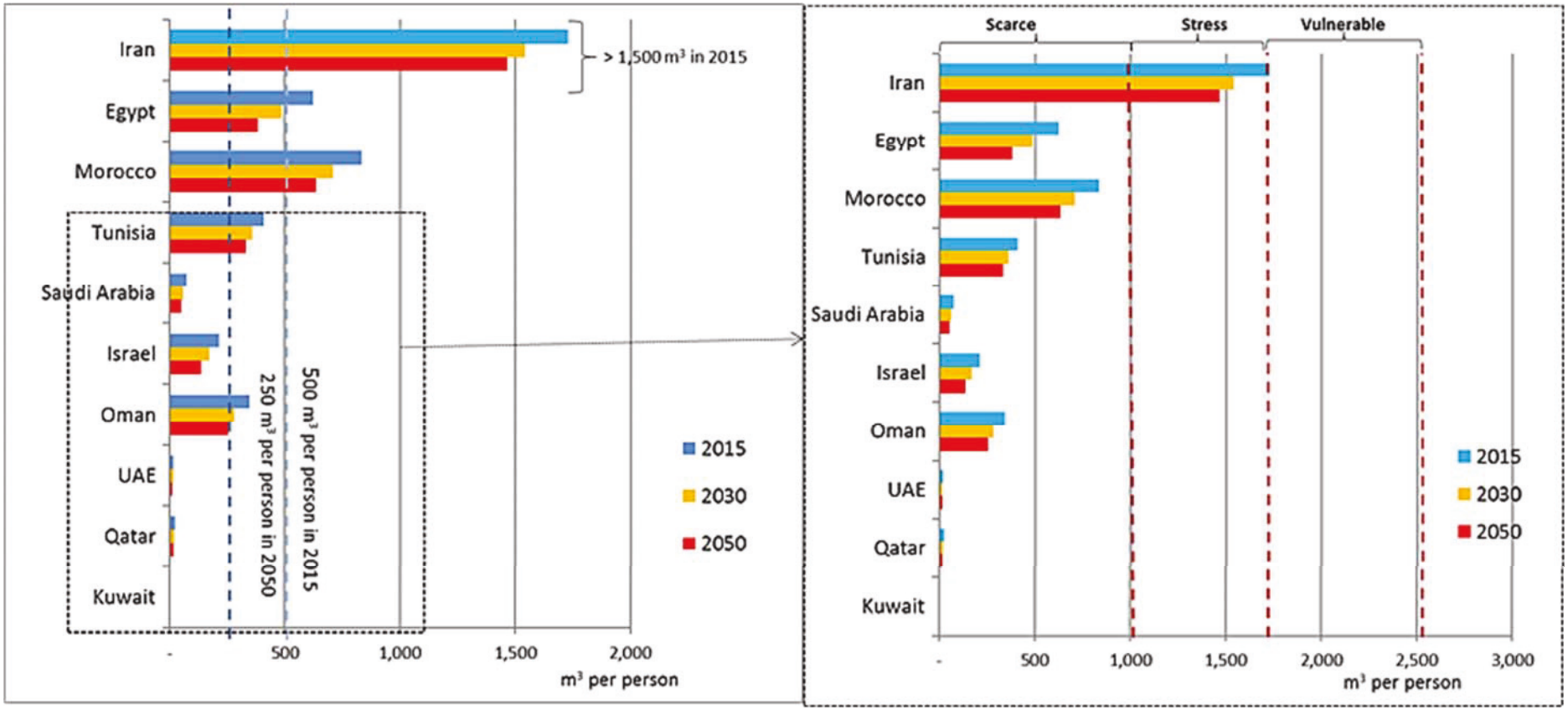
This section assesses the impact of water security in the various scenarios, using the attributes of water availability, water demand, water stress and water intensity.

7.1.1 Water availability

In 2015, the average renewable available water in the countries in this research annually per person was 427 m^3. As the population will be 1.4 times in 2050 what it was in 2015, this growth is likely to place significant pressure on this resource, potentially reducing annual water availability per person to 346 m^3 by 2030 and to and 328 m^3 by 2050. Such a decline in water availability would put the countries as a whole under additional stress over the 35 years to 2050. According to the UNEP (UNEP 2008), water availability of less than 1000 m^3 of per person per year is considered water scarcity.

While the renewable water resources available in 2015 varied across the countries in this research, they all (in contrast with energy) suffered from a lack of renewable water.

Figure 7.1: Water availability Per-capita for the countries



Source: See Appendix B, Section C, Table C1, based on data from the (FAO 2016) and (UNEP 2008)

- According to the UNEP definition, in 2015, Egypt, Morocco, Tunisia, Saudi Arabia, the UAE, Israel, Oman, Qatar and Kuwait were water scarce countries because their water availability was less than 1000 m^3 per person per year (see Figure 7.1).

- Water availability in Oman, Kuwait, Qatar, the UAE, Israel, Saudi Arabia and Tunisia was less than 500 m^3, in Egypt it was 622 m^3 and in Morocco 834 m^3 in 2015.

- Iran, with water availability of between 1700 m^3 and 2500 m^3 per person per year, was a water vulnerable country in 2015.

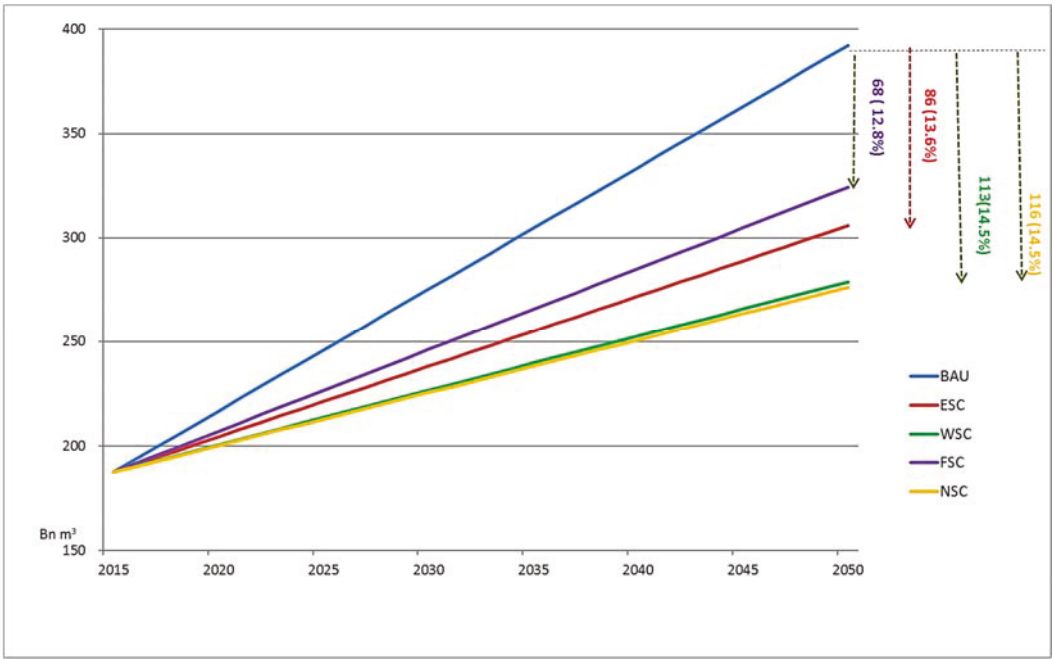
- In the BAU scenario, Iran is likely by 2030 to become a water-stressed country, while the rest of the countries are likely to remain water scarce but worsening. Tunisia, Saudi Arabia, Israel, Oman, UAE, Qatar and Kuwait will remain in a condition of water availability of less than 500 m^3 per person per year.

- In the alternative scenarios (ESC, WSC, FSC and NSC), the amount of per-capita available renewable water will not be affected, since the population is assumed to have the same growth in all of the scenarios. However, the growth in water demand and the level of available resources from surface water, groundwater, seawater desalination and treated wastewater across these scenarios will all have implications for water availability (refer to Section 7.3.3).

7.1.2 Water demand

In the **BAU** scenario**,** population and economic growth will increase the demand for water across the countries, on average by 2.0% per year from 187 billion m^3 in 2015 to 275 billion m^3 by 2030 and to 392 billion m^3 by 2050 (see Figure 7.2).

Figure 7.2: Total water demand in in the selected countries in various scenarios



Source: See Appendix B, Section C, Table C2

The 10 countries in this research account for 67% of the MENA region's total water demand (Droogers et al. 2012).

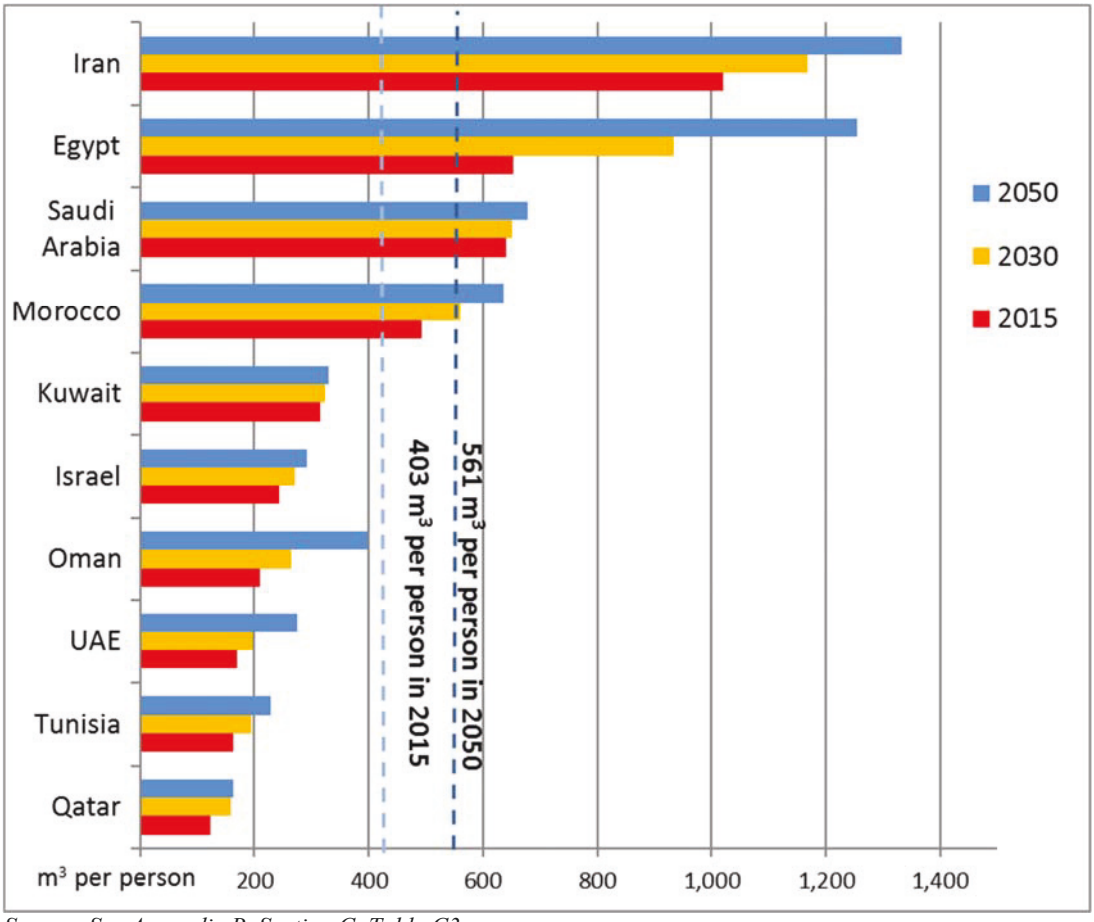
- Iran and Egypt are the major water users in the MENA, accounting for 28% and 21% respectively of the total water usage in the region. Economic and population growth rates in Egypt will further increase the country's share of water usage to 2050 and Egypt will be the country with the highest water demand of all the countries in this research. Egypt's total water demand will increase from 58 billion m^3 in 2015 to 112 billion m^3 by 2030 and to 192 billion m^3 by 2050. This is equivalent to an average annual growth rate of 3.3% over the 35 years, which is the highest among the countries in this research.

- Water demand in Oman, Qatar and the UAE is likely to grow moderately (more than 2%) over the study period, the main driver for the higher demand for water would be increased demand from the food sector as a result of population growth.

- On a per-capita basis, Egypt and Iran are the major water users of all the countries in this research, averaging more than 600 m^3 of water per person per year (see Figure 7.3). In Iran, this usage is likely to exceed 1000 m^3 by 2050.

- The average water usage per person per year in the selected countries in 2015 was 403 m^3. In addition to Iran and Egypt, those that exceeded this average were Morocco (492 m^3) and Saudi Arabia (640 m^3) in 2015. The water demand average of the countries is likely to grow to 472 m^3 by 2030 and to 561 m^3 by 2050, with Saudi Arabia (677 m^3), Morocco (636 m^3), Egypt (1254m^3) and Iran (1333 m^3) expected to go above, and in two cases (Iran and Egypt) significantly above, this average by 2050 (see Figure 7.3).

Figure 7.3: Per-capita per year water demand in the BAU scenario, 2015 – 2050



Source: See Appendix B, Section C, Table C3

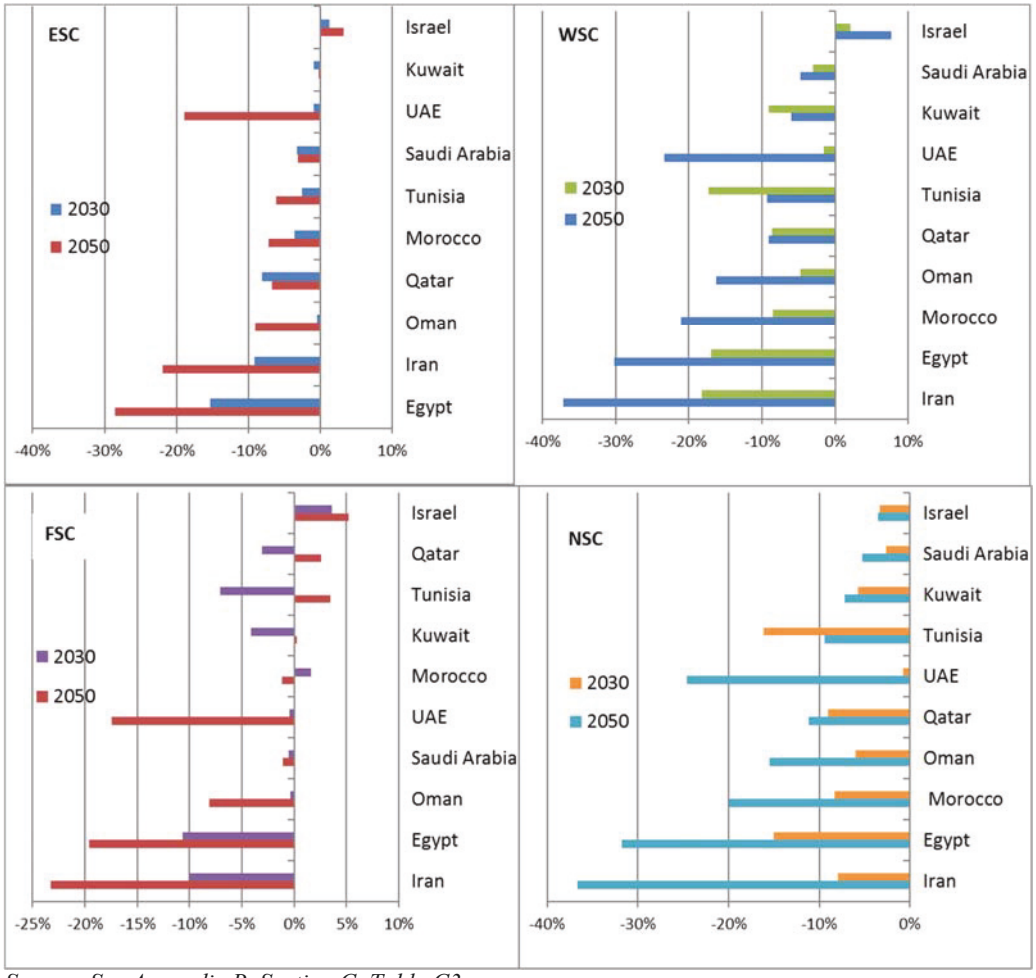
ESC, WSC and FSC scenarios

- In the **energy-oriented scenario (ESC)**, the average annual demand for water in most of the countries in this research will decrease compared with the BAU scenario, which most of the decline would happen in the agriculture and residential sectors (see Figure 7.4). The use of energy-intensive fertiliser in the production of food could be the main reason for these water savings. Israel is the only country, which is likely to have increase in water usage from 2 billion m^3 in 2015, to 4 billion m^3 in 2050. This approximately 0.1 billion

m^3 (3%) higher than the demand in the BAU scenario. Most of the additional water will be used in the industrial sector.

- Countries likely to experience a substantial (more than 20%) reduction in water demand are Egypt and Iran, while Morocco, Oman, Qatar and Tunisia are expected to experience a relatively considerable (5%- 10%) reduction in water demand (see Figure 7.4). The UAE is likely to experience a significant reduction (19%) in water usage from 3.6 billion m^3 in the BAU scenario, to 2.9 billion m^3 in the ESC scenario by 2050.

Figure 7.4: Changes in water demand in 2050, compared with the BAU scenario



Source: See Appendix B, Section C, Table C3

In the **water-oriented scenario (WSC)**, the demand for water will decrease (as it did in the ESC scenario) in most of the countries in this research, the main reasons for this reduction being less demand from the agriculture and energy sectors.

- The majority of the countries include the low-middle income countries of Egypt and Morocco, could expect a substantial (more than 20%) reduction in water demand. The upper-middle income country of Iran could expect a relatively considerable reduction (5%-10%) in water demand compared to the BAU scenario (see Figure 7.4).

- In contrast, Israel, the only country, could demand a relatively considerable increase of 8% compared with the BAU scenario (see Figure 7.4).

Although the same trend can be observed in both the short (2015-2030) and the long term (2030-2050) in the ESC and WSC scenarios, the rate of change in both scenarios would increase in the long term for most of the countries except for Qatar, Saudi Arabia and Tunisia (see Figure 7.4). In Saudi Arabia and Qatar, the rate of change in water demand is relatively similar in both the ESC and WSC scenarios. However, Tunisia is likely to experience a faster reduction during the short term (2015-2030) as compared to the long term (203-2050).

In the **food-oriented scenario (FSC**), the decline in water demand in all the countries will be less compared to the decline in water demand in the BAU, ESC and WSC scenarios and one that is explained by the higher water demand from the agriculture sector.

- Six out of 10 countries in this scenario could expect a reduction in their water demand compared with the BAU scenario. These countries are Iran (23%), Egypt (20%), the UAE (17%), Oman (8%), Saudi Arabia (1%) and Morocco (1%) (see Figure 7.4).

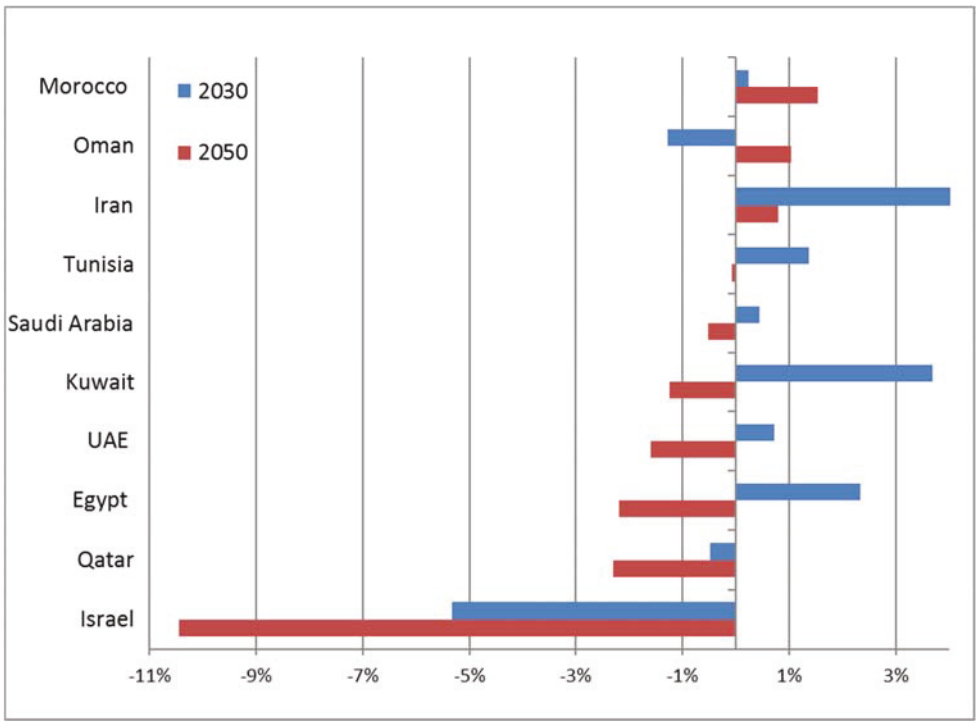
- In contrast, Qatar, Israel, Tunisia and Kuwait are likely to experience an increase in their water demand by 2050. In Qatar, for example, water demand will increase from 0.3 billion m^3 in 2015, to 0.7 billion m^3 in 2050, which is approximately 0.02 billion m^3 (3%) higher than its demand in the BAU scenario.

The only two countries likely to have additional demand in this scenario compared to the BAU in the period 2015-2030 are Israel (ESC, WSC and FSC scenarios) and Morocco (FSC scenario). The rest of the countries will demand less water than the BAU in 2030. However, the trend would change more rapidly in the long term in all the three scenarios, when water demand will increase by 6% on average compared with the BAU scenario, while in the short term the demand will rise by 4% on average compared with the BAU scenario.

NSC scenario

In the **NSC scenario**, water demand is expected to fall considerably in all countries compared with the BAU scenario (see Figure 7.4). Countries such as Egypt, Iran, Morocco and the UAE could expect substantial decline in their water demands in the NSC scenario as compared to the BAU scenario by 2050. Shifts in crop production practices, from being water intensive to less water intensive, would be the main reason for this reduction.

Figure 7.5: Changes in water demand in the NSC scenario compared with the WSC scenario



Source: See Appendix B, Section C, Table C3

Most countries will experience lower water demand, even more, in the NSC scenario compared with the WSC scenario by 2050[21]**.** However, Iran, Oman and Morocco will experience the opposite. Morocco's water demand, for example, is estimated to increase from 17 billion m^3 in 2015 to 22.9 billion m^3 and 23.2 billion m^3 in the WSC and NSC scenarios, respectively, in 2050. This implies that the demand for water in the NSC scenario is 1.3% higher than the demand in the WSC scenario.

[21] In this research, the NSC scenario will be compared with the closest scenario for each sector. For example, in the energy sector, the change in the NSC scenario will be compared with the ESC scenario. In the water sector, the comparison will be between the NSC and WSC scenarios, and in the food sector, the NSC scenario is compared with the FSC scenario.

Most of the countries (except Israel, Qatar and Oman) are likely to experience further reduction in water demand in the NSC scenario after 2030 (as compared to the WSC scenario). Countries include Morocco, Iran, Tunisia, Saudi Arabia, Kuwait, the UAE and Egypt are likely to benefit further in WSC scenario in terms of reduction in their water demands as compared to the NSC scenario in the short term. For instance, the demand of water in Iran would reduce further significantly (13%) in the WSC scenario (as compared to the NSC scenario) by 2030. In the long term, however, the majority of the countries would experience the opposite. NSC scenario would be more beneficial for all the countries except Iran, Morocco and Oman that would demand more water in the long term (2030 to 2050) in this scenario. In the case of Iran and Morocco, the demand for water in the WSC scenario will be less than the demand in the NSC in both the short term and long term.

7.1.3 Water stress

The information in sections 7.3.1 and 7.3.2 is collected together in this section to provide information about water stress levels in the selected countries in this research (see Figure 7.6). Water stress is expressed as the ratio (or percentage) of total available freshwater that can be withdrawn in response to water demand. According to the UNEP (UNEP 2008), countries with water stress ratios of more than 20% are defined as having a chronic fresh water problem, bearing in mind that not all available fresh water can be physically used.

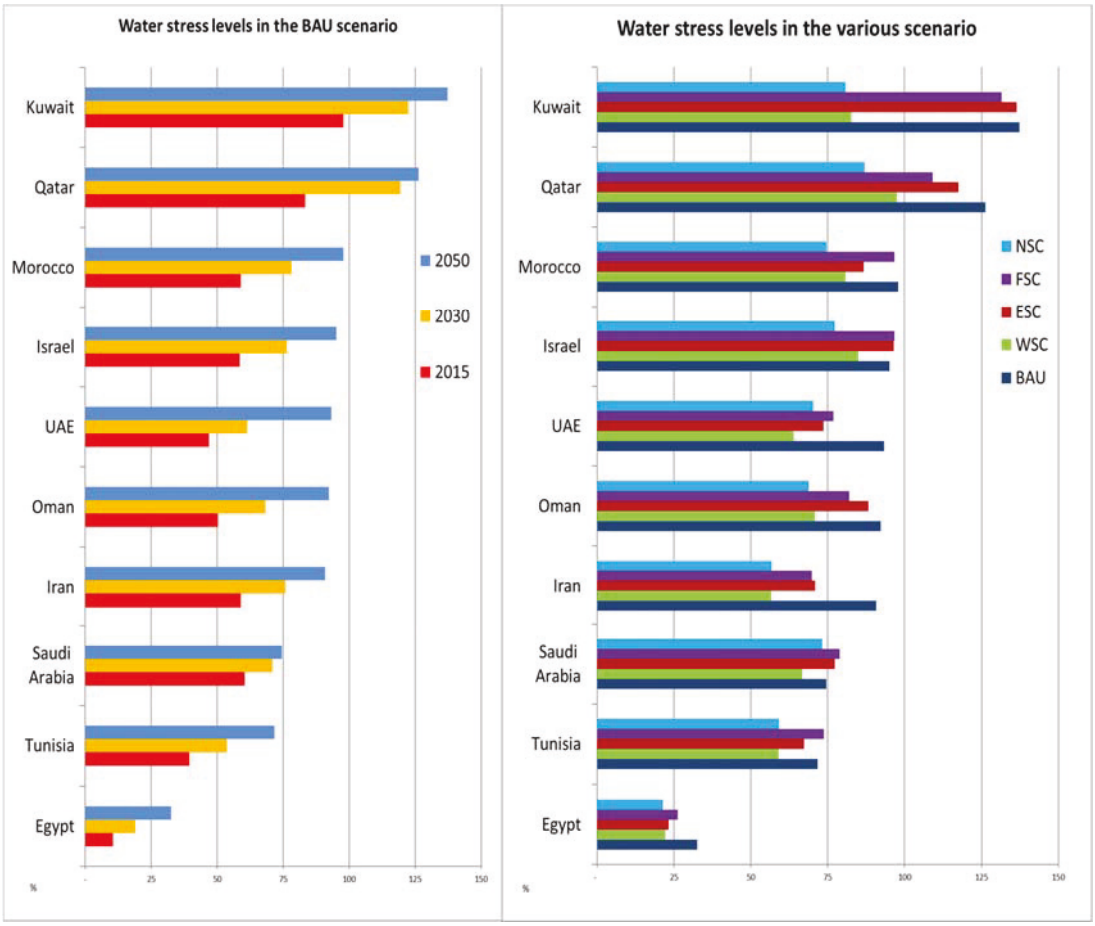
- According to the UNEP definition, all countries in this research except Egypt were facing a serious chronic freshwater shortage in 2015, with a water stress level of more than 20%. Increases in water demand in all countries except Egypt in the **BAU scenario** would raise their water stress to extraordinary levels (see Figure 7.6), above 50% by 2030 and 70%, by 2050.

- The level of water stress for Egypt in 2015 was 10%, is likely to increase to 19% by 2030 and to increase significantly to 33% by 2050.

- The results of the analysis show that water demand in all countries except Iran, Morocco and Tunisia is likely to exceed the supplies of available fresh water by 2050. Kuwait and Qatar had the highest level of water stress (98% and 83% respectively) in 2015, levels that could grow by 0.7% in both countries over the period to 2050.

- Iran, Israel, Morocco, Oman and the UAE could expect an increase in their water stress levels to more than 90% by 2050.

Figure 7.6: Water stress levels in the countries of the study



Source: See Appendix B, Section C, Table C4

- In the **energy-oriented scenario (ESC),** water stress will be lower than in the BAU scenario in all the countries except Israel and Saudi Arabia by 2050. This is due to their lower water demand and the availability of alternative water supply options, such as seawater desalination and treated wastewater.

- In Israel, the water stress level could increase further from 59% in 2015, to 77% in 2030 and 96% in 2050 in the ESC scenario. These levels would be higher by 1% in both the short term and the long term compared with the BAU scenario (see Figure 7.6).

- In Saudi Arabia, the level of water stress by 2030 will be 1% less than in the BAU scenario. However, by 2050, its level of water stress will have increased by 4% compared with the BAU scenario.

- Reducing water stress levels in the other countries requires increased investment in water infrastructure. The UAE, for example, could reduce its water stress level from 93% in BAU the scenario to 74% in the ESC scenario by 2050. However, this would require nearly US$2.6 billion in the short term (to 2030) to develop water infrastructure, in addition to the US$9 billion required in the BAU scenario. The country would also require another US$22 billion between 2030 and 2050 to keep the level of water stress 20% below that in the BAU scenario. More than 90% of this amount would be needed to develop energy-intensive seawater desalination plants (see Figure 7.6).

- In the **water-oriented scenario (WSC)**, the level of water stress in all countries could drop significantly by 2050. Kuwait likely to experience the greatest reduction in water stress, from 137% in the BAU scenario to below 85% by 2050, an improvement that would require 90% of the water demand to be supplied by seawater desalination (see Figure 7.6). Kuwait would require an additional investment of US$10.5 billion (compared to the investment required in the BAU scenario) to develop the necessary water infrastructure, mainly for desalination seawater systems, over the 35 years from 2015 to 2050.

- In this scenario, apart from Qatar, all the countries would have water stress levels below 85% by 2050. The water stress level of Iran (57%), Israel (84%), Morocco (81%), Oman (71%) and the UAE (64%) would decline significantly in the WSC scenario while the countries in this group would expect the levels of water stress more than 90% in the BAU scenario by 2050.

- Even though Qatar's level of water stress would drop by 23% compared with the BAU scenario, it would still be the most water stressed country in the WSC scenario.

- In the short term (2015-2030), the rate of change in water stress is much slower as compared to the long term (2030-2050). Although it is expected that all the countries will improve their water stress levels, Saudi Arabia's will be 3% higher in the WSC scenario than in the BAU scenario by 2030. Saudi Arabia's investment in water systems in the WSC scenario will be additional US$1.4 billion (on the top of the investment in the BAU scenario) between 2015 and 2030, mainly to develop seawater desalination plants.

In the **food-oriented scenario (FSC),** the level of water stress varies across the countries. While the majority are likely to have less water stress in this scenario compared with the BAU scenario, Israel, Saudi Arabia and Tunisia could face higher water stress ratios by 2050.

- The highest reduction (as compared to the BAU scenario) among the countries would happen for Iran in this scenario by 2050, due to its application of more advanced technologies, such as genetic modification and improving agricultural productivity. In this scenario, Iran's level of water stress would drop from 91% in the BAU scenario to 70% (see Figure 7.6).

- Egypt (20%), the UAE (18%), Oman (11%) and Qatar (14%) are likely to face a significant reduction in water stress in this scenario. The rest of the countries include Kuwait and Morocco would expect reductions of less than 5% compared to the BAU scenario by 2050.

- In the short term, the only two countries likely to expect higher water stress levels are Morocco and Saudi Arabia in the FSC scenario compared to the BAU. The level of water stress for Saudi Arabia would increase by 8%, from 71% in the BAU scenario to 79% in the FSC scenario by 2030. In the case of Tunisia, the level of water stress in the FSC scenario will be moderately (4%) less than the BAU scenario during the short term, while it will increase by 2% in the long term (See Appendix B, Section C, Table C4)

Although the reduction in water stress levels would happen in almost all countries in the ESC, WSC and FSC scenarios, none of the scenarios would be able to take the water stress level, and hence the chronic fresh water problem, below the UNEP definition of 20% in any of the countries in this research.

NSC scenario

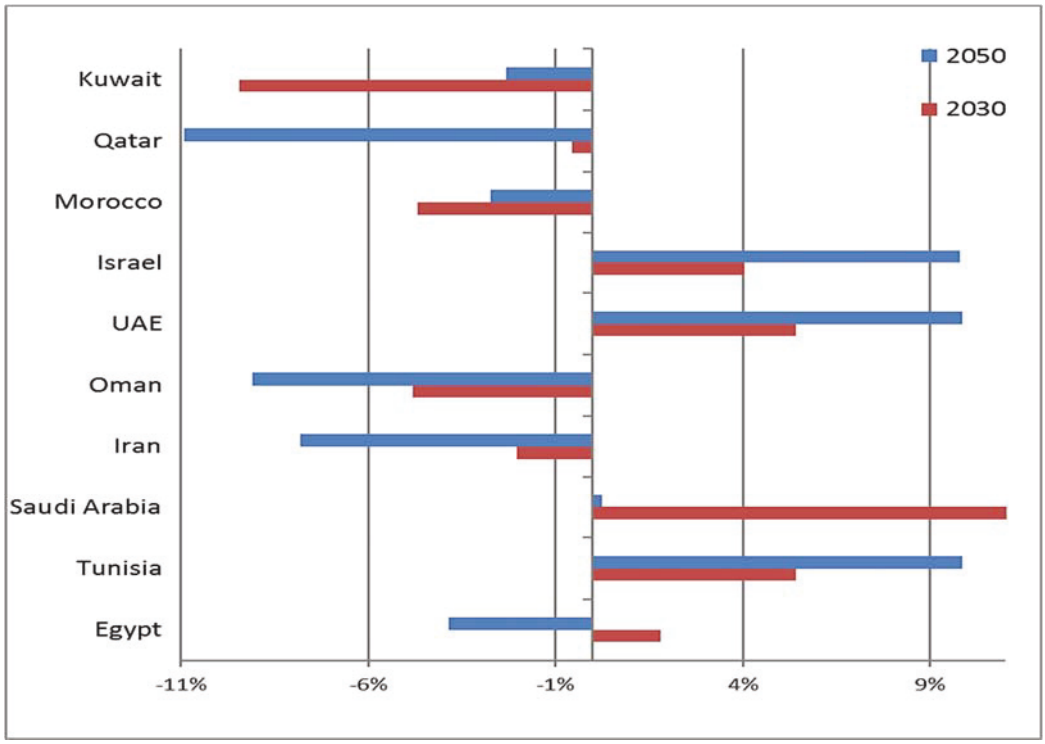
Reduced water demand and increased alternative option for suppling water (treated wastewater) in **NSC scenario** will reduce water stress levels further for all countries in this research (see Figure 7.6). For Kuwait, as the most water stress country in the world, the reduction (in the NSC scenario) is expected to be 41% compared with BAU scenario and 2.3% as compared with the WSC scenario. The significant reduction in the level of water stress in this scenario for Kuwait requires further $5.8 billion (in addition to the BAU scenario) of investment mainly for treated wastewater and seawater desalination. However, Most of the water reduction in this scenario is

due to the change in the pattern of crops reduction from water-intensive to less water-intensive in agriculture sector.

In comparison with the WSC scenario, Israel, Tunisia, Saudi Arabia, and the UAE are the countries in which the impact of the NSC scenario on water stress levels would be less than in the WSC scenario. For Israel, Tunisia and the UAE, the water stress level in the NSC scenario is expected to increase considerably (by less than 10%) compared to the WSC scenario, while the increase in water stress level is slight (0.2%) for Saudi Arabia compared with WSC scenario by 2050. These levels of water stress are still significantly lower than in the BAU scenario in the long term (see Figure 7.7).

By 2030, while all the countries are likely to reduce the levels of the water stress in the NSC scenario as compared to the BAU scenario, Saudi Arabia would experience 7% increase on water stress level (see Figure 7.6). The NSC scenario would have a moderate to considerable positive impact (decrease water stress level) for Qatar (0.6%), Oman (4.8%), Iran (2%), Morocco and Kuwait (9.4%) compared with the WSC scenario. The rest of the countries would expect negative (increase water stress level) impact on the level of water stress as compared with the WSC scenario (see Figure 7.7). For example, the level of water stress for Egypt would rise by 2% in the NSC scenario as compared to the WSC scenario.

Figure 7.7: Changes in water demand in the NSC scenario compared with the WSC scenario



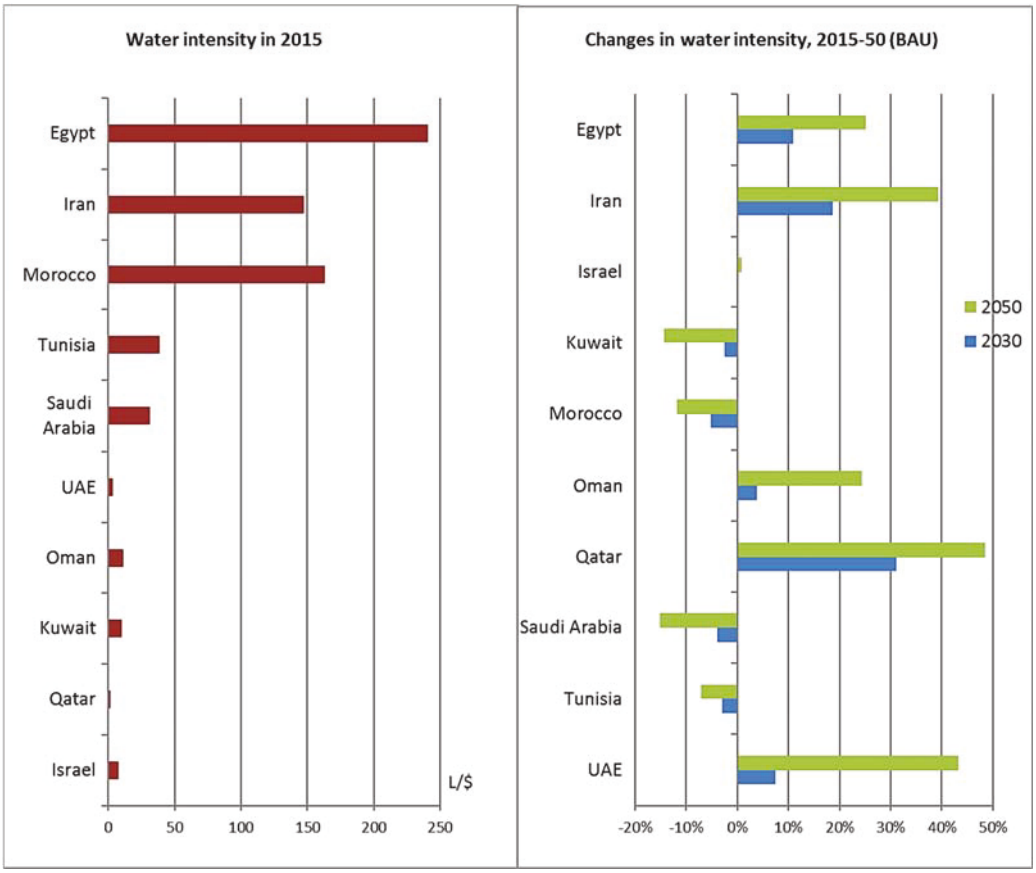
Source: See Appendix B, Section C, Table C4

7.1.4 Water intensity

There are currently considerable contrasts in water intensities among the countries in this research (see Figure 7.8). Water intensity is defined as litres of water required to produce US$1 of GDP.

- Egypt (241 l per US$), Iran (147 l per US$) and Morocco (163 l per US$) have significantly high water intensities in comparison with the other countries in this research, whose water intensities are less than 40 l per US$. The least water intensive economy is Qatar with 2.5 l per US$.

Figure 7.8: Water intensities for the countries in this research



Source: See Appendix B, Section C, Table C5

- In the **BAU scenario,** water intensities would decline for some of the countries. The highest discount would be for Saudi Arabia where the water intensity is expected to fall by 16% (by 2050) from 31 l per US$ in 2015, to 30 l per US$ in 2030 and 26 l per US$ in 2050. Kuwait and Morocco are also likely to experience significant (more than 10%) reduction in their water intensities. Tunisia could expect a moderate reduction of 3% by 2030 and of 7% by 2050 (see Figure 7.8).

- In contrast, the water intensities of the remaining countries are expected to increase over the years to 2050. Iran and Egypt economies, for example, are likely to experience increases of more than 20% in their water intensities, specifically, 147 l per US$ to 205 l per US$ for Iran and 241 l per US$ to 301 l per US$ for Egypt. Other countries likely to expect a substantial increase in their water intensities are Oman (24%), Qatar (48%) and the UAE (43%) (see Figure 7.8).

By 2030, in the BAU scenario, the rate of change compared with 2015 will be slower than the changes from 2030 to 2050 (long term). The average growth of water intensity, in the short term (from 2015-2030), among the countries is 6% in average (as compared to 2015) while the intensity, in the long term (from 2030-2050) increase by 7% on average (compared to 2015). It is expected that Iran, Qatar and Egypt experience the considerable growth in their water intensity in both short term and long term between the selected countries (see Figure 7.8). While the water intensity would rise moderately for Oman and the UAE (by 4% and 7% respectively) in the short term, both countries are likely to face a substantial increase (24% (Oman) and 43% (UAE)) in the long term compared with 2015.
In contrast, Tunisia, Kuwait, Morocco and Saudi Arabia are expected to decline the water intensity by just 3.5% on average from 2015 to 2030 in the BAU scenario.
In this period (2015-2030), no applicable change would be observed in the water intensity of Israel's economy.

In the **energy-oriented scenario (ESC)**, the water intensities of most countries would improve compared with the BAU scenario.

- Egypt (214 l per US$) and Iran (152 l per US$) will have substantially lower (by more than 20%) water intensity by 2050. Oman and the UAE are likely to experience falls in their water intensities of more than 10% compared with the BAU scenario (see Figure 7.9).

- Israel is the only country that could be negatively impacted in the ESC scenario in both the short term and the long term; its water intensity is estimated to increase marginally (by 3%) to 8 l per US$ in 2050, compared with 7.8 l per US$ in the BAU scenario (see Figure 7.9).

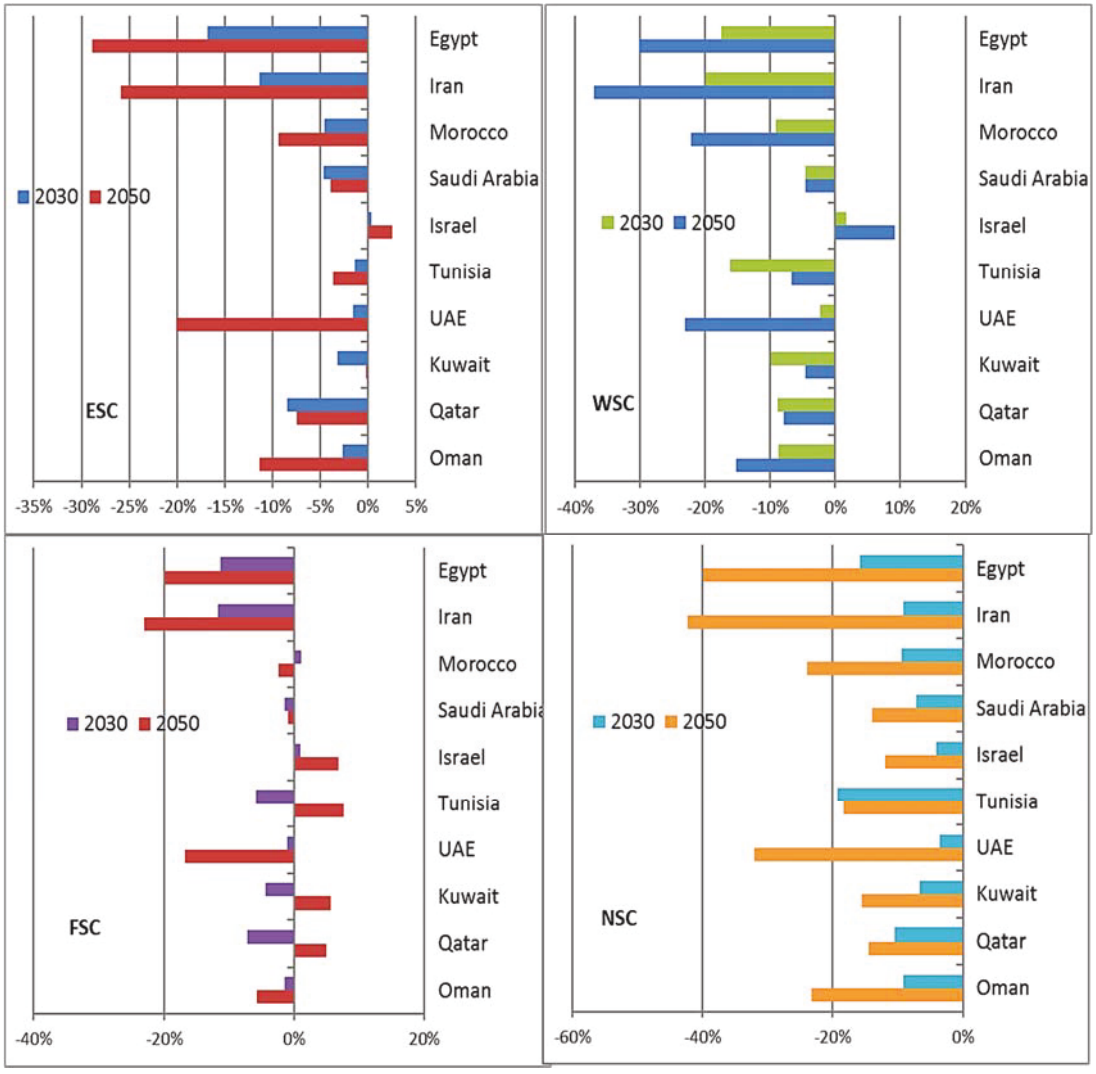
- Kuwait is the only country to experience no appreciable impact on its water intensity in the ESC scenario relative to the BAU scenario.

In the **water-oriented scenario (WSC)**, the water intensity would follow the same trend as the ESC scenario, with further reductions in their water intensities compared with both the BAU and ESC scenarios.

- Iran, Egypt, Morocco and the UAE would expect substantially lower water intensities, by 37% (or 129 l per US$), 30% (or 211 l per US$), 22% (or 112 l per US$) and 23% (or 4 l per US$) respectively by 2050 (see Figure 7.9).

- In contrast, Israel is likely to become more water intensive in both the short term and the long term. Israel's water intensity, for example, would increase slightly from 8 l per US$ in 2015 to 8.4 l per US$ by 2050 in the WSC scenario, compared with both the BAU (7.8 l per US$) and ESC (8 l per US$) scenarios.

Figure 7.9: Water intensity reduction, 2015-2050



Source: See Appendix B, Section C, Table C5

In the **food-oriented scenario (FSC),** fewer countries (compared to the WSC and ESC scenarios) would expect further improvement in their water intensities relative to the BAU scenario (see Figure 7.9).

- Israel, Kuwait, Qatar and Tunisia will become more water intensive by 2050 in the FSC scenario, but their water intensities are expected to increase considerably. Tunisia's water intensity would rise by 8%, from 36 l per US$ in the BAU scenario to 39 l per US$, and Qatar's by 5%, from 2 l per US$ to 3 l per US$.

- By 2030, while all the countries are likely to improve their water intensities as compared to the BAU scenario, Israel would experience slightly increase on its water intensity in all the three scenario (ESC, WSC and FSC) (see Figure 7.9). In the case of Morocco, the water intensity in the FSC scenario will be slightly (1%) increase than the BAU scenario during the short term, while it will decrease by 2% in the long term (see Figure 7.9)

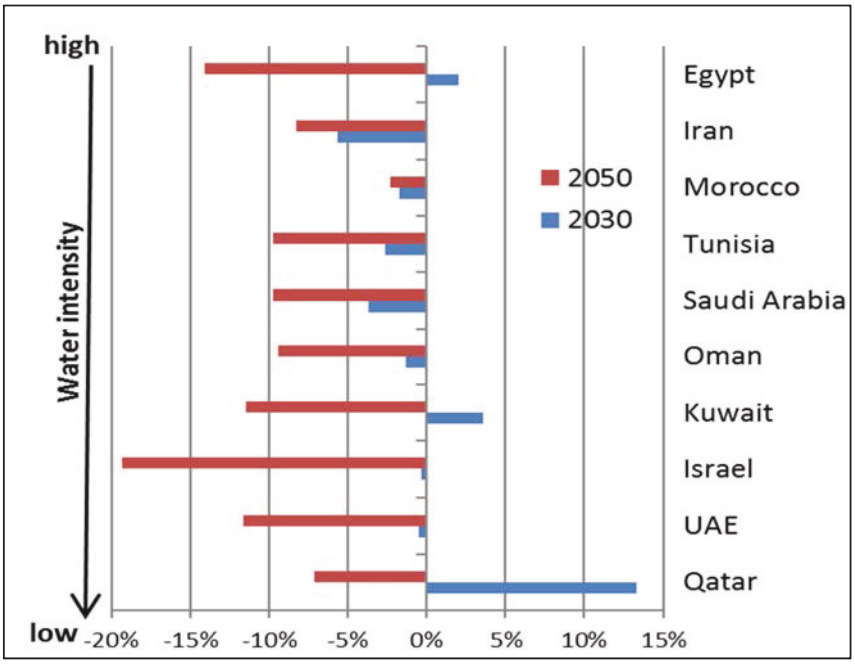
Water intensities for all the countries considered in this research would decline in the **NSC scenario**, as compared with the BAU and WSC scenarios by 2050 (see Figures 7.9 and 7.10).

- Egypt's water intensity will drop by 40% to 181 l per US$ and Iran's by 42% to 118 l per US$ by 2050.

- Qatar, which had the lowest water intensity economy in 2015, would expect a decline of 14% to 2 l per US$ by 2050.

- In comparison to the WSC scenario in the short term, Egypt, Qatar and Kuwait would experience an increase on its water intensity in the NSC scenario. Water intensity in Qatar would considerably increase (7%) While the water intensity would rise moderately for Egypt and Kuwait (by 2.2% and 3.6% respectively) in the short term in the NSC scenario (as compared to the WSC scenario)

Figure 7.10: Change in water intensity, NSC scenario compared with the WSC scenario



Source: See Appendix B, Section C, Table C5

7.2 Food security

This section provides an assessment of the impacts of various scenarios on food security for the countries in this research. The attributes for assessing these impacts include food accessibility, food import dependency and food affordability.

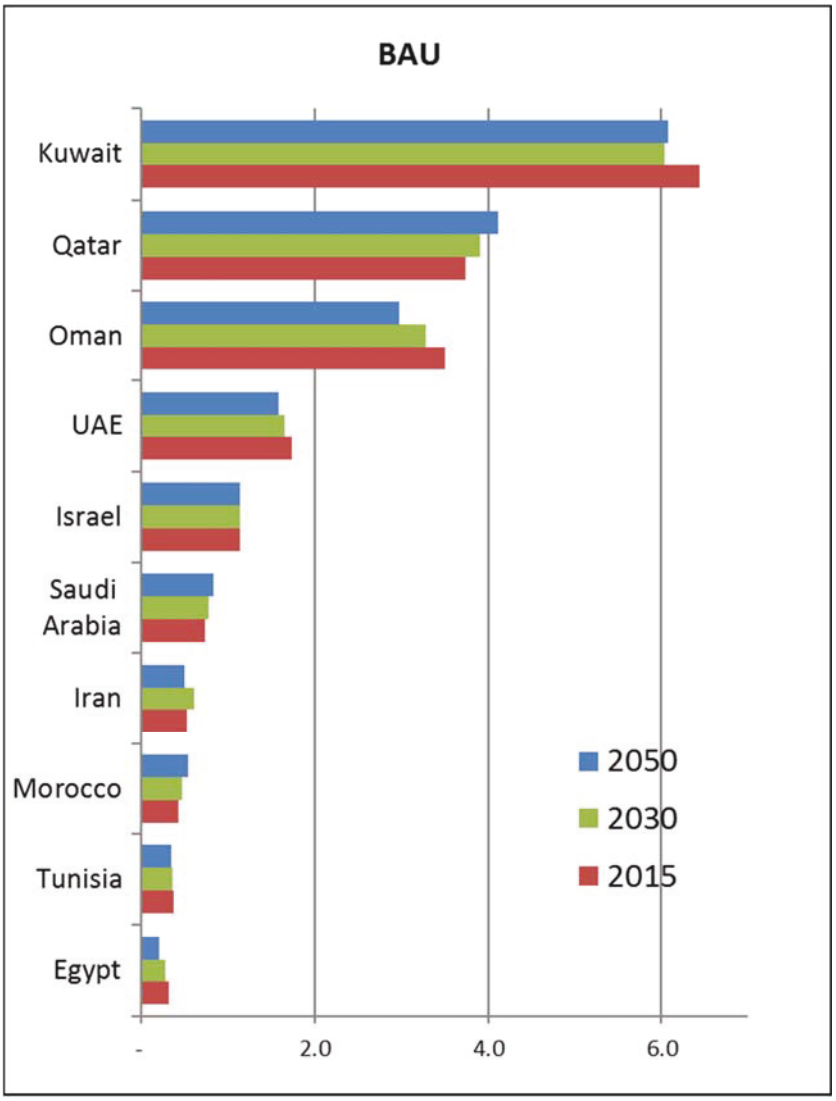
7.2.1 Food accessibility

Improvements in transport systems result in better physical access to food (FAO 2019). In this research, this relationship is expressed as the ratio of food supplied (measured in US$) for each dollar of transport service as food accessibility. Figure 7.11 provides a summary of food accessibility in the **BAU scenario**.

In 2015, Kuwait, Qatar and Oman have better food accessibility indices compared with the other countries in this research. The low-middle income countries of Egypt, Tunisia and Morocco, had the lowest in terms of food accessibility. In the **BAU scenario,** most of the countries would maintain the same level of food accessibility as in 2015. People in Qatar, Saudi Arabia and Morocco would expect better access to food (as compared to 2015) but those in Iran, Kuwait, Oman, the UAE and Egypt would experience worse (as compared to 2015) access to food by 2050. In this period (2015-2050), no applicable change would be observed in the food accessibility for Israel (see Figure 7.11).

- By 2030, Iran would experience a 16% improvement in food accessibility, from 0.5 in 2015 to 0.6 in 2030. However, by 2050, its food accessibility would drop by 5% to 0.5.

Figure 7.11: Food accessibility index for the countries in this research in BAU



Source: See Appendix B, Section D, Table D1

- In **energy-oriented scenario (ESC),** improvement in food accessibility would be observe by some countries include Egypt, Iran, Saudi Arabia, Oman, Qatar, Tunisia and Kuwait both in the short term and in the long term (see Figure 7.12). For Iran, for example, food accessibility would stay almost stable at 0.5 over the period 2015 to 2050 in the BAU scenario. In the ESC scenario, however, this index would increase by 41%, to 0.7 by 2050. This means more food would be available for the people as the transport service

increased. Approximately US$237.0 billion (2010 price) would be required by 2050, in order to improve the transport infrastructure in this scenario. This is almost US$46.6 billion more than the amount required in the BAU scenario and more than three quarters of this investment would be required for land transport infrastructure.

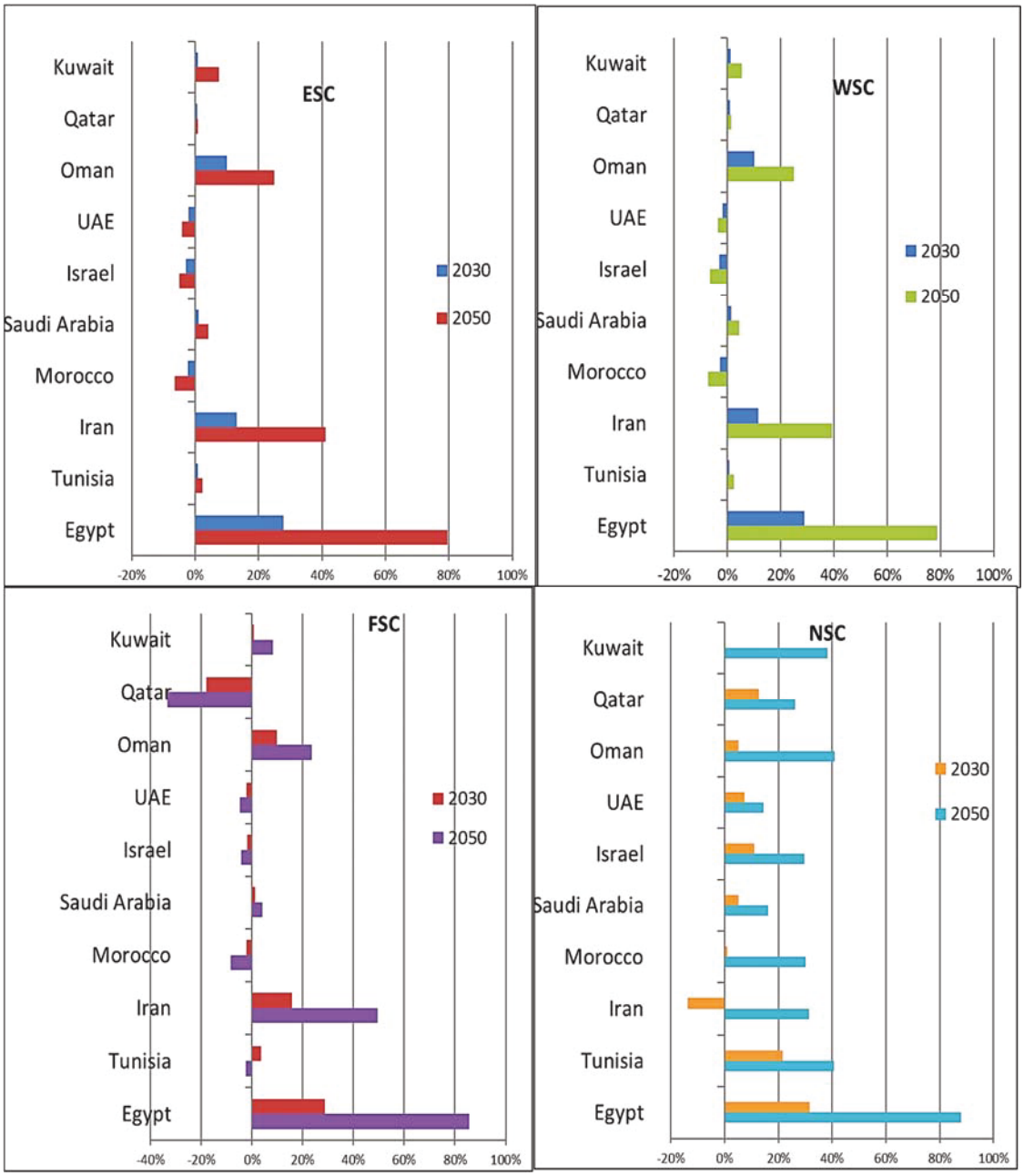
- In contrast, Israel, Morocco and the UAE could expect a marginal decline in their food accessibility index by 5%, 6% and 4% respectively relative to the BAU scenario both in the short term and in the long term.

- In the **water-oriented scenario (WSC),** the trend would be similar to the ESC scenario. However, the rate of the change would be faster. All countries except Morocco, Israel and the UAE could expect better food accessibility than in the BAU scenario. Egypt would experience the highest rate of improvement in its food accessibility, from 0.22 in the BAU scenario to 0.38 in the WSC scenario, by 2050. Morocco, the UAE and Israel are exceptions and are likely to experience the same trend as ESC scenario (see Figure 7.12).

- In the **food-oriented scenario (FSC)**, Egypt, Iran, Oman, Kuwait and Saudi Arabia would experience improvement in their food accessibility relative to the BAU scenario. Egypt's improvement would be the highest, 86%, compared to the BAU scenario in the period from 2015 to 2050 and its food accessibility index would increase from 0.22 in the BAU scenario to 0.4 in this scenario. The value of its accessibility would be 0.38 in both the ESC and WSC scenarios. For this improvement to occur, Egypt would need to invest US$26 billion in addition in FSC scenario to its US$28 billion investment in the BAU scenario in the period to 2030 and US$180 billion in total to 2050 for transportation infrastructure in the FSC scenario.

- In contrast, consumers in Qatar, the UAE, Israel, Morocco and Tunisia could expect less food to be available in this scenario compared with the BAU scenario. Qatar is the only country in this group to have a substantial (33%) reduction in its food accessibility, and its food accessibility index would drop from 4.1 in the BAU scenario to 2.7 in the FSC scenario. The rest of the countries would be impacted negatively by less than 8%. Tunisia in the period to 2030 would enjoy a positive impact of 3%; however, its food accessibility index to 2050 would worsen by 2%, from 0.36 in the BAU to 0.34 in the FSC scenario (see Figure 7.12).

Figure 7.12: Food accessibility changes in the alternative scenarios compared with the BAU scenario



Source: See Appendix B, Section D, Table D1

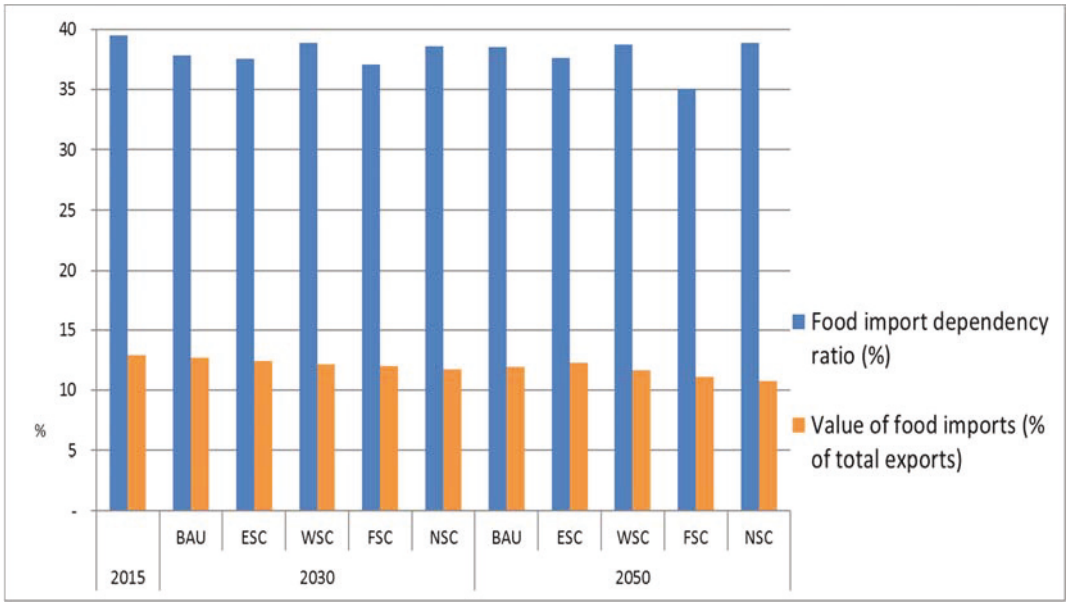
- In contrast to all the above scenarios, the food accessibility index in the **NSC scenario** would increase in all the countries in this research. Egypt particularly would enjoy substantial improvement in its access to food, shown by the increase in its index to 0.4 in 2050, a rise of 88% compared with the BAU scenario. Egypt would require approximately US$291 billion over the 35 years to 2050 to develop transport infrastructure in this scenario (see Figure 7.12).

- By 2030, all countries could expect moderate change in their food accessibility in this scenario. However, in the period 2015 to 2030, Iran food accessibility index would decline further by 14% (as compared with the BAU scenario), while, in the long term (2030 to 2050) the country will experience a 30% improvement, from 0.5 in the BAU scenario to 0.65 in the NSC scenario.

7.2.2 Food import dependency

Overall, the countries in this research import on average 39.5% of the food needed to meet their domestic demand (see Figure 7.13). This percentage is estimated to decline in the **BAU scenario** to 37.9% to 2030 and increase to 38.8% by 2050. This ratio would decrease further to 37.6% in the ESC scenario and to 35.1% in the FSC scenario by 2050, due to improved agricultural productivity, which in turn would be driven mostly by the use of energy-intensive fertilisers. In the WSC and NSC scenarios, in contrast, food import dependency will increase to 38.7% and to 38.9% by 2050, respectively. However, the increase in both scenarios would not adversely affect the countries' finances, as the value of food imports[22] would be lower by 10.8% in the NSC scenario and by 11.6% in the WSC scenario, compared with 12% in the BAU scenario. Therefore, the increase in food imports would not increase the food security risk. The value of food imports in 2030 and 2050 in the entire scenarios would be lower than in 2015, when the countries spent on average 12.8% of their total earnings on food imports.

Figure 7.13: Average food import dependency for the countries in this scenario



Source: See Appendix B, Section D, Tables D2 & D3

[22] Value of food imports (expenditure on food imports) measured as a percentage of total merchandise exports in this research (FAO 2019).

Figure 7.14 shows the food import dependency of the countries in this research by 2050.

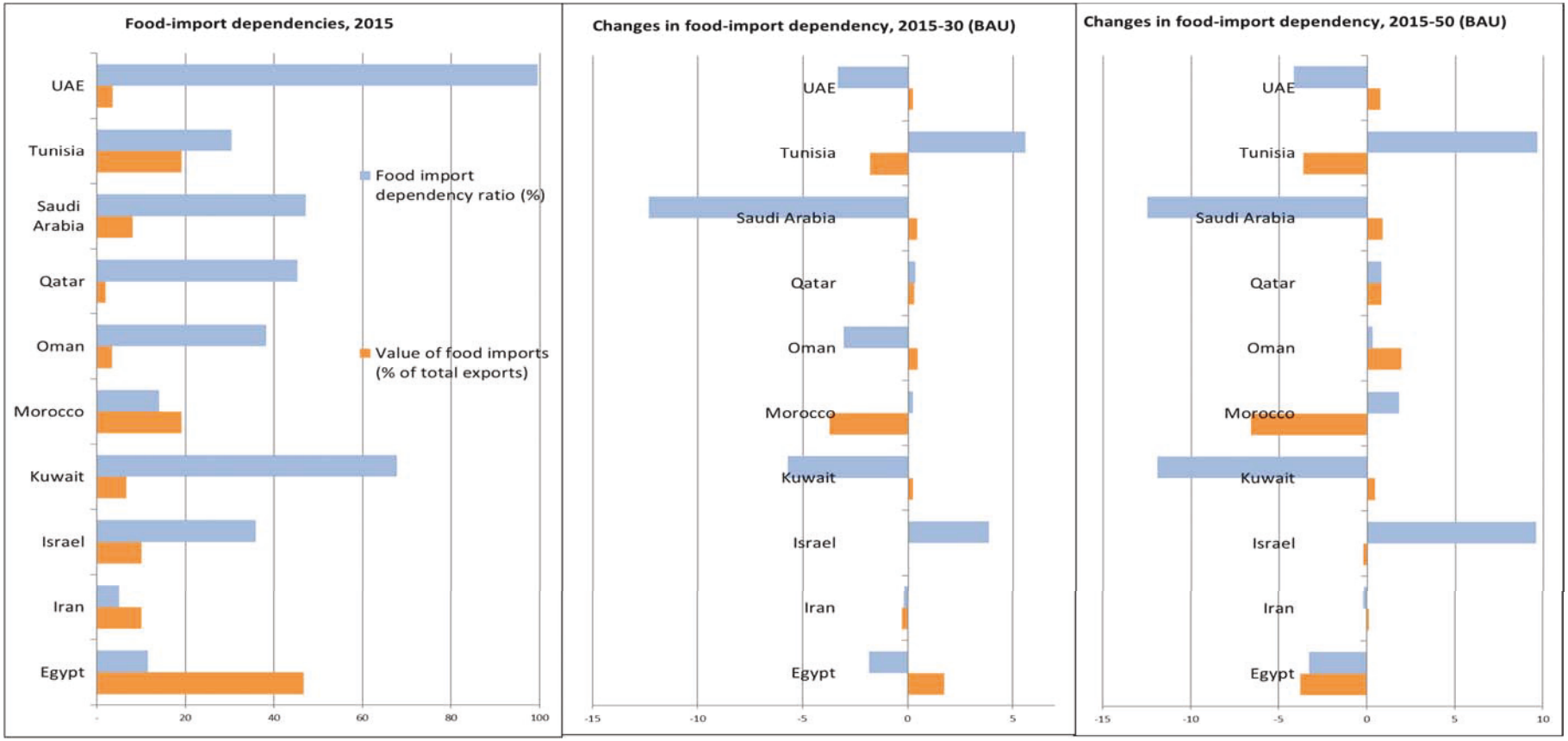
- In 2015, all the high-income countries, namely, the oil-exporting countries of the UAE, Saudi Arabia, Qatar, Oman and Kuwait and the oil-importing country of Israel, rely heavily on food imports. The average of food import dependency between these countries are 55.6% while the average of food dependency between all the countries in this research is 39.57% in 2015. However, compared with the other countries, some spend a relatively low proportion of their export earnings on food imports. The value of food imports, for example, for Qatar, the UAE, Oman and Kuwait are 2%, 3.6%, 3.5% and 6.6%, of their export income respectively. Saudi Arabia and Israel, however, spend 8.1% and 10.1% of their export earnings on food imports. In the high-income countries, the UAE has the highest food dependence, importing 99.5% of its food from outside the country.

- In contrast, in 2015, the lower-middle income countries of Egypt, Tunisia and Morocco and the upper middle-income country of Iran spend 46%, 19.3% and 19.5% and 10% of their export earnings on food imports, respectively. All the countries in this group apart from Tunisia (30%) have an import dependency of below 15%; however, they spend a large proportion of their export earnings on food imports.

- The food import dependency across the countries would change in the BAU scenario. For example, most of the oil-exporting countries (high-income) such as the UAE, Saudi Arabia and Kuwait are expected to rely relatively less on food imports, but to spend a slightly higher proportion of their export earnings on food (see Figure 7.14). To take this example further, Saudi Arabia could expect a reduction of 12.5% on its food dependency by 2050; however, the value of these imports (expenditure on food imports) is expected to rise, from 8.1% (export earnings) in 2015 to 9% by 2050.

- In contrast, Israel and Tunisia are likely to spend a slightly lower proportion of their export earnings on food imports (see Figure 7.14). For example, while Tunisia's would expect to meet its domestic food requirements increasingly from imports (from 30% of domestic food requirements in 2015 to 40% in 2050), the value of these imports), the value of these imports (expenditure on food imports) would decline slightly, from 19% of export earnings in 2015 to 15.5% in 2050. The change in Iran would not be significant in the BAU scenario (by 2050) compared with 2015.

Figure 7.14: Food import dependencies for the countries in this scenario by 2050



Source: See Appendix B, Section D, Tables D2 & D3

- While Qatar and Oman are likely to face higher food security risks in terms of their dependence on food imports in the future in the BAU scenario by 2050, Egypt would face reduced risks. For example, the food-import dependency ratio for Qatar is expected to increase by approximately 0.8%, from 45.3% in 2015 to 46.2% in 2050; the value of its food imports is also expected to increase, from 2% in 2015, to 2.8% in 2050 (see Figure 7.14). In contrast, the food-import dependency ratio for Egypt is likely to decline by 3.3%, from 11.5% in 2015 to 8.2% in 2050 and the value of the imports for Egypt (expenditure on food imports) would decline moderately, from 46.8% of export earnings in 2015 to 43.2% in 2050.

- In the short term (2015-2030), only, Egypt, Iran and Oman would be likely to act differently in terms of their food import dependency as compared to the long term (2030-2050). The food dependency of Egypt and Oman would decline slightly by 2030 (see Figure 7.14). However, due to increasing demand in the case of Oman or worsening trade conditions in the case of Egypt, they are expected to spend an even larger amount of export earnings on importing food between 2015 and 2030.

- Iran could expect higher food security in terms of its dependence on food imports in the period to 2030 because it would spend less on these imports. However, in the long term to 2050, although the country would expect a drop in its food dependency, the value of these food imports (expenditure on food imports) would increase due to its worsening international trade position.

- In the **energy-oriented scenario (ESC**), Iran, Kuwait, Tunisia and the UAE are likely to experience lower food dependency. Iran and the UAE would benefit from reduced risks in their dependency on food imports. For example, the UAE would reduce it is heavily reliance on food imports by 13% compared with the BAU scenario by 2050. However, its expenditure on food imports would decline only marginally compared with the BAU scenario (see Figure 7.16). In contrast, while Kuwait and Tunisia could also expect a reduction in their dependency, they would spend more on the food they imported.

- Egypt and Israel are likely to face higher food security risks while the value of their imports is expected to be higher in ESC scenario as compared to the BAU scenario. Morocco, Qatar, Oman and Saudi Arabia could expect a slight (less than 5%) increase in food imports in the ESC scenario but the ratio of their export earnings spent on food imports would decline marginally (less than 1%).

- In the short term, in ESC scenario, except Egypt, Iran and Oman, the rest of the countries are likely to experience the same trend in their food import dependency as compared to the long term. The food dependency of Egypt, Iran and Oman would increase by 2030. However, due to increasing demand in the case of Oman, the country is likely to spend slightly larger amount of export earnings on importing food between 2015 and 2030 as compared to 2050. In contrast, Egypt and Iran are likely to spend a slightly lower proportion of their export earnings on food imports (see Figure 7.15).

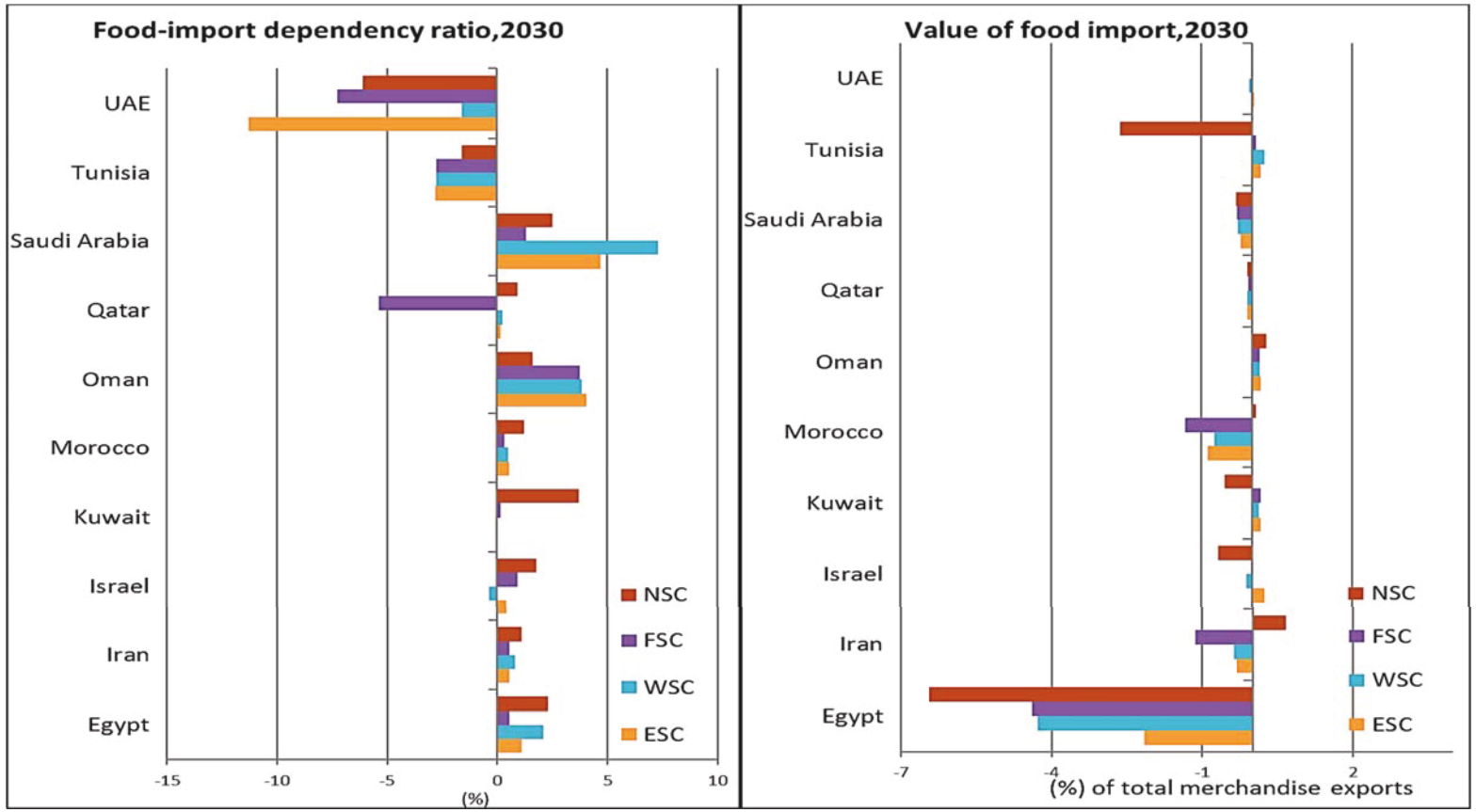
- In the **water-oriented scenario (WSC),** the dependence on imports of food for most of the countries would increase. This would be due to the fall in the production of water-intensive agricultural products for the sleeted countries. However, the expenditure on food imports in most of the countries would decline (see Figure 7.16).

- Egypt, Iran, Morocco, Oman, Qatar and Saudi Arabia could expect higher food import dependency by 2050 in this scenario compared with the BAU scenario. Saudi Arabia, for example, could expect a 4.8% increase in its food import dependency, from 34.7% in the BAU scenario, to 39.6% in WSC scenario, to meet the food requirements of its consumers by 2050. However, the country could expect to spend a smaller proportion of its export earnings, from 9% in the BAU scenario to 8.5% in the WSC scenario, a drop of 0.5%, on the value of food imports.

- In contrast, Israel, Kuwait, Tunisia and the UAE are likely to reduce their food imports in the WSC scenario slightly (by less than 5%). However, Kuwait and Tunisia could expect to increase their expenditure on food imports marginally, by approximately 0.5% in 2050 from 7% and 15.5% respectively in the BAU scenario.

- In the short term, in WSC scenario, only Oman would act differently in terms of their food import dependency as compared to the long term. By 2030, the food dependency of Oman would increase and the country would spend marginally a larger proportion of its export earnings on the value of importing food.

Figure 7.15: Food import dependencies for the countries in 2030, compared with the BAU scenario



Source: See Appendix B, Section D, Tables D2 & D3

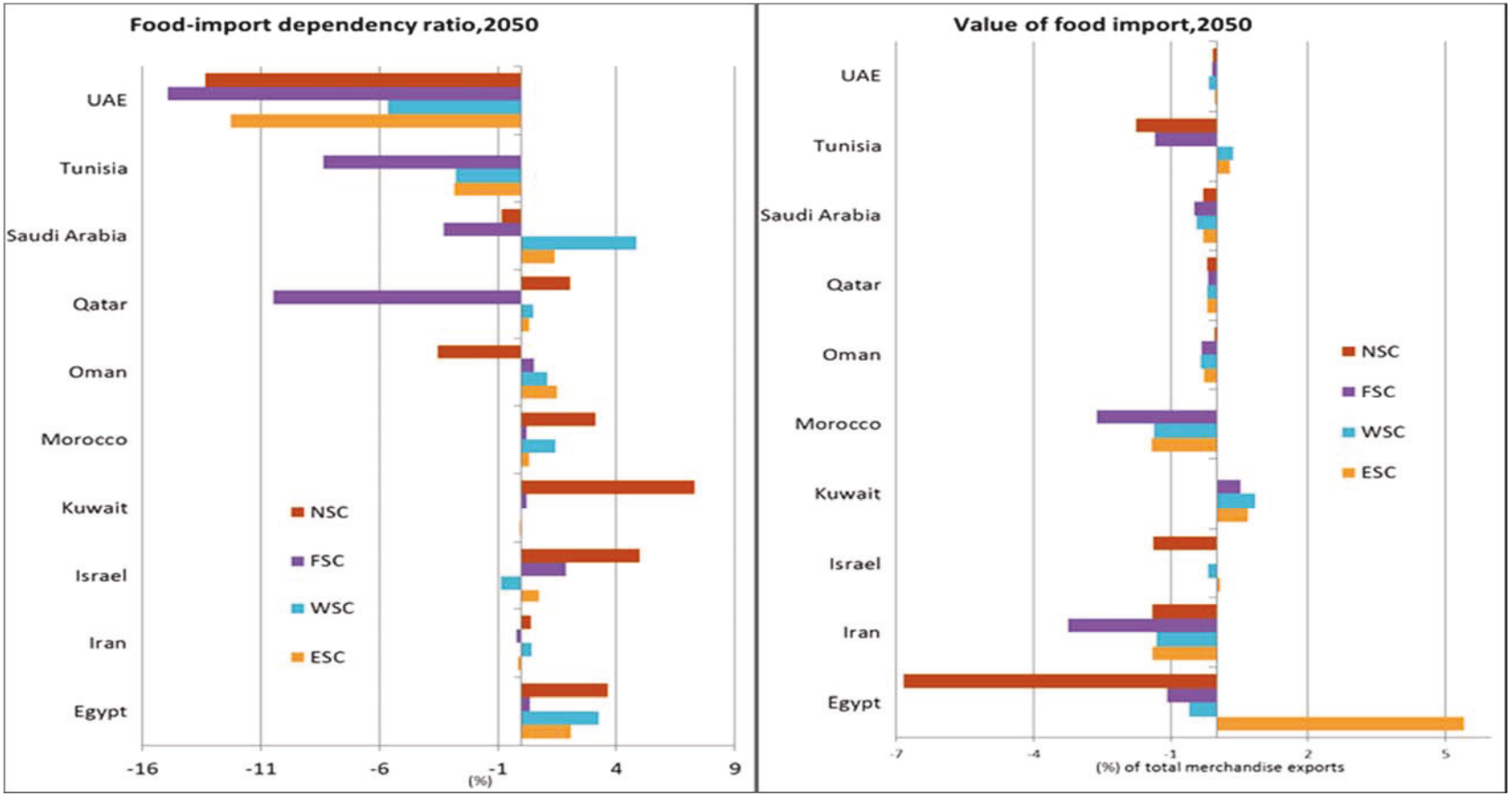
- In the **food-oriented scenario (FSC)**, the focus of which is to improve agricultural production, most of the countries could expect lower food import dependency. This is true for Iran, Qatar, Saudi Arabia, Tunisia and the UAE. The improvement (reduction in dependency) in food imports would be significant (more than 10 %) for Qatar and the UAE and relatively lower (less than 10%) for Saudi Arabia and Tunisia to meet the requirements of their domestic demand. Iran would experience a marginal change in its food imports, from 4.9% in the BAU scenario to 4.7% in the FSC scenario. Food import expenditure would decline in all the countries in this group compared with the BAU scenario, but at different rates. For instance, Iran could expect to spend 3.2% less in the FSC scenario by 2050 (from 10.2% in the BAU scenario to 7% FSC) (see Figure 7.16).

- Egypt, Israel, Kuwait, Morocco and Oman can expect slight increases in their food imports in the FSC scenario. Israel and Kuwait are likely to face less food security while the cost of their food imports is expected to be marginally higher compared to the BAU scenario, by an additional 0.02% of export earnings for Israel and 0.5% of export earnings for Kuwait. However, expenditure on food imports would decline Egypt, Morocco and Oman in the FSC scenario as compared to the BAU by 2050.

- By 2030, Saudi Arabia and Iran would rely more on importing food to meet the demand for their residents. For instance, due to increasing demand, the food dependency of Saudi Arabia would increase by 1.5% in the short term as compared to the BAU scenario. Further, while the food import dependency of Tunisia and Oman are likely to follow the same trend as in the long term, the countries would expect to spend a higher proportion of its export earnings on the value of food imports (see Figure 7.15).

- In the **NSC scenario**, the food-import dependency ratios are expected to increase for most of the countries in this research (see Figure 7.16). Particularly significant increases would happen for Morocco (19%) and Kuwait (63%) by 2050 compared with 15.9% for Morocco and 55.8% for Kuwait a in the BAU scenario. However, the increase in food imports in the NSC scenario would not impact the financial situation negatively for any of the countries. It is expected that all the countries in this research will spend relatively less of their export earnings on food imports.

Figure 7.16: Food import dependencies for the countries in 2050, compared with the BAU scenario



Source: See Appendix B, Section D, Tables D2 & D3

- Oman, Saudi Arabia and the UAE would expect reduction on their food import dependency while the value of these imports would also be lower as compared with the BAU scenario by 2050. The UAE, for example, would enjoy a 13% reduction in its food import dependency in 2050 while spending marginally (0.1%) less value for importing food compared with the BAU scenario.

- In the short term, countries are likely to act differently as compared to the long term. While the majority of the countries expect higher food import dependency, Tunisia and the UAE would benefit from reduced risks in their dependency on food imports between 2015 and 2030. In addition to the increase in food import dependency (in the NSC scenario), some countries such as Iran, Morocco and Oman are likely to spend a higher portion of their export earnings on the value of importing food (see Figure 7.15).

7.2.3 Food affordability

Food expenditure (share of household expenditure spend on food) is one of the main indicators of food affordability (FAO 2019). In 2015, the average expenditure on food among the countries in this research was 14% of their income. Iran as the upper income country and Egypt, Morocco and Tunisia as the middle-lower income countries spent more than 20% of their income on food in 2015. The rest of the countries, being high-income countries, spent less than 10% of their revenues on food in that year.

- Over the 35 years to 2050, the proportion of food expenditure in **the BAU scenario** would increase in some countries. The most noticeable increase, from 27% in 2015 to 36% in 2050, would occur in Egypt.

- By contrast, consumers in Iran, Israel, Morocco, Qatar and Saudi Arabia would expect to spend a smaller proportion of their income on food in the BAU scenario by 2050. The proportion of food expenditure for households in Iran would significantly reduce (18%) in the short term, while they would spend only 0.4% less on food in the long term (compared with 2015). However, countries include Qatar and Saudi Arabia would likely experience a reduction of 7% and 15% in their food expenditure in the short term and the long term, respectively, compared with 2015 (see Figure 7.17).

- The impact of the **ESC, WSC and FSC scenarios** on household expenditure on food would be quite similar to each other. Egypt, Iran, Kuwait, Oman, Saudi Arabia and Tunisia could expect a positive impact, that is, households would spend a smaller

proportion of their income on food but the rate would differ from the BAU scenario. For example, food expenditure in Egyptian households would fall from 36% in the BAU scenario to 25% in the ESC scenario, to 26% in the WSC scenario and to 27% in the FSC scenario (see Figure 7.17).

- In contrast, consumers in Israel and the UAE are expected to spend slightly (less than 1%) more of their income on food in all three scenarios.

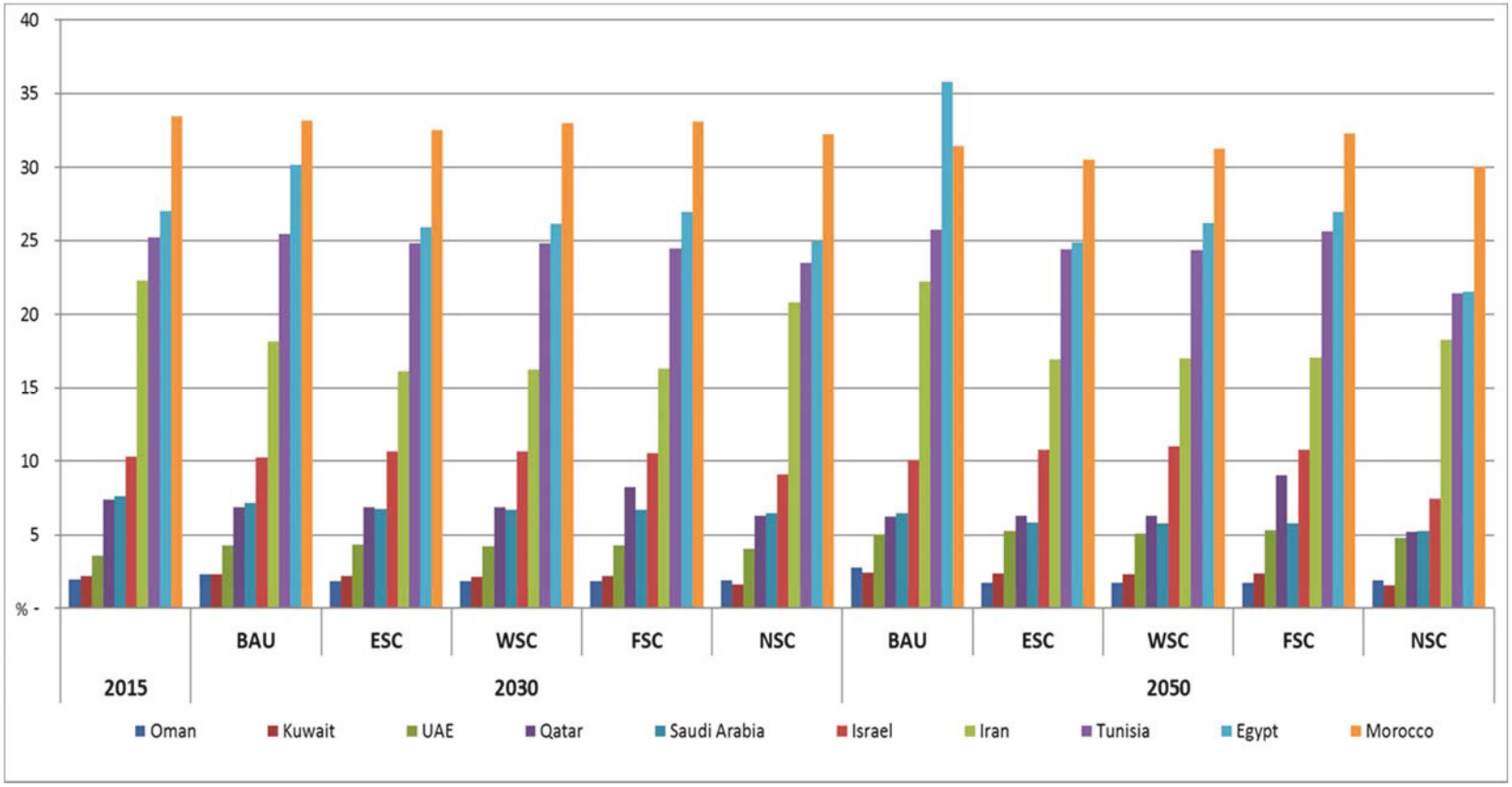
- In Morocco, households would spend 31% of their income on food in the ESC and WSC scenarios, compared to 31.5% in the BAU scenario, but would face a marginal increase (to 32%) in the FSC scenario.

- By 2030, while countries would spend less in dollar terms on their food, residents in Israel and the UAE would be spending a higher proportion of their income on food in the ESC, WSC and FSC scenarios. During this period, the reduction in food expenditure would be slower than the long term.

- By 2050, food affordability for households in all the countries is expected to improve in the **NSC scenario** (see Figure 7.17). Although this reduction would for most of the countries be less than 5%, the food affordability for Egypt would improve significantly, from 36% in the BAU scenario to 22% in the NSC scenario.

- Compared with the FSC scenario, Iran and Oman are expected to spend slightly higher proportions of their incomes on food in the NSC scenario by 2050. For instance, the share of food expenditure in Iran is expected to be 18% in NSC scenario, which is 1.2% higher than the share in FSC scenario in 2050. However, the share of food expense in the NSC scenario for Iran (18%) is still lower than the share of the income (22%) that would be spend on food in the BAU scenario (see Figure 7.17).

Figure 7.17: Share of food expenditure in the countries of this research



Source: See Appendix B, Section D, Table D4

7.3 Summary and conclusion

Water Security

Water availability

Across all the countries in this research, in 2015, an average of 427m^3 of renewable water resources is available annually per person. As the population in 2050 is likely to be 1.4 times what it was in 2015, the intervening 35 years are likely to place significant pressure on this resource, potentially reducing annual water availability per person to 346 m^3 by 2030 and to 328 m^3 by 2050.

Residents in the countries of study already are faced with limitations in water availability: Egypt, Morocco, Tunisia, Saudi Arabia, the UAE, Israel, Oman, Qatar and Kuwait are currently water scarce countries and Iran is water vulnerable. In the BAU scenario, the water situation in these countries will worsen to the extent that by 2050, Kuwait, Qatar, Oman, Israel, the UAE, Saudi Arabia, Tunisia and Egypt will become more water insecure, with water availability of less than 300 m^3 per person, which retain the status of the countries as water scarce. Morocco as another water scarce country in 2015 would expect the better condition as compared with rest of the countries (expect Iran). However, the water availability for citizens of Morocco would be still less than 1000 m^3 per person which is defined by the UNEP as a critical level of water scarcity. Iran is the only country that is likely to maintain its status as a water stressed country.

Water demand

Economic and population growth in the **BAU scenario** will lead to increased water demand in all the countries in this research. Overall, water demand will more than double, from 187 billion m^3 in 2015 to 392 billion m^3 in 2050. This is equivalent to a growth rate of 2.0% per year over this period.

Countries with strong growth in water demand include Egypt, Oman, Qatar and the UAE, where the growth rates of water demand are expected to exceed 2% per year over the study period. On a per-capita basis, Egypt and Iran are the major water users, and their consumption will average more than 1000m^3 of water per person per year by 2050.

The water demand in the **ESC and WSC scenarios** will be lower for most of the countries compared with the BAU scenario and most of the water savings are expected to occur in the agriculture and energy sectors. The use of energy-intensive fertilisers in agriculture would be the main driver for water savings but water use in the industrial sector would increase as countries in the region industrialise in the years to come. Israel is the only country that is likely to have a marginal increase in its water use in both scenarios while the countries likely to experience

significant reductions (i.e. more than 10%) in water demand in both scenarios are Egypt, Iran and the UAE.

Although the water demand would decrease in both in short term (2015-2030) and long term (2030-2050) in the ESC and WSC scenarios, the rate of change in both scenarios would be faster in the long term (2030-2050). In some countries, such as Saudi Arabia and Qatar the rate of the change in water demand is similar in both ESC and WSC scenarios.

In the **FSC scenario**, water demand will increase for most of the countries compared with the ESC and WSC scenarios, but the demand in some countries will be still lower than in the BAU scenario. Qatar, Israel, Kuwait and Tunisia could expect higher water demand (but less than 5%) in the FSC scenario compared with the BAU scenario by 2050. The countries that are likely to experience significant (more than 10%) reductions in water demand are Egypt, Iran and the UAE.

In the short term (2015 to 2030), however, the only two countries that would expect additional demand than in the BAU scenario would be Israel and Morocco. The rest of the countries would demand less water than the BAU scenario by 2030. However, water demand would increase at a faster rate in the long term in all the three scenarios compared to the short term. In the long term (2030-2050), water demand would increase by 6% on average compared to the BAU scenario while in the short term (2015-2030) demand will rise by 4% on average compared to the BAU scenario.

In the **NSC scenario**, water demand is expected to reduce in all countries by 2050 compared with the BAU scenario. Shifts in crop production patterns in the agriculture sector, from water intensive to less water intensive, would be the main reason for this reduction. In the short term, most of the countries (except Israel, Qatar and Oman) are likely to experience further reduction in water demand in the NSC scenario as compared to the WSC scenario. Countries include Morocco, Iran, Tunisia, Saudi Arabia, Kuwait, the UAE and Egypt are likely to benefit further in the WSC scenario in terms of reduction in their water demand as compared to the NSC scenario in the short term. In the long term, however, NSC scenario would be more beneficial for the majority of the countries in this study. Iran, Morocco and Oman are the only countries that would demand more water in the long term (2030 to 2050) in the NSC scenario. In the case of Iran and Morocco, the demand for water in the WSC scenario will be less than the demand in the NSC in both the short term and long term.

Water stress

In 2015, all the countries in this research except Egypt were facing chronic freshwater shortages, with water stress levels (measured on the scale of 1% to 100%) of more than 20%[23]. Increased water demand in these countries in the **BAU scenario** would raise the water stress both in the short term and long term to unprecedented levels, exceeding 50% (20 2030) and 70% (by 2050) in all countries except Egypt. Even in Egypt, the water stress level from 10% in 2015, is likely to increase significantly to 19% by 2030 and 33% by 2050. Iran, Israel, Morocco, Oman and the UAE could expect their water stress levels to exceed 90% by 2050. The level of water stress in Kuwait and Qatar would increase by 7% over the period of 2015 to 2050, which is likely to take their level of water stress to 100%.

Reduced water demand and more options for alternative water supplies (for example, seawater desalination) in the **ESC, WSC and FSC scenarios** will lower the water stress levels in most the countries, except Israel and Saudi Arabia in the ESC and FSC scenarios and Tunisia in the FSC scenario by 2050. However, none of the scenarios (ESC, WSC and FSC) would be able to take the water stress level, and hence the chronic fresh water problem, below the UNEP definition of 20% in any of the countries in this research.

Reduced water demand and increased consumption of treated wastewater in the **NSC scenario** will lower the water stress levels for all countries (as compared to the BAU scenario) in the long term, achieved mainly by switching from water-intensive to less water-intensive crops.

Water intensity

In 2015, Egypt (241 l per US$) and Morocco (163 l per US$), followed by Iran (147 l per US$), had significantly higher water intensity in comparison with other countries in the study, which had water intensities of less than 40 l per US$. In the **BAU scenario**, water intensities will decline moderately over the period 2015-2050 in some countries, with noticeable reductions (more than 10%) in Kuwait, Morocco and Saudi Arabia. Tunisia is likely to experience a moderate (less than 10%) reduction in its water intensity. Iran, Egypt, Oman, Qatar and the UAE should expect significant increases (more than 10%) in water intensity in the 2015-2050 period.

By 2030 in the BAU scenario, water intensity would grow with the slower rate than the changes in long term. In this period (2015-2030), no noticeable change would be observed in Israel's water intensity while Tunisia, Kuwait, Morocco and Saudi Arabia could expect a slight decline in their water intensities.

[23] According to the UNEP (UNEP 2008), countries with water stress ratios of more than 20% are defined as having a chronic fresh water problem.

The water intensity of most countries will improve in the **ESC and WSC scenarios** compared with the BAU scenario. Egypt, in particular, will have considerably lower water intensity by 2050, with 214 l per US$ in the ESC scenario and 211 l per US$ in the WSC scenario. Iran is likely to experience significant reductions in water intensity in these scenarios. The water intensity for Israel in both the ESC and the WSC scenarios, however, is expected to increase.

In the FSC scenario, Iran and Egypt could expect a more than 20% improvement in their water intensity but at a slower rate relative to the ESC and WSC scenarios. In contrast, Israel, Kuwait, Qatar and Tunisia will become more water intensive.

The water intensity of all the countries considered in this research would decline in the **NSC scenario** compared with the BAU and WSC scenarios. However, in comparison to the WSC scenario in the short term, Egypt, Qatar and Kuwait would expect an increase on its water intensity in the NSC scenario.

Food Security

Food accessibility

Kuwait, Qatar and Oman have better food accessibility than the other countries in this research but Egypt, Morocco and Tunisia have among the lowest in 2015. In the **BAU scenario,** most of the countries would stay same in food accessibility over the 35 years studied, although people in Qatar, Saudi Arabia and Morocco are likely to have better accessibility to food, people in Kuwait, Oman, the UAE and Egypt would have poorer accessibility by 2050.

In the short term (2015-2030), food accessibility in Iran would improve considerably but this would fall in the long term (2030-2050) in the BAU scenario.

In the **ESC, WSC and FSC scenarios**, food accessibility will improve only for some countries, namely, Egypt, Iran, Saudi Arabia, Oman and Kuwait. Israel, Morocco and the UAE could expect less food to be available in all the three (ESC, WSC and FSC) scenario compared with the BAU scenario both in the short term and the long term. Food accessibility in the **NSC scenario** will increase for all countries in the study, due to significant investment (approximately US$628 billion more than in the BAU) in transport infrastructure.

Food-import dependency

The countries in this research import on average about 39.5% of their food to meet their domestic food demand in 2015. The high-income countries of Israel, the UAE, Kuwait, Saudi Arabia, Oman and Qatar rely heavily on food imports but they spend a relatively low proportion of their export earnings on these imports. Egypt, Tunisia and Morocco, being lower middle-income countries, spend more than 20% of their export earnings on food imports.

The food-import dependency of all countries is likely to change in the **BAU scenario by 2050**. Some of the high-income countries such as Kuwait, Saudi Arabia and the UAE are expected to rely less on food imports by 2050 but they spend a slightly higher proportion of their export earnings on food. Israel and Tunisia are likely to spend a lower proportion of their export earnings on food imports even though their domestic food requirements are expected to be met increasingly from imports. Oman, Qatar and Egypt in this scenario will be exceptions; Oman and Qatar will increase both its import dependence and the proportion of its export earnings on food while Egypt will experience the reverse.

In the short term (2015-2030), Egypt, Iran and Oman would act differently in terms of their food import dependency as compared to the long term (2030-2050). The food import dependency in Egypt and Oman will decline slightly while Iran will seek greater food security and spend less on importing food.

In the **ESC scenario**, some countries, namely, Iran, Kuwait, Tunisia and the UAE will become less dependent on food imports as a result of improved agricultural productivity, driven primarily by the use of energy-intensive fertilisers. The UAE will reduce its heavy reliance on food imports significantly by 2050. Other countries include Egypt, Israel, Qatar, Oman, Saudi Arabia and Morocco will experience a slight increase in their food imports. In the short term, in ESC scenario, except Egypt, Iran and Oman, the rest of the countries are likely to experience the same trend in their food import dependency as compared to the long term.

In the **WSC scenario,** the food import dependency of most countries will increase due to the reduced production of water-intensive agricultural products. However, the expenditure on food imports in most of the countries would decline. Egypt, Iran, Morocco, Oman, Qatar and Saudi Arabia could expect higher food import dependency by 2050 in this scenario while Israel, Kuwait, Tunisia and the UAE will import slightly less food than previously as compared to the BAU scenario by 2050. In the short term, in WSC scenario, only Oman would expect higher food dependency while the country would spend marginally a larger proportion of its export earnings on the value of importing food.

In the **FSC scenario**, with its focus on improving agricultural production, some countries would reduce their food import dependency. This would be true for Iran, Qatar, Saudi Arabia, Tunisia and the UAE. Egypt, Israel, Kuwait, Morocco and Oman, however, can expected a marginal increase in their food imports in this scenario.

In the period 2015-2030, while Qatar, Tunisia and the UAE would enjoy a moderate reduction in their dependence on of food imports, the rest of the countries would become more dependent on food imports.

In the **NSC scenario**, food-import dependency will increase for most countries by 2050 with a particularly significant increase occurring in Morocco and Kuwait. However, the increase in food imports in this scenario would not impact the financial situation of any of the countries, including Kuwait and Morocco. It is expected that all the countries in this research will spend a relatively smaller proportion of their export earnings on food imports as compared to the BAU scenario by 2050.

In the short term, while the majority of the countries expect higher food import dependency, Tunisia and the UAE would benefit from reduced risks in their dependency on food imports between 2015 and 2030. In addition to the increase in food import dependency (in the NSC scenario), some countries such as Iran, Morocco and Oman are likely to spend a higher portion of their export earnings on the value of importing food.

Food affordability

The expenditure on food in 2015 was on average 14% of total household expenditure in the countries in this research. In the **BAU scenario**, food affordability in 2050 would increase marginally, with expenditure rising to 14.8% and the most noticeable increase expected to occur in Egypt. However, consumers in Iran, Israel, Morocco, Qatar and Saudi Arabia could expect to spend a slightly smaller proportion of their income on food in 2050.

The impact of the **ESC, WSC and FSC scenarios** on household expenditure on food will be quite similar. Households in Egypt, Iran, Kuwait, Oman, Saudi Arabia and Tunisia will spend a smaller proportion of their income on food by 2050. In contrast, consumers in Israel and the UAE are expected to spend slightly (less than 1%) higher proportion of their income on food in all three scenarios.

The average household expenditure on food in the region is expected to reduce to 12% in the **NSC scenario by 2050**. All countries are likely to experience some reduction in food expenditure.

Chapter 8: A Policy Perspective on the EWF Security Challenge in the selected MENA countries

Chapters 6 and 7 showed the impacts of the BAU, ESC, WSC, FSC and NSC scenarios in terms of economic and social outcomes and energy, water and food security on the 10 selected MENA countries. The aim of this chapter is to combine the results and extend the analysis to obtain a policy perspective on the EWF security challenge in the countries in this research. In particular, the analysis will examine the trade-offs that may arise between policies whose aims may differ from each other and might have conflicted objectives under each of the scenarios.

For this purpose, this chapter is organised as follows: Section 8.1 will discuss the development of the security indicators. Section 8.2 will explain the EWF security trade-offs in the five scenarios. Section 8.3 will focus on the economic, social and security EWF trade-offs for the countries based on their income groups. Finally, Section 8.4 will summarise the trade-off policies for the scenarios.

8.1 Development of security indicators

Existing studies about the concept of energy, water and food security show that it is critical to address the security challenge of these resources. This is due to the rapidly increasing demand for energy, water and food, all of which have a limited supply. However, addressing the security concept is a complex task as it is multidimensional in nature and include diverse aspects (Brooks, 2010). The concept of security has been stated through certain measurable indicators to reflect the different aspects of the security of energy, water, food resources. As discussed in Chapter 2 (see Section 2.2), the different aspects which could be reflected through security are availability (access to adequate and reliable resources), affordability (economic accessibility of resources and utilising resources efficiently) and acceptability (access to clean and safe resources). In this research, composite indices have therefore been developed based on the availability, affordability and acceptability aspects of security to reflect the complexity of the security definition. Table 8.1 shows some of the EWF security indicators selected for this research. Of selected indicators, only the one in bold will be applied to measure the EWF security.

Table 8.1: Selected indicators of EWF security

Some of the selected indicators	Availability	Affordability	Acceptability
Energy security	**Energy import dependency** Access to electricity	**Energy efficiency** **Energy Intensity** **Energy affordability**	**Energy diversity**
Water security	**Renewable water availability** **Water stress**	**water intensity**	Water pollution
Food security	**Food accessibility** **Food import dependency** Agricultural productivity	**Food affordability** **Value of food imports**	Fertiliser consumption

To examine the policy trade-offs, this research applied economic (GDP) and social (employment) indicators and the composite security indices that capture the various aspects of EWF security. The calculation of the composite indices was based on the weighted mean of the selected indicators for energy, water and food. For example, the composite index for water is the weighted mean of all the water security indicators, encompassing renewable water availability, water stress and water intensity (see Chapter 5, Figure 5.11). Since the selected indicators were calculated based on different measurement units, they needed to be converted to values without dimensions. For this purpose, the indicators were normalised and then evaluated on a scale from 0-100, where 0 shows the worst condition and 100 the best.

Normalisation for the indicators, where an increase in value shows better results (for, say, energy efficiency, renewable water availability, food accessibility), is calculated by Equation 1:

$$I = \frac{[x - Min(x)]}{[Max(x) - Min(x)]} \quad (1)$$

For the indicators where an increase in value shows the worst condition (for, say, energy/water intensity, energy/food import dependency, water stress), the normalisation is calculated with Equation 2:

$$I = \frac{[x - Max(x)]}{[Max(x) - Min(x)]} \quad (2)$$

Where

- I= the normalisation value
- X= the actual indicator value
- Max(x)= the highest value related to the particular indicator between the countries
- Min(x) = the lowest value related to the particular indicator between the countries.

The composite indices are calculated for each country and based on country grouping for the period 2015-2050 (short term and long term). The calculation of the composite indices will help

the analysis to show the trade-offs between the EWF securities and the economic and social results. The calculation of normalisation in this research did not apply different weights for the indicators and all of them were considered equally. Many studies, such as ECOFYS (2009), EIU (2019) and Sovacool (2013), which constructed the composite index, also assumed equal weights for the indicators in their calculations.

8.2 EWF security trade-offs

In this section, the scenario impacts and the policy implication of the different scenarios for the countries in this research will be discussed.

8.2.1 BAU scenario

If current trends continue (BAU scenario), the size of the economy over the 35 years to 2050 will increase for all the countries in this research, by an average of 1.8 fold (from US$2.6 trillion in 2015 to US$3.5 trillion in 2050). However, the economic growth of the countries would vary (see Table 8.2). Egypt could expect the highest growth, with average income increasing more than one and a half times by 2050. High-income countries could expect moderate benefits, with the average per-capita income improving by 20%. This trend could improve the economic status of Egypt, Morocco and Tunisia from being low/middle-income countries to upper/middle-income countries by mid-century. Change in economic growth in the short term (2015-2030) would be 7% (on average) faster than in the long term (2030-2050).

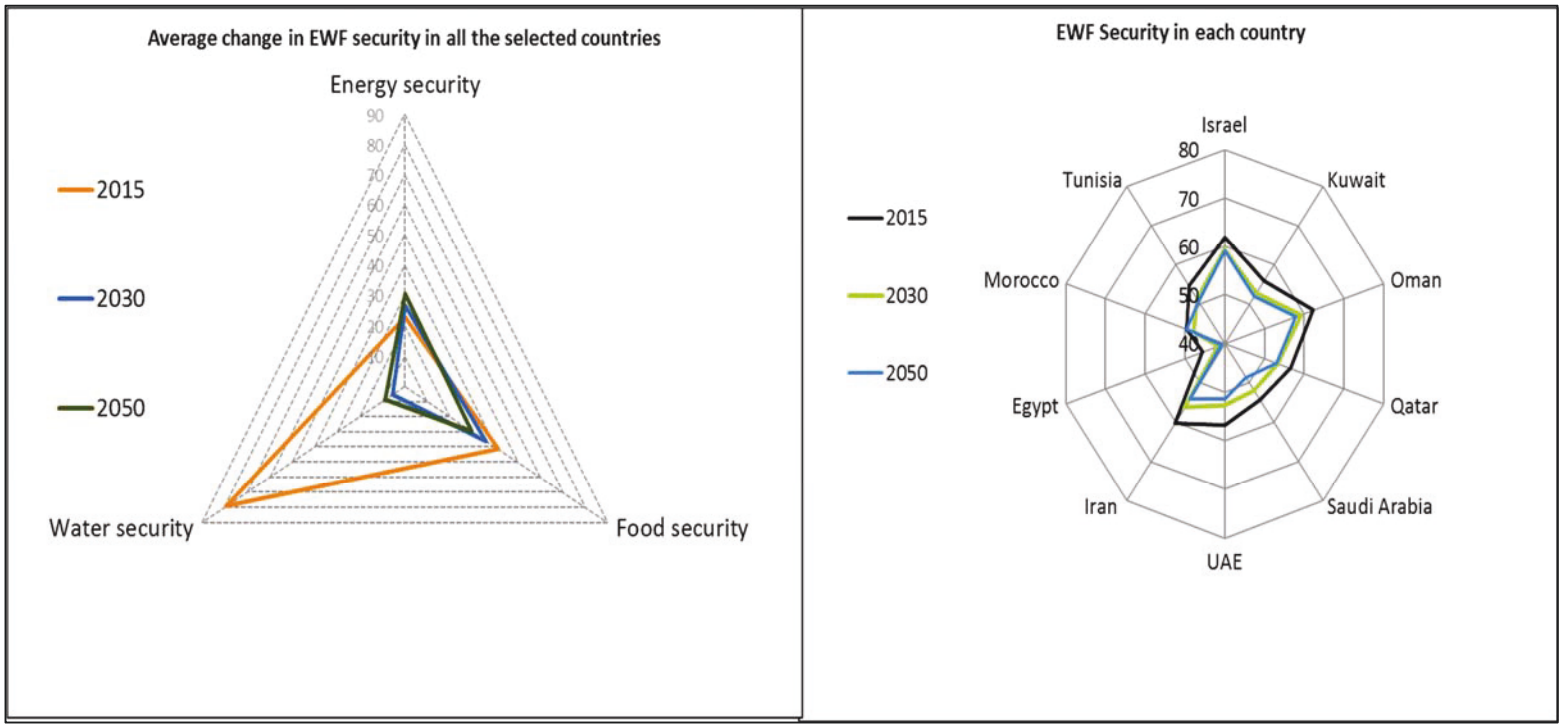
Table 8.2: Change in economic, social and EWF security results in the BAU scenario

					Percentage of change over the period 2015-2050				
Country	Region	Income group	Energy resources	Water availability	Economic	Social	Energy security	Water security	Food security
Israel	Middle East	High	Poor	Scarce	87%	84%	11%	-19%	-4%
Kuwait	Middle East	High	Rich	Scarce	73%	91%	8%	-24%	2%
Oman	Middle East	High	Rich	Scarce	109%	113%	19%	-21%	-4%
Qatar	Middle East	High	Rich	Scarce	40%	46%	5%	-24%	2%
Saudi Arabia	Middle East	High	Rich	Scarce	75%	103%	-30%	-7%	7%
UAE	Middle East	High	Rich	Scarce	63%	75%	-1%	-22%	-2%
Iran	Middle East	Upper-middle	Rich	Stress	25%	24%	-1%	-28%	0%
Egypt	North Africa	Lower-middle	Moderate	Scarce	151%	170%	5%	-33%	-12%
Morocco	North Africa	Lower-middle	Poor	Scarce	92%	85%	11%	-23%	12%
Tunisia	North Africa	Lower-middle	Poor	Scarce	99%	75%	1%	-15%	-2%

Source: See Appendix B, Section E, Tables E1, E2 & E3

The economic improvement in all the countries by 2050 would be an average of 81% better than 2015, but would require additional primary energy and water resources. The primary energy and water requirements across the countries would increase, by 77% (from 1187 Mtoe to 2102 Mtoe) for energy and by 109% (from 187 billion m^3 to 392 billion m^3) for water. This could impact the EWF security of all the countries over the 35 years to 2050, as shown in Table 8.2 and Figure 8.1.

Figure 8.1: Change in EWF security in the BAU scenario



Source: See Appendix B, Section E, Tables E1, E2, E3&E4[24]

[24] Note: Values closer to the origin shows worse security results.

Of all the resources in the BAU scenario, **water security** is the most significant. All the selected countries are likely to face high levels of water insecurity in both the short and long term (see Table 8.2 and Figure 8.2). For example:

- The composite water security indices for Egypt, Morocco, Iran, Oman, Kuwait, the UAE and Israel would fall over the 35 years to 2050. Apart from Iran, all the countries are water scarce (i.e., water availability is less than 1000 m^3 per person per year) and water resources are likely to experience further pressure (see Chapter 7, Figure 7.1).

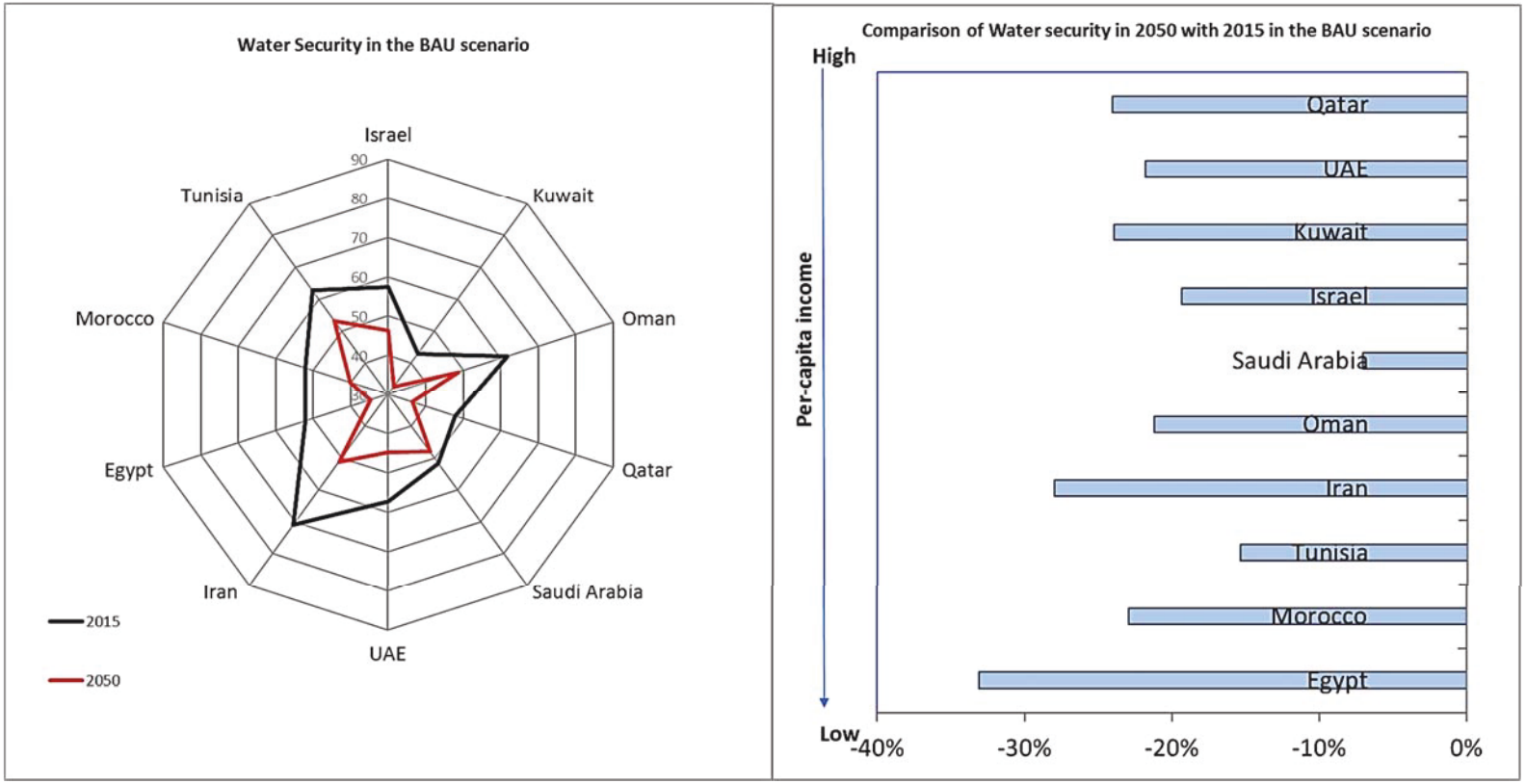
- Kuwait, which had the lowest composite water index in 2015, has the lowest water security index of the countries in this research (see Figure 8.2). This is because Kuwait is the most water stressed (approximately 5 m^3 per person per year). However, the water intensity of Kuwait's economy is low (about 10 litres per dollar) and this could help it slightly to avoid the negative impacts of water security to 2050. The same situation would apply to Qatar, Oman and the UAE.

- In contrast, Egypt will have the lowest composite water index in 2050. While the country ranked second among the countries in this research in terms of water availability in 2015, it enjoys the highest water intensity (approximately 310 litres per dollar) in its economy. Without necessary changes in the sub-structure of the economy, the water security condition in Egypt would worsen by 2050.

- Iran is the only country with water stress in this research (the rest of the countries are water scarce), yet it had the highest water security in 2015. However, the water security of the country would further decrease in this scenario as the water intensity is relatively high (about 214 l/US$) compared to the other countries in this research. If it continues along the same path for the 35 years to 2050, the country would put its water security at further risk.

- In the short term (2015-2030) all the countries (except Egypt) would expect higher water insecurity as compared to the long term (2030-2050). This would be mainly due to the faster population (8%) and economic (7%) growth in the short term (see Table 8.3).

Figure 8.2: Composite water security index in BAU scenario



Source: See Table 8.2 and Appendix B, Section E, Table E2

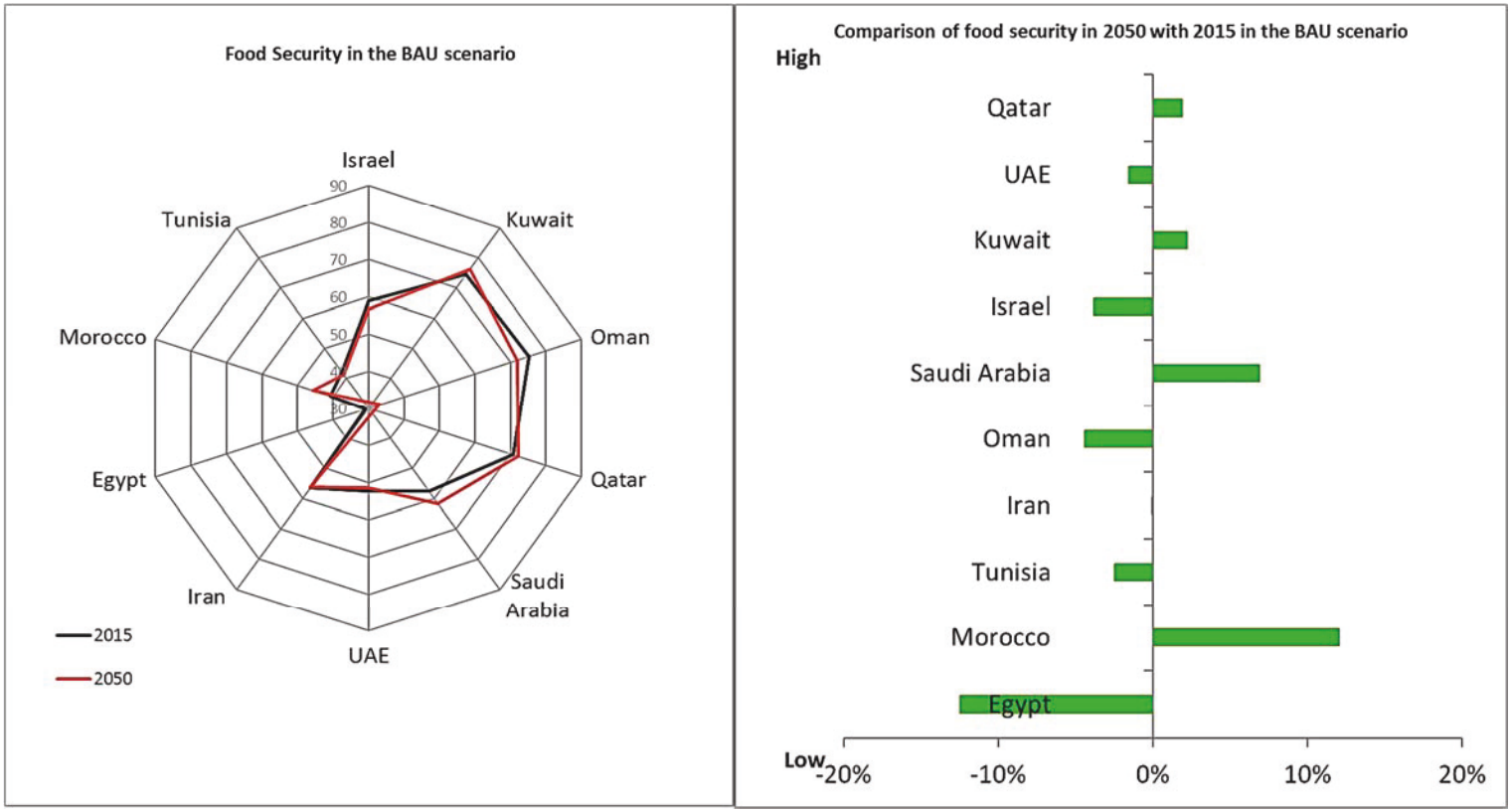
Food security could be an issue for the selected countries in the BAU scenario for the period 2015-2050 (see Table 8.2 and Figure 8.3). Food accessibility would decline and the countries would rely more on importing food. However, different countries would face different situations. For example:

- In 2015, Egypt, a low/middle-income country, had the lowest food security index and its food insecurity could be expected to increase further by 2050 (see Table 8.2 and Figure 8.3). This would be due mainly to the excessive decline in food accessibility (see Chapter 7, Figure 7.11) and increases in food prices (see Chapter 7, Figure 7.17). As its food accessibility would decline at a slower rate in the short term compared to the long term, its food security in the short term (2015-2030) would be higher than in the long term (2030-2050) (see Table 8.3). Tunisia, with a similar geographic and economic structure, would also experience food insecurity by 2050. However, as its decline in food affordability is minor, its food security risk would not be as severe as that of Egypt.

- The BAU scenario could also impact the food security of some high-income countries, such as Israel, Oman and the UAE. The UAE and Oman would experience a decline in their access to food in both the short and long term (see Chapter 7, Figure 7.11) and food would become relatively expensive (see Chapter 7, Figure 7.17). The UAE could also expect a decline in its food import dependency over both the short and the long term. Oman, however, could expect a decline in its food import to 2030 but an increase in the long term (compared to 2015) (see Table 8.3). Both countries will need to spend a greater proportion of their export earnings on importing food by 2050 to meet their domestic demand (see Chapter 7, Figure 7.14).

- In terms of Israel, the main reason for its food insecurity by 2050 will be its increasing dependence on food imports (see Chapter 7, Figure 7.14). However, as food will have become more affordable in Israel in 2050 compared with 2015, food insecurity in the country will not be a serious issue.

Figure 8.3: Composite food security index in the BAU scenario



Source: See Table 8.2 and Appendix B, Section E, Table E2

- Saudi Arabia, Qatar and Kuwait will have improved their food security by 2050 (see Table 8.2 and Figure 8.3). All these countries are in located in GCC with the same geographical and economic structure and a relatively high portion of lost and wasted food (see Chapter 5, Figure 5.23). Improving transport infrastructure would increase food accessibility in Saudi Arabia and Qatar, which could enhance food security in these countries. In Kuwait, the main reason for improving food security is that the country will become less dependent on food imports (see Chapter 7, Figure 7.14).

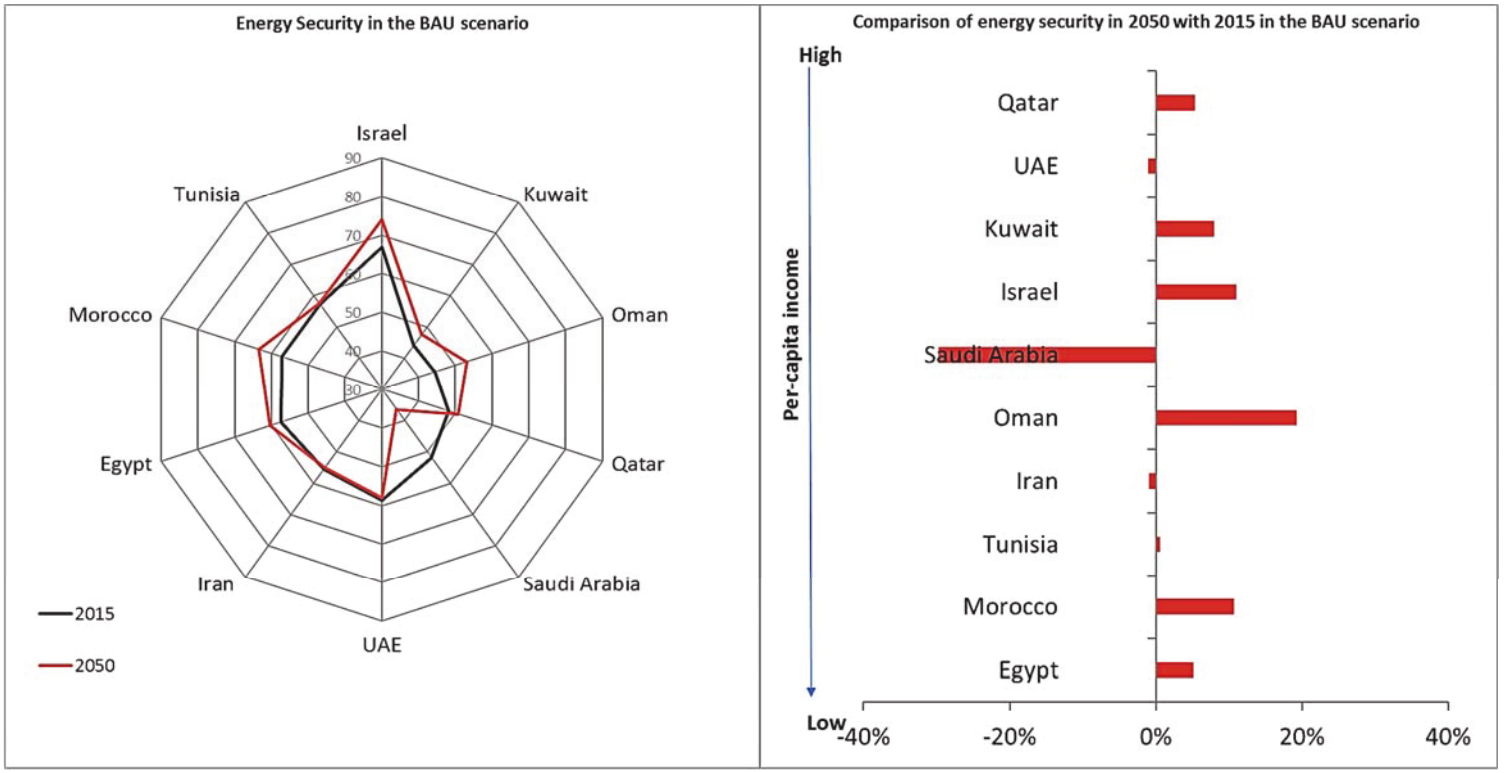
- In general, the high-income countries of Israel, Oman, Qatar, Saudi Arabia and the UAE could expect higher food security in the short term (2015-2030) compared with the long term (2030-2015). Kuwait is the only high-income country, which expect lower food security in the short term as compared to the long term (see Table 8.3).

- Morocco, a low/middle-income country, could expect the highest food security of all the countries in this research by 2050 because improvements in transportation particularly will increase food accessibility (see Chapter 7, Figure 7.11). In addition, food will have become relatively more affordable in Morocco by 2050 compared with 2015 (see Chapter 7, Figure 7.17).

The countries in this research will become more vulnerable in terms of **energy security**, but less than their water and food security (see Figure 8.1). As the countries move towards a more diverse energy mix (that is, less oil and gas and more renewables), their dependency on energy import would decline relatively. However, as they experience new technologies for supplying their domestic need, citizens in some countries will spend a higher proportion of their income on energy, which will affect energy affordability. The implications of energy security will also differ from country to country. For example:

- Following the current development trend could put the energy security of Saudi Arabia, as an energy exporting country, under threat (see Table 8.2 and Figure 8.3) and it by 2050 it would have the lowest energy security index in the BAU scenario. It could expect an excessive increase in energy intensity, from 511 toe/US$ in 2015 to 671 toe/US$ in 2050 (see Chapter 6, Figure 6.16), while its energy efficiency would not improve significantly (see Chapter 6, Figure 6.20). Its reliance on oil and gas would increase, with a negative effect on energy diversity (see Chapter 6, Figure 6.23).

Figure 8.4: Composite energy security index in BAU scenario



Source: See Table 8.2 and Appendix B, Section E, Table E1

- Iran and the UAE, as energy exporting countries, would also face a risk to their energy security. Their demand for electricity would increase significantly by 2050 (see Chapter 6, Figure 6.10), while Iran and the UAE make slight changes in their energy mix (see Chapter 6, Figure 6.23). However, the energy affordability for people in Iran would decrease due to the slow economic growth, thus less income per-capita compare to 2015. The country would have a slight decline in its energy security by 2030 compared to 2015; however, its energy security would be similar to 2015 in the long term (by 2050) (see Appendix B, Section E, Table E1). For the UAE, energy security would decline as the country would rely more on imports (see Chapter 6, Figure 6.26) and citizens would need to spend a larger proportion of their income on the purchase of energy (see Chapter 6, Figure 6.29).

- Countries with fewer energy resources, namely, Egypt, Israel, Morocco and Tunisia, energy security would improve by 2050. This would be due to the reduction of energy intensity of their economy (see Chapter 6, Figure 6.16) which would make them less dependent on energy imports (see Chapter 6, Figure 6.26).

- In the short term, all the countries (except Israel and Saudi Arabia) are likely to be slightly more energy insecure as compared to the long term. Over all, the countries would expect higher energy intensity (4%) in their economy, which would increase their dependency on importing energy (2%) in the short term (2015-2030).

Table 8.3: Change in economic, social and EWF security results in 2015-2030 and 2030-2050 in the BAU scenario

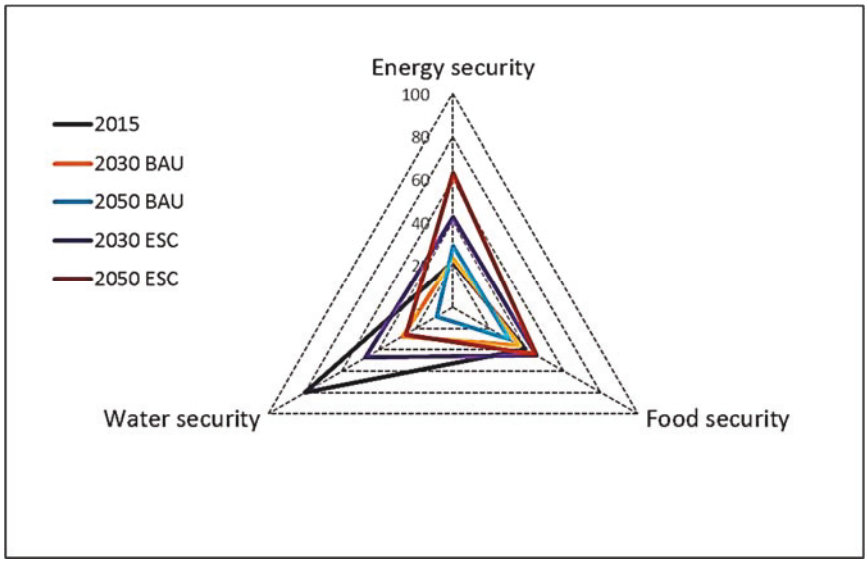
	Percentage of change over the period 2015-2030					Percentage of change over the period 2030-2050				
	Change in economic, social and securities results in BAU scenario									
	Economics	Social	Energy security	Water security	Food security	Economics	Social	Energy security	Water security	Food security
Israel	39%	38%	6.1%	-18.2%	-1.6%	35%	34%	4%	-1.5%	-2.2%
Kuwait	29%	35%	3.8%	-24.2%	-0.1%	34%	42%	4.2%	0.4%	2.1%
Oman	49%	50%	7.4%	-19.9%	-0.5%	40%	42%	9.7%	-1.7%	-3.9%
Qatar	23%	26%	2.1%	-23.9%	1.0%	13%	42%	2.8%	-0.2%	0.9%
Saudi Arabia	30%	40%	-11.2%	-7.6%	6.1%	34%	46%	-16.7%	0.5%	0.8%
UAE	30%	34%	-0.6%	-21.5%	0.1%	25%	30%	-0.2%	-0.4%	-1.7%
Iran	23%	21%	-1.6%	-21.1%	6.1%	2%	3%	0.8%	-8.7%	-5.8%
Egypt	64%	70%	-0.2%	-15.0%	-9.4%	53%	59%	4.8%	-21.3%	-3.4%
Morocco	41%	40%	5.8%	-22.5%	5.6%	36%	33%	6.8%	-0.6%	6.0%
Tunisia	41%	42%	0.1%	-14.8%	-1.6%	41%	43%	0.7%	-0.6%	-0.8%

See Appendix B, Section E, Tables E1, E2 &E3

8.2.2 ESC scenario

In the ESC scenario in this research, the overall EWF securities would improve in the selected countries.

Figure 8.5: Trade-offs between EWF securities in the ESC scenario



Source: See Table 8.2 and Appendix B, Section E, Tables E, E2 &E3

The impact on EWF security of implementing new technologies in this scenario is presented in Figure 8.5. Energy security would enjoy the most positive impact, followed by water and food securities. Compared with the BAU scenario, in both the short term and the long term, EWF security would improve in this scenario. However, in comparison with 2015, increase in energy and food securities could be expected while the security in the water sector will worsen. However, the pathway for each country would vary in this research (see Table 8.4).

Table 8.4: Change in economic, social and EWF security in ESC scenario by 2030 and 2050

	ESC compared with BAU -2030					ESC compared with BAU -2050				
	Change in economic, social and securities results in ESC scenario									
	Economics	Social	Energy security	Water security	Food security	Economics	Social	Energy security	Water security	Food security
Israel	0.9%	-0.5%	11.0%	10.2%	-1.1%	0.6%	1.7%	10.9%	-0.8%	-1.6%
Kuwait	2.4%	-2.0%	5.8%	13.3%	0.1%	0.0%	-3.9%	18.4%	0.7%	1.4%
Oman	2.2%	0.1%	9.3%	13.7%	0.6%	2.6%	-0.8%	17.2%	2.5%	3.9%
Qatar	0.3%	0.1%	3.0%	13.9%	0.1%	0.7%	-0.2%	7.7%	6.4%	0.1%
Saudi Arabia	1.4%	-3.3%	13.5%	2.6%	-1.3%	0.8%	-6.7%	38.5%	-1.2%	0.6%
UAE	0.6%	1.2%	13.0%	19.5%	5.3%	1.5%	-2.7%	25.1%	11.9%	5.6%
Iran	2.5%	0.2%	3.3%	14.3%	3.0%	5.3%	-0.2%	6.5%	21.8%	9.3%
Egypt	1.7%	-6.3%	9.0%	13.0%	15.0%	0.4%	-11.7%	11.4%	34.9%	18.7%
Morocco	0.9%	-1.5%	-0.7%	17.4%	1.7%	2.3%	-2.6%	-2.5%	11.1%	2.8%
Tunisia	-1.3%	-1.9%	15.9%	9.7%	2.7%	-2.6%	-4.0%	32.9%	2.4%	3.9%

Source: See Appendix B, Section E, Tables E1, E2 &E3

- All countries in the region except Morocco could expect an improvement in their **energy security** by 2050 compared with the BAU scenario. The most substantial improvement is expected for Saudi Arabia, Tunisia and the UAE, whose composite energy security indices by 2050 would be more than 20% higher than the index in the BAU scenario (see Table 8.4 and Figure 8.13). Other countries that could expect a significant increase in their energy security (between 10% and 20%) are Israel, Kuwait, Oman and Egypt. In contrast, Morocco would experience risk in its energy security as its energy diversity improves and the citizens will need to spend more of their income on modern energy.

- Most of the countries are likely to become more **water secure** in the ESC scenario compared with the BAU scenario (see Table 8.4 and Figure 8.14). Egypt and Iran would expect a substantial (more than 20%) improvement in their water index security than in the BAU scenario as the water intensity of their economy would decline in ESC scenario. Other countries that could expect a significant (between 10% and 20%) increase in their water security are the UAE and Morocco.

- In contrast, Israel and Saudi Arabia are likely to face water security risk in the ESC scenario compared to the BAU scenario. Both countries can expect increases in water stress in this scenario, with further pressure on fresh water availability compared with the BAU scenario.

  In the short term, all the countries are likely to improve their water security in this scenario due to greater availability of fresh water compared to the long term. Water security would decline in the long term for all the countries except Iran and Egypt which have higher water security index than in the BAU scenario (see Table 8.4).

- In terms of **food security**, modest improvement is expected by 2050. Egypt is the only country that would experience a significant increase in its food security due to improvements in transportation, which would impact its food accessibility in both the short and long term. Iran (upper/middle- income country) and the UAE (high-income country) are likely to face considerable improvement compared to the BAU scenario (see Table 8.4 and Figure 8.15).

- However, in the short term, food security is likely to deteriorate modestly (less than 2%) in Israel and Saudi Arabia (see Table 8.4). While the condition would improve

slightly for Saudi Arabia in the long term, Israel is likely to experience further reduction in its food security.

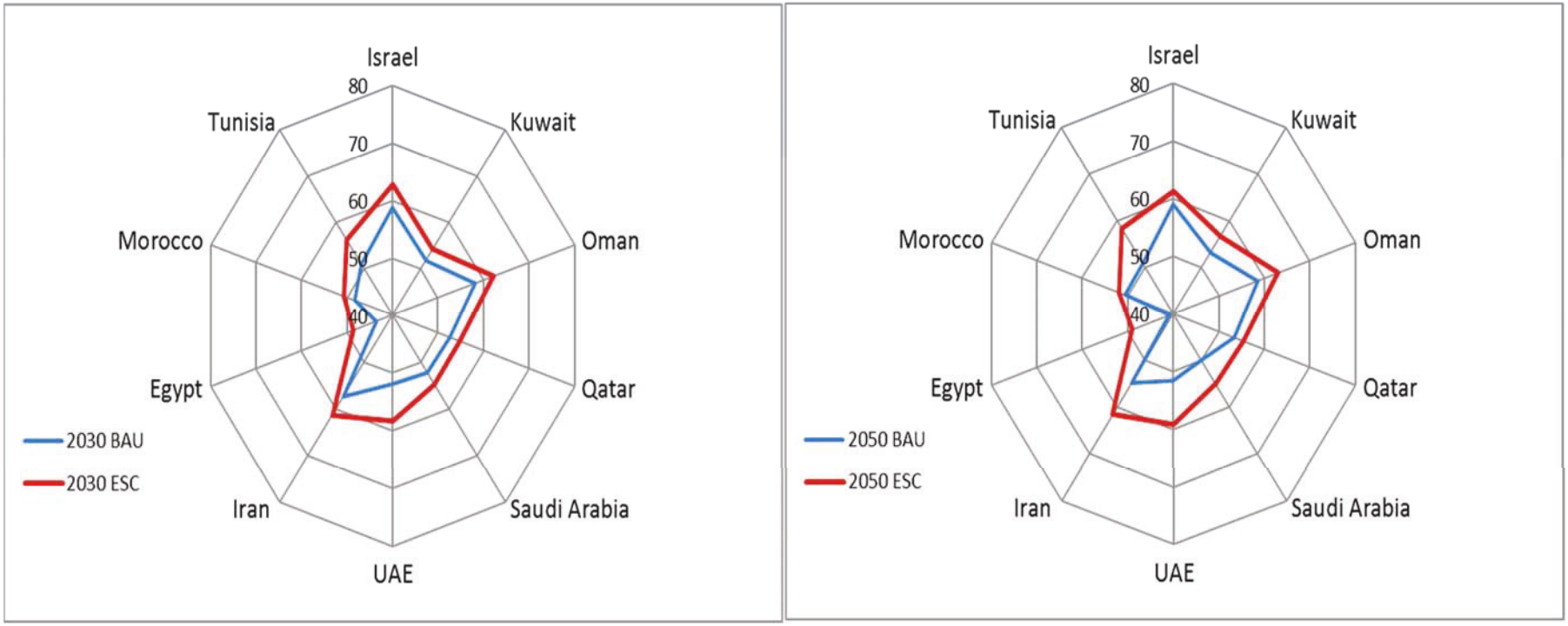
Balancing EWF security[25] could be more difficult for the low/middle-income countries. Egypt and Morocco could expect the lowest EWF composite index in this scenario due to declines in their energy affordability. While these countries would become less dependent on energy and rely more on renewables to meet their domestic requirements, the citizens of these countries would spend more of their income on energy (see Figure 8.6).

The EWF security outcomes in this scenario could be impacted by several policy measures such as seawater desalination to supply additional water, increasing the use of fertilisers to enhance the agricultural products and change the economic structure of countries more towards industry. All of the measures applied in this scenario are highly energy-intensive which could impact energy security negatively. Thus, the aim of the scenario is to improve the efficient usage of energy.

As a result of implementing the ESC scenario, demand for primary energy would decline by 5% (to 1546Mtoe) in short term and 13% (to 1867 Mtoe) in the long term (see Chapter 6, Figure 6.11). Demand for water is likely to reduce by 10% (to 247 billion m^3) by 2030 and 21% (to 306 billion m^3) by 2050 (see Chapter 7, Figure 7.2). It is expected that, on average, GDP will improve slightly while job opportunities will be impacted negatively (mainly jobs in the agriculture sector).Compared with the BAU scenario by 2050, GDP is likely to increase by 1.2% (US$66 billion) while employment will decline by 3.1% (12 million jobs) (see Chapter 6, Tables 6.1 and 6.4). In the short term (2015-2030), GDP would improve by 1% (US$49 billion) while employment is likely to decrease by 1.4% (4.8 million jobs) (see Chapter 6, Tables 6.1 and 6.4).

[25] Balancing of energy, water and food securities in this research means the average of the composite indices of energy, water and food securities in each scenario.

Figure 8.6: EWF security in the ESC scenario by 2030 and 2050

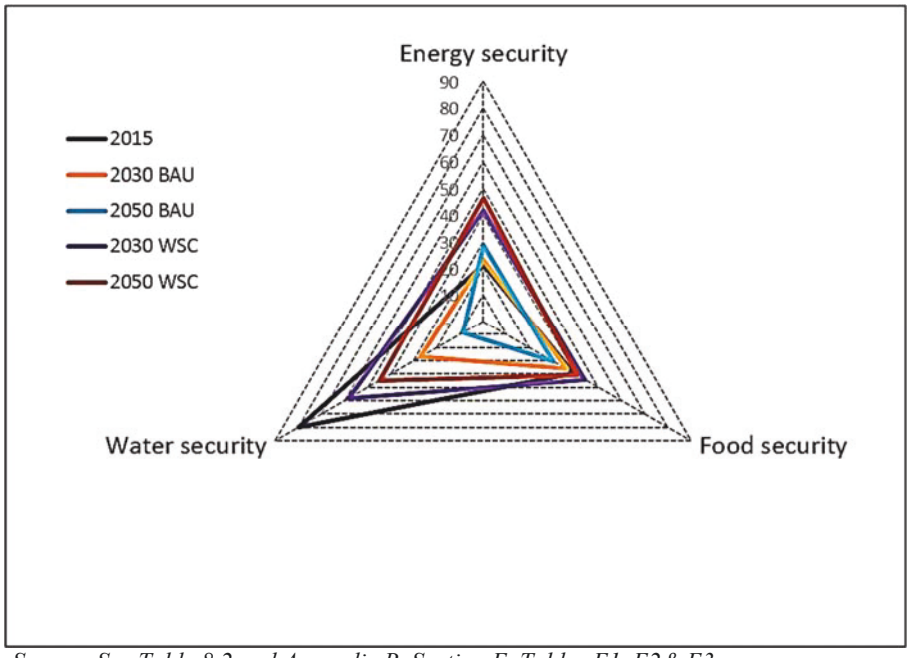


Source: See Appendix B, Section E, Table E4

8.2.3 WSC scenario

EWF security could improve by implementing **WSC scenario** in the countries in this research.

Figure 8.7: Trade-offs between EWF securities in the WSC scenario



Source: See Table 8.2 and Appendix B, Section E, Tables E1, E2& E3

Figure 8.7 presents the overall impact of the WSC scenario across the countries compared with the BAU scenario in both the short term and the long term. Based on the WSC scenario, water security would progress significantly followed by energy and food security. The WSC scenario, however, would produce a better result in the short term compared with the long term. The water and food insecurity would be expected to decline further in 2030 compared with the outcomes in the long term (Figure 8.7). Compared to 2015, water security will deteriorate and food security will improve slightly.

Table 8.5: Change in economic, social and EWF security in the WSC scenario by 2030 and 2050

	WSC compared with BAU -2030					WSC compared with BAU -2050				
	Change in economic, social and securities results in WSC scenario									
	Economics	Social	Energy security	Water security	Food security	Economics	Social	Energy security	Water security	Food security
Israel	0.4%	-0.4%	3%	12%	-1%	-1.4%	2.0%	5%	6%	-1.0%
Kuwait	1%	-2%	-1%	35%	0%	-1.6%	-3.8%	11%	44%	0.9%
Oman	4%	0.3%	3%	17%	1%	-1.3%	0.1%	6%	12%	4.1%
Qatar	0%	0.0%	2%	26%	0%	-1.3%	-0.1%	4%	21%	0.2%
Saudi Arabia	2%	-3%	8%	1%	-2%	-0.1%	-5.9%	26%	5%	-0.7%
UAE	1%	0.1%	4%	23%	1%	-0.4%	-0.3%	10%	18%	2.7%
Iran	2%	0.3%	3%	21%	3%	-0.1%	-0.3%	4%	34%	8.9%
Egypt	1%	-5%	9%	14%	20%	-0.2%	-9.3%	9%	37%	25.9%
Morocco	1%	-1%	0%	31%	1%	1.3%	-2.6%	-3%	20%	5.9%
Tunisia	-1%	-2%	10%	15%	3%	-2.7%	-3.9%	20%	7%	3.8%

Source: See Appendix B, Section E, Tables E1, E2 & E3

In this scenario, countries are likely to have different trends. For example:

- All countries in the region would expect to improve in **water security** in the WSC scenario compared with the BAU scenario (see Table 8.5 and Figure 8.14). The most positive impact would be experienced by Kuwait, Iran and Egypt, as their water stress and water intensity would decline (see Chapter 7, Figures 7.6 and 7.9). Other countries that expect to experience substantial improvement in their water security are Qatar and Morocco while Oman and the UAE are likely to face considerable change (between 5% and 10%) in their water security, by 12% and 18% higher respectively than in the BAU scenario. In the short term (2015-2030), the water security could improve substantially on average for all the countries expect Saudi Arabia as compared to the BAU scenario (see Table 8.5)

- In terms of **energy security**, all countries except Morocco are likely to experience an improvement in the WSC scenario compared with the BAU scenario (see Table 8.5 and Figure 8.13). Similar to the ESC scenario, Saudi Arabia and Tunisia are likely to experience a substantial improvement, with composite energy security 26% and 20%, respectively, greater than in the BAU scenario. Kuwait could expect significant (between 10% and 20%) change in its energy security compared to the BAU scenario and the rest of the countries a positive impact in their energy security index of less than 10% as compared to the BAU scenario.

- In the short term, however, energy security would expect to change modestly (4%) on average between the countries. Kuwait is the only country, which could expect the slight deterioration in its energy security in the short term as the citizens will need to spend more of their income on modern energy. In contrast, Tunisia is likely experience the highest positive impacts in its energy security between all the countries as the economy of the country would be less energy intensive (see Table 8.5).

- In terms of food security, the most positive impact would be observed in the low/middle- and upper-income countries (see Table 8.5 and Figure 8.15). Egypt is likely to have the greatest improvement in its food composite, both in the short and long term, thanks to improvements in its transport infrastructure and declines in the price of its food. In contrast, the improvement in food security for some of the high-income countries will differ only slightly from the BAU scenario. Oman could expect the highest change in its composite food security index (by 4.17% more than the BAU scenario) among the countries in this group, but Israel and Saudi Arabia are likely to face further risk to their

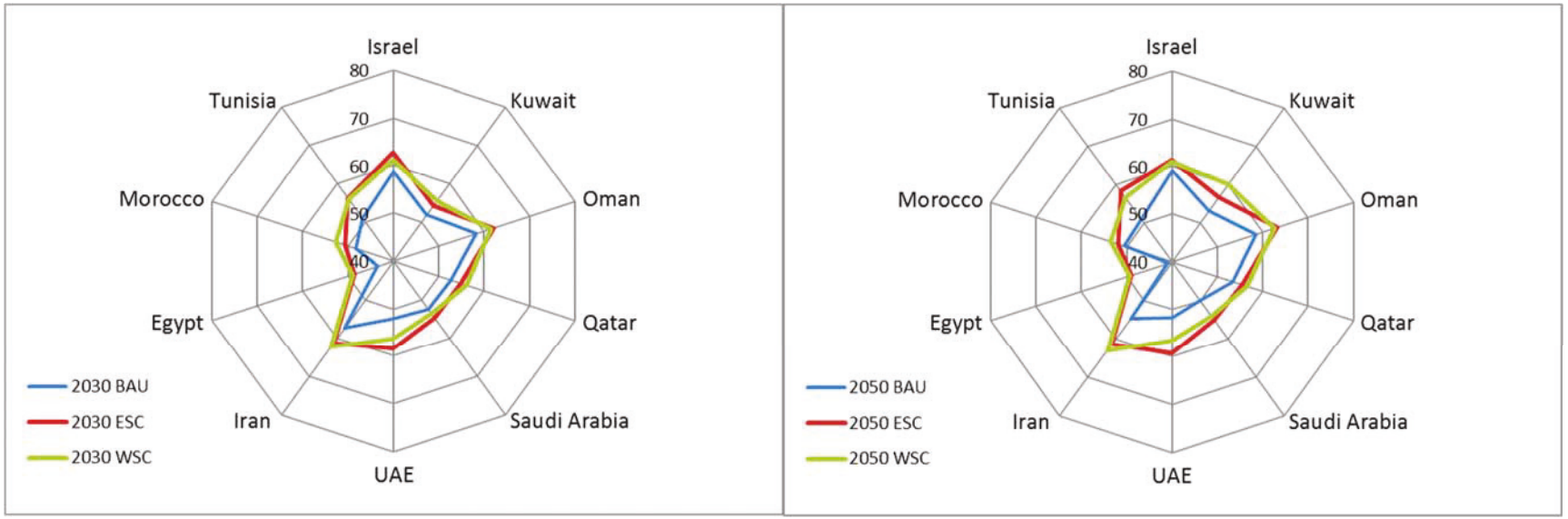
food security compared with the BAU scenario by 2050. The same trend would be observed in the short term for the countries in this group (see Tables 8.5).

Balancing EWF security, both in the short term and long term, would be the most beneficial for Kuwait (the most water-stressed country in this research) in the WSC scenario compared with both the BAU and the ESC scenarios while Iran, Qatar and Morocco would have a considerable EWF security balance in the WSC scenario compared to the BAU scenario. Egypt and Oman are likely to have similar outcomes in ESC and WSC scenarios, but the rest of the countries would benefit more in the ESC scenario than in the WSC scenario (see Figure 8.8).

The results of the WSC scenario reflect the impact of implementing several policies, such as improving energy diversity for implementing seawater desalination technology and minimising production of water-intensive agriculture products by applying less fertiliser (compared to the ESC scenario) to boost agricultural output.

Implementing the WSC scenario will lead to reduced primary energy and water requirements of the countries by on average 2% (to 1595Mtoe) and 15% (to 234 billion m^3) in short term and 5% (to 1997Mtoe) and 28% (to 279 billion m^3) in long term respectively (see Chapter 6, Figure 6.11 and Chapter 7, Figure 7.2). While the scenario has positive impact on the GDP in short term, which would increase the GDP on average by 1% (US$41 billion), in the long term GDP would be drop on average by 0.8% (US$22 billion) (see Chapter 6, Table 6.1). However both in the short term and long term, the scenario will have negative impact on employment, which would drop on average by 1.3% (3288 million jobs) and 2.4% (9350 million jobs) respectively (see Chapter 6, Table 6.4).

Figure 8.8: EWF security in the WSC scenario by 2030 and 2050

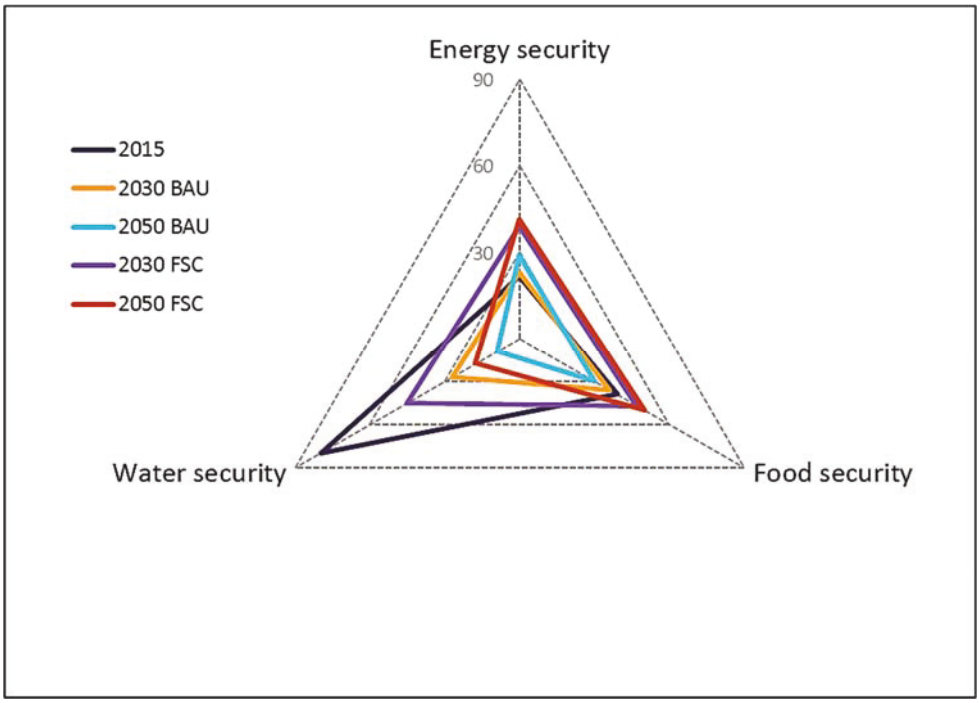


Source: See Appendix B, Section E, Table E4

8.2.4 FSC scenario

The severity of energy, water and food security risks would improve in the FSC scenario compared to the BAU scenario), as shown in Figure 8.9. In this scenario, the greatest improvement could be expected in food security, followed by energy and water security, by 2050. When comparing the short term and the long-term impact of the FSC scenario, energy and food security will have the same outcomes but water security will deteriorate further in the long term. In comparison to 2015, it would expect to have better outcomes in energy and food securities while water security severely become worsen by 2050.

Figure 8.9: Trade-offs between EWF securities in the FSC scenario



Source: See Table 8.2 and Appendix B, Section E, Tables E1to E3

Table 8.6 shows the results of the FSC scenario for each country both in short term and long term. As with the ESC and WSC scenarios, it is expected that countries will have different trends in this scenario. For example:

- The **food security** of most of the countries will improve in the FSC scenario compared to the BAU scenario. Egypt is the only country with substantial improvement; by 28% more than in the BAU scenario (see Table 8.6 and Figure 8.15). While the results show significant improvement (between 10% and 20%) for Iran, other countries include Kuwait, Saudi Arabia, Oman, the UAE, Morocco and Tunisia could expect a less than

10% improvement in their composite food security index compared with the BAU scenario.

- In contrast, Israel and Qatar would be more food insecure in this scenario compared with the BAU scenario, due to their spending a higher portion of their income on food but having less accessibility to food.

Table 8.6: Change in economic, social and EWF securities in the FSC scenario by 2030 and 2050

	FSC compared with BAU -2030					FSC compared with BAU -2050				
	Change in economic, social and securities results in FSC scenario									
	Economics	Social	Energy security	Water security	Food security	Economics	Social	Energy security	Water security	Food security
Israel	0.3%	-0.5%	1%	10%	-1%	-1.5%	1.8%	2.1%	-1.0%	-2.0%
Kuwait	0%	-1%	2%	18%	0%	-5.0%	-2.0%	7.5%	4.5%	1.6%
Oman	1%	0%	2%	14%	0.6%	-2.6%	-0.3%	5.1%	5.7%	4.1%
Qatar	1%	1%	1.6%	12%	-2%	-2.2%	2.5%	2.8%	12.3%	-4.6%
Saudi Arabia	1%	-3%	5%	-2%	0%	-0.2%	-5.8%	21.5%	-2.3%	2.9%
UAE	1%	-1%	4%	21%	3%	-0.8%	-1.9%	9.5%	11.0%	6.9%
Iran	2%	1%	-3%	15%	4%	-0.4%	2.5%	-11.6%	21.0%	11.2%
Egypt	1%	-2%	4.8%	10%	17%	0.3%	-1.9%	4.0%	24.0%	27.8%
Morocco	1%	-1%	-3%	12%	1%	1.2%	-0.5%	-7.5%	1.7%	1.3%
Tunisia	-1%	-2%	6%	11%	3%	-3.8%	-4.2%	14.6%	-1.6%	7.3%

Source: See Appendix B, Section E, Tables E, E2 & E3

- High-income and some low/middle-income countries are likely to experience improved **energy security** by 2050 in the FSC scenario in comparison with the BAU scenario (see Table 8.6 and Figure 8.13). However, the energy security in Iran and Morocco is likely to worsen both in short term and long term. In addition to the higher energy intensity, citizens in these counties will need to spend a greater proportion of their income on energy, which will make these countries more energy insecure.

- **Water security** in the FSC scenario could have substantial impact for Iran and Egypt, with 21% and 24%, respectively, further improvement than in the BAU scenario (see Table 8.6 and Figure 8.14). Among the high-income countries, Qatar and the UAE are likely to experience significant (between 10% and 20%) improvement in water security. However, the rest of the countries will either improve slightly or could expect a negative impact on their composite water security. Israel, Saudi Arabia and Tunisia could expect their water security to worsen in the FSC scenario compared with the BAU scenario, even though in the short term, the water security of Israel and Tunisia could be expected to improve. This trend would change during the long term as water demand and water intensity increase.

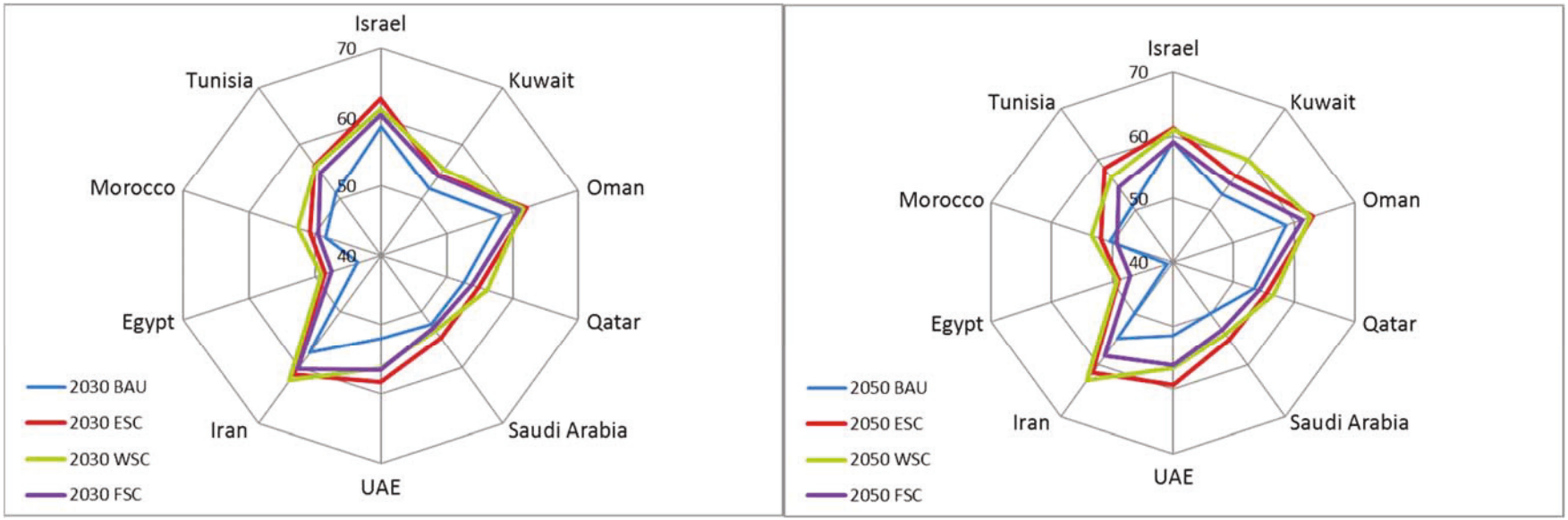
- In the short term, the balancing of energy, water and food would be beneficial for all the countries in FSC scenario as compared to the BAU scenario in 2030. In comparison to the ESC and WSC scenarios, all the countries are likely to experience less improvement in their EWF security balance (Figure 8.10).

- In the long term, while balancing energy, water and food security in the FSC scenario would be beneficial for most of the countries, however, Morocco would be in a better situation in terms of EWF security in the BAU scenario. In addition, the EWF securities balancing for Israel would be similar in both FSC and BAU scenarios (Figure 8.10). Clearly, all the countries will be in a better position in terms of their overall EWF securities in both the ESC and WSC scenarios as compared to the FSC scenario.

The security outcomes in this scenario are a combination of several policy measures, such as improvement in food accessibility (less loss and waste), increased use of fertilisers and improved agricultural productivity. In addition, the water required in this scenario would be provided through wastewater treatment and agricultural drainage water options.

While the measures (on average) would result in a negligible increase in primary energy by 1% to 1634Mtoe in the short term and to 2116Mtoe in the long term (see Chapter 6, Figure 6.11). However, water requirement would decline by 8% (to 253 billion m^3) and 17% (to 324 billion m^3) in short term and long term respectively (see Chapter 7, Figure 7.2). In addition, it is expected that GDP will decline on average by 1.5% (US$38 billion) while in the short term a slight improvement is expected (by less than 1% (US$38 billion)) (see Chapter 6, Table 6.1). However, job opportunities would decrease by 1% to 1140 million jobs in the short term and 2610 million jobs in the long term (see Table 6.4).

Figure 8.10: EWF security in the FSC scenario by 2030 and 2050



Source: See Appendix B, Section E, Table E4

8.2.5 NSC scenario

In the **NSC scenario,** EWF security could expect further improvement. Figure 8.11 shows the impact of all the scenarios on EWF security in all the countries in both short term and long term. The results show that EWF security outcomes in the NSC scenario are better than the ESC, WSC and FSC scenarios both in the short and long term. In comparison to 2015, overall, countries could expect to improve their energy and food security but would face a risk in their water security. Hence, while the composite energy and food security indices for the NSC scenario are higher in 2050 than in 2015, however, the composite water security index in this scenario is lower (Figure 8.11).

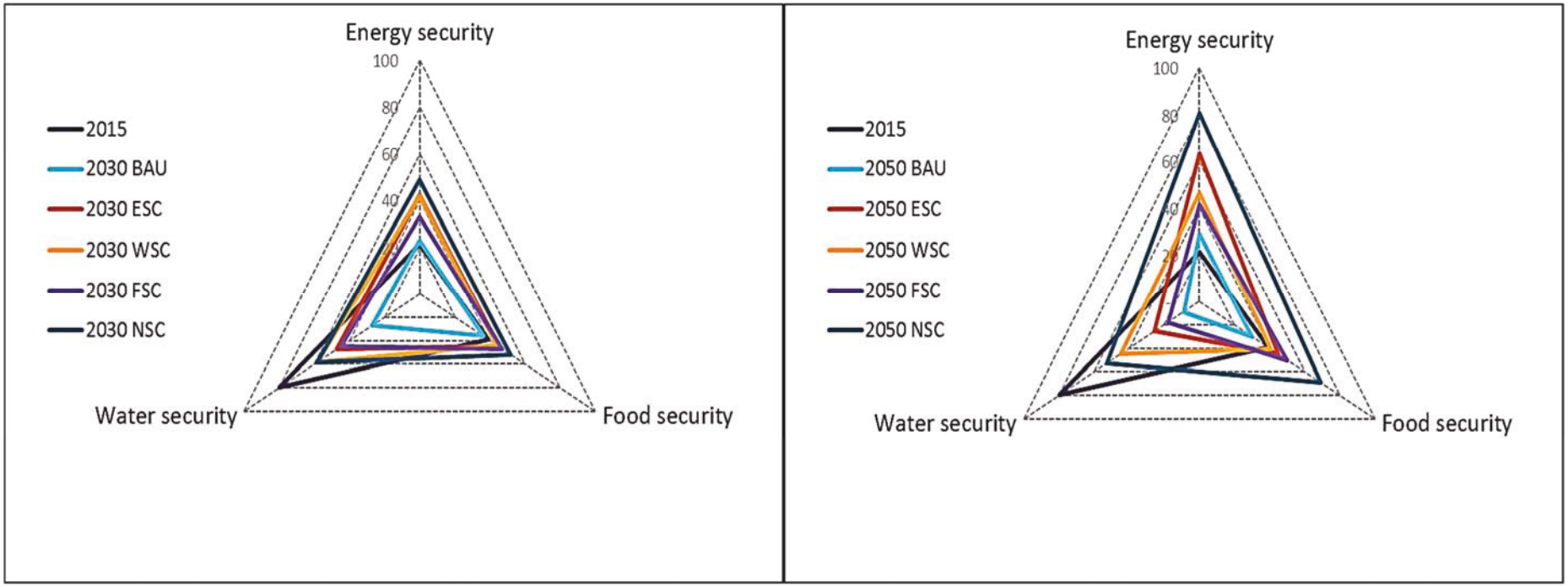
The countries could expect the following results:

- By 2050, unlike in the ESC, WSC and FSC scenarios, all countries are likely to experience improved food security in the NSC scenario compared to the BAU scenario (see Tables 8.4, 8.5, 8.6 and 8.7). Improvements in transportation infrastructure and increases in food affordability in this scenario will put countries from different income groups in this research in a better position, thus helping to alleviate food security risks further. Compared to the FSC scenario, most of the countries except Iran and Saudi Arabia would show further improvement in their composite food security index in NSC scenario (see Tables E4 and E5).

- In terms of water security, most of the countries will experience better outcomes compared with the ESC, WSC and FSC scenarios. Saudi Arabia and the UAE would have better composite water security indices in the WSC scenario compared with the NSC scenario (see Tables E2).

- Compared with the BAU and ESC scenarios, all countries, but particularly the energy-poor countries, are likely to improve their energy security in the NSC scenario. Although citizens in some countries such as Kuwait and the UAE would spend a greater proportion of their income on energy compared with the ESC scenario (see Chapter 6, Figure 6.29), improvements in energy efficiencies and a less energy-intensive economy (see Chapter 6, Figures 6.16 and 6.22) will reduce the risk of energy insecurity in this scenario.

Figure 8.11: Trade-offs between EWF securities in the NSC scenario in 2030 &2050



Source: See Table 8.2 and Appendix B, Section E, Tables E1 to E3

Table 8.7: Change in economic, social and EWF security results in the NSC scenario by 2030 and 2050

	NSC compared with BAU -2030					NSC compared with BAU -2050				
	Change in economic, social and securities results in NSC scenario									
	Economics	Social	Energy security	Water security	Food security	Economics	Social	Energy security	Water security	Food security
Israel	1%	1%	8%	15%	2%	9.5%	6.7%	11.4%	10.3%	4.2%
Kuwait	1%	3%	-9%	28%	0%	9.8%	5.2%	18.9%	46.1%	7.6%
Oman	3%	5%	5%	13%	1%	10.1%	10.3%	26.1%	13.4%	9.6%
Qatar	2%	2%	3%	7%	2%	3.8%	4.6%	18.8%	28.5%	5.0%
Saudi Arabia	5%	0%	9%	-0.3%	0%	10.0%	1.0%	57.4%	1.6%	2.8%
UAE	3%	5%	7%	15%	4%	10.8%	10.4%	27.1%	14.0%	8.7%
Iran	1%	3%	2%	13%	-5%	9.7%	2.2%	16.5%	36.3%	7.1%
Egypt	1%	-2%	13%	10%	15%	13.5%	-2.4%	16.9%	46.9%	50.8%
Morocco	1%	0%	1%	30%	1%	5.3%	1.1%	6.6%	24.8%	6.6%
Tunisia	4%	7%	24%	15%	8%	10.9%	5.6%	45.2%	7.6%	11.1%

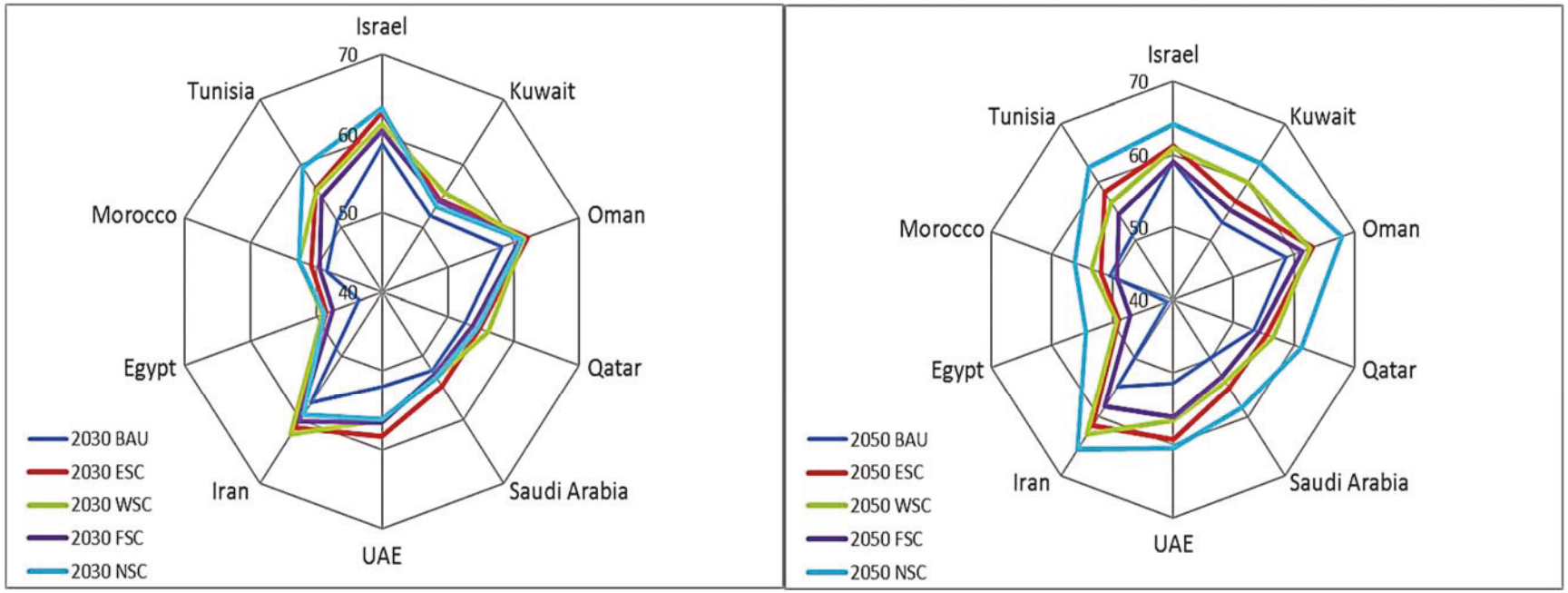
Source: See Appendix B, Section E, Tables E1, E2 &E3

- In contrast, in the short term, not all countries would improve their EWF security in the NSC scenario. Compared to the BAU scenario in 2030, some countries will be less EWF secure (see Table 8.7). For example, Kuwait will have a higher risk of energy insecurity in the NSC scenario compared with the BAU in 2030. Another example is Iran, whose composite food security index will be 5.2% lower than in the BAU scenario, while in Saudi Arabia, water security would be 0.3% less in the NSC scenario than in the BAU scenario.

- The NSC scenario will produce very different outcomes for the countries in this research compared to those in the ESC, WSC and FSC[26] scenarios in the short term (see Figure 8.12). While the balancing of EWF securities in NSC scenario would be higher than in the BAU scenario, the energy-rich countries can expect slightly higher EWF security in the ESC scenario compared with the NSC scenario in the short term. The balancing of EWF securities will have better outcomes in the WSC scenario compared with the NSC scenario. All countries except Israel and Tunisia are likely to experience a higher composite EWF security index in the WSC scenario compared with the NSC scenario. This will be due mainly to a more water-intensive economy and an increase in water demand in all the countries in the short term (see Chapter 7, Figures 7.6 and 7.10).

[26] The examples presented mainly compare the NSC scenario with the most improved security index (energy, water or food) in each scenario.

Figure 8.12: EWF security in the NSC scenario by 2030 and 2050



Source: See Appendix B, Section E, Table E6

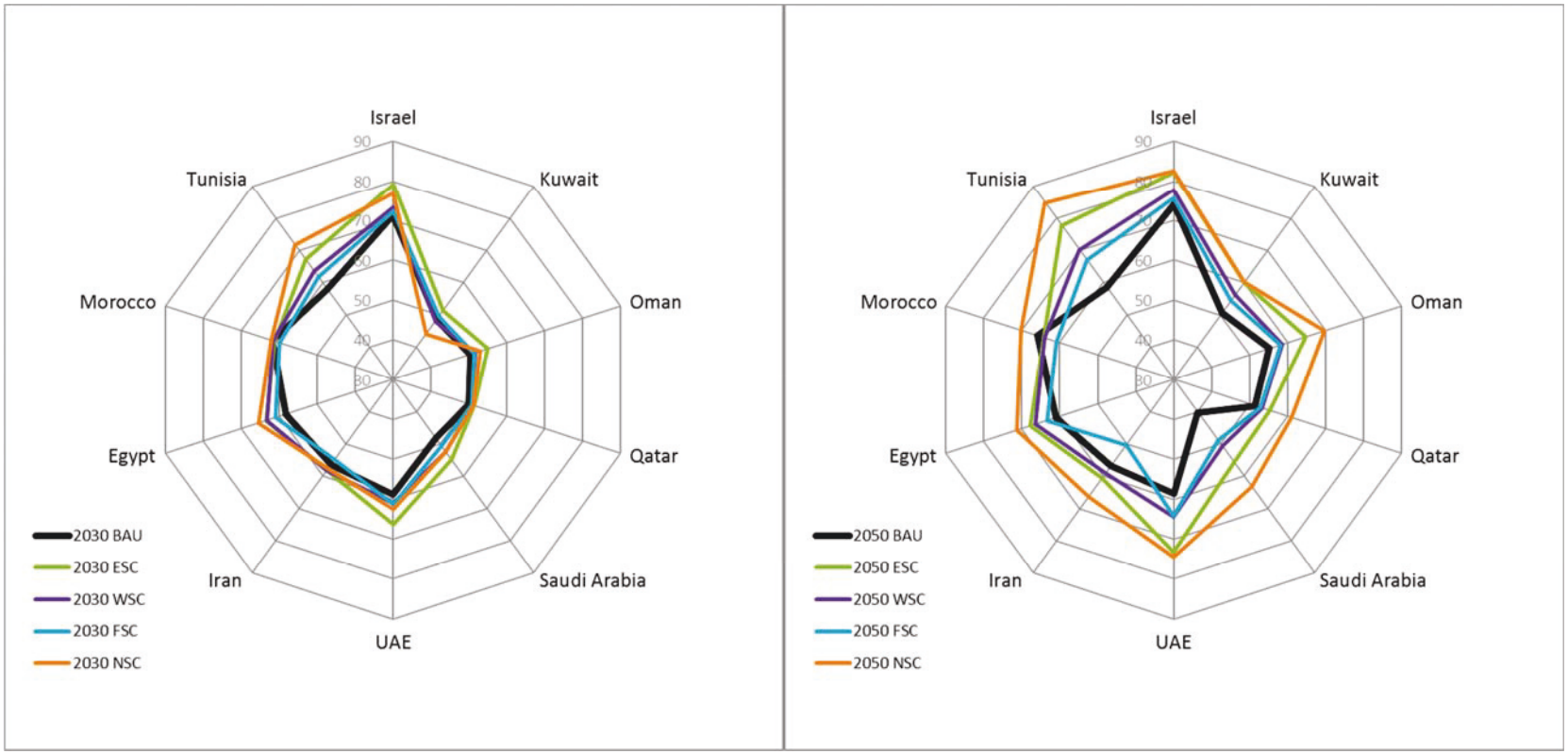
- In comparison with the FSC scenario, the NSC scenario would produce higher results for most of the countries by 2030. Kuwait, the UAE and Iran could expect higher balancing of EWF securities in the FSC scenario. Iran, for example, would have higher food accessibility in FSC scenario (as compared to the NSC scenario), hence reducing its risk of food insecurity further.

- In the long term, as the results show, in all the countries balancing the EWF security would expect the highest outcomes as compared to the other scenarios (see Figure 8.12).

The changes in EWF security in this scenario are due to the implementation of policies that consider the nexus of energy, water and food. These policies include considering small scale renewable energy technologies, increasing the share of waste water through investment in advanced wastewater technologies, improving land transportation, moving towards a less water- and energy-intensive agricultural system and transferring from industrial and agricultural economies towards less energy-intensive service sectors.

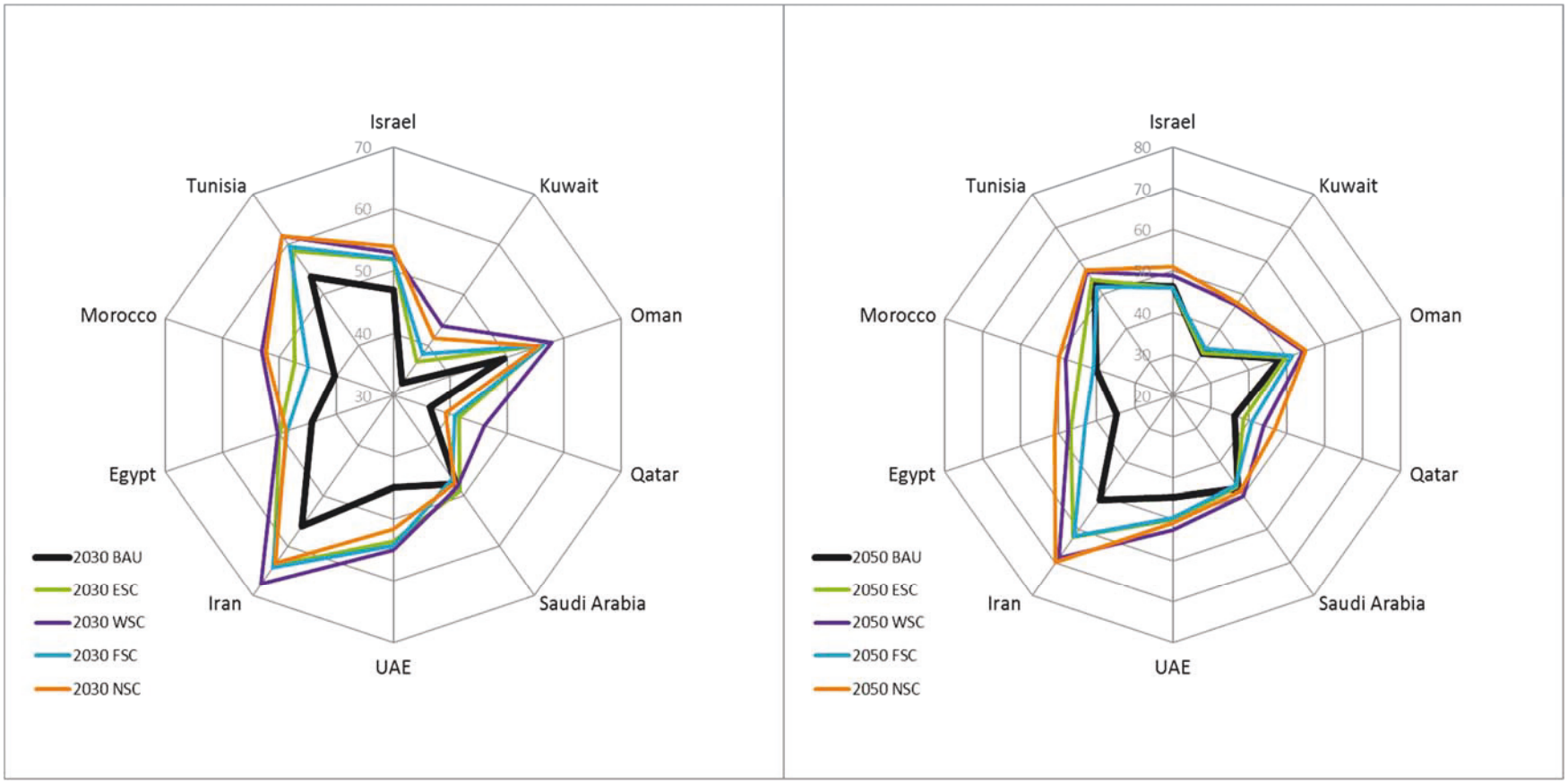
These measures would reduce the demand for primary energy by 4% to 1564Mtoe by 2030 and 15% to 1792Mtoe by 2050 (see Chapter 6, Figure 6.11). The water demand would decline by 10% to 247 billion m^3 by 2030 and 30% to 276 billion m^3 by 2050 (see Chapter 7, Figure 7.2). In addition, it is expected that GDP on average will increase by 2.2% (US$86 billion) in the short term and 9.4% (US$451 billion) in the long term (see Chapter 6, Table 6.1). In addition, job opportunities are likely to increase by 2.4% (828 million jobs) in the short term and by 4.5% (1660 million jobs) in the long term (see Chapter 6, Table 6.4).

Figure 8.13: Composite energy security index in the various scenarios



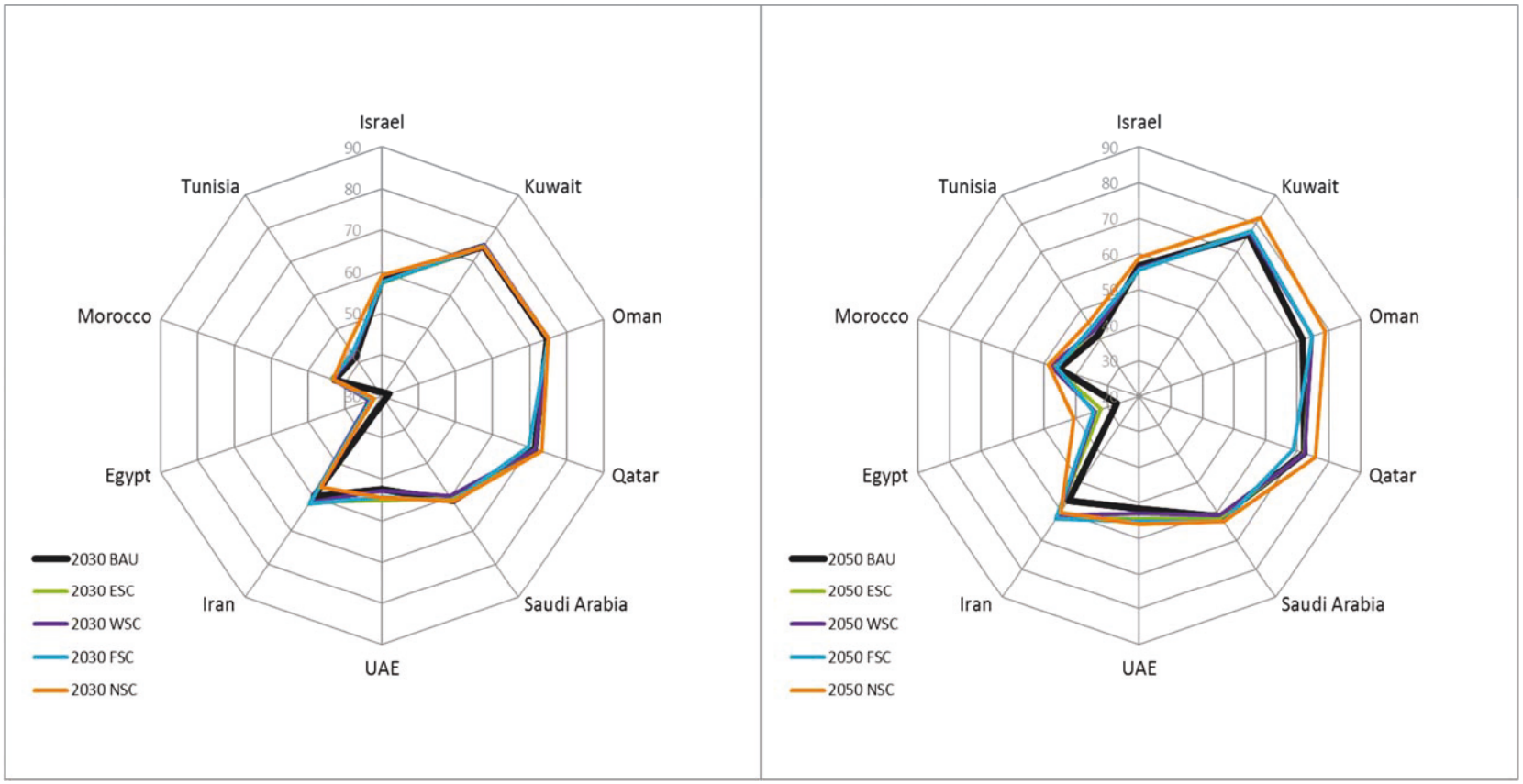
Source: See Tables 8.2 to 8.7

Figure 8.14: Composite water security index in the various scenarios



Source: See Tables 8.2 to 8.7

Figure 8.15: Composite food security index in the various scenarios



Source: See Tables 8.2 to 8.7

Table 8.8: Change in economic, social and EWF securities trade-offs, by country groupings

a) BAU scenarios (2030 and 2050) as compared to 2015

Country grouping	Economic Outcomes (GDP)		Social outcomes (Jobs)		Energy Security		water Security		Food Security	
	2030	2050	2030	2050	2030	2050	2030	2050	2030	2050
High- income	Slight improvement	Slight improvement	Modest improvement	Slight improvement	Slight improvement	Modest worsening	Substantial worsening	Substantial worsening	Modest improvement	Modest worsening
Upper/Low middle-income	Modest improvement	Slight improvement	Modest improvement	Modest improvement	Modest improvement	Modest improvement	Substantial worsening	Substantial worsening	Slight worsening	Negligible impact
Energy -rich	Slight improvement	Slight improvement	Slight improvement	Slight improvement	Slight improvement	Slight worsening	Substantial worsening	Substantial worsening	Modest improvement	Modest worsening
Energy-Poor	Modest improvement	Modest improvement	Modest improvement	Modest improvement	considerable improvement	considerable improvement	Substantial worsening	Substantial worsening	Modest worsening	Slight worsening
Water availability(less than 500 m3/person/yr)	Modest improvement	Slight improvement	Modest improvement	Modest improvement	Modest improvement	Modest improvement	Substantial worsening	Substantial worsening	Slight worsening	Slight improvement
Water availability(more than500 m3/person/yr)	Slight improvement	Slight improvement	Modest improvement	Slight improvement	Modest improvement	Slight improvement	Substantial worsening	Substantial worsening	Modest improvement	Negligible impact

Notes 1. BAU represents the outcome over the period of 2015-2050, while ESC, WSC , FSC and NSC scenarios represents the outcome of 2050, in comparison with BAU (2030 and 2050)
2. Energy,-water-food trade-off shown in this table are also presented in Appendix B

b) Various scenarios as compared to the BAU scenario-2030

Country grouping	Economic Outcomes (GDP)				Social outcomes (Jobs)			
	ESC	WSC	FSC	NSC	ESC	WSC	FSC	NSC
High-income	Slight improvement	Slight improvement	Slight improvement	Modest improvement	Slight worsening	Slight worsening	Modest worsening	Modest improvement
Upper/Low middle-income	Slight improvement	Slight improvement	Slight improvement	Slight improvement	Modest worsening	Modest worsening	Slight worsening	Negligible impact
Energy-rich	Slight improvement	Slight improvement	Slight improvement	Modest improvement	Slight worsening	Slight worsening	Negligible impact	Modest improvement
Energy-Poor	Slight improvement	Negligible impact	Negligible impact	Slight improvement	Modest worsening	Modest worsening	Slight worsening	Slight worsening
Water availability(less than 500 m3/person/yr)	Modest improvement	Slight improvement	Slight improvement	Slight improvement	Modest worsening	Modest worsening	Slight worsening	Negligible impact
Water availability(more than500 m3/person/yr)	Slight improvement	Slight improvement	Slight improvement	Modest improvement	Slight worsening	Slight worsening	Modest worsening	Modest improvement

Country grouping	Energy Security				water Security				Food Security			
	ESC	WSC	FSC	NSC	ESC	WSC	FSC	NSC	ESC	WSC	FSC	NSC
High-income	Significant improvement	Modest improvement	Modest improvement	Modest improvement	considerable improvement	Significant improvement	considerable improvement	Modest improvement	Negligible impact	Negligible impact	Negligible impact	Modest worsening
Upper/Low middle-income	considerable improvement	considerable improvement	Slight improvement	considerable improvement	considerable improvement	Significant improvement	considerable improvement	Modest improvement	considerable improvement	considerable improvement	considerable improvement	Negligible impact
Energy-rich	considerable improvement	Modest improvement	Modest improvement	Modest improvement	considerable improvement	Significant improvement	considerable improvement	Modest improvement	Slight improvement	Negligible impact	Slight improvement	Negligible impact
Energy-Poor	considerable improvement	considerable improvement	Modest improvement	considerable improvement	considerable improvement	Significant improvement	considerable improvement	Modest improvement	Modest improvement	Modest improvement	Modest improvement	Modest improvement
Water availability(less than 500 m3/person/yr)	Modest improvement	Modest improvement	Negligible impact	Slight improvement	Significant improvement	Significant improvement	considerable improvement	Modest improvement	considerable improvement	considerable improvement	considerable improvement	Slight worsening
Water availability(more than500 m3/person/yr)	Significant improvement	Modest improvement	Modest improvement	considerable improvement	considerable improvement	Significant improvement	considerable improvement	Negligible impact	Slight improvement	Negligible impact	Negligible impact	Modest improvement

c) Various scenarios as compared to the BAU scenario-2050

Country grouping	Economic Outcomes (GDP)				Social outcomes (Jobs)			
	ESC	WSC	FSC	NSC	ESC	WSC	FSC	NSC
High-income	Slight improvement	Slight worsening	Slight worsening	considerable improvement	Modest worsening	Modest worsening	Modest worsening	Modest improvement
Upper/Low middle-income	Modest improvement	Negligible impact	Negligible impact	Significant improvement	Considrable worsening	Considrable worsening	Slight worsening	Slight worsening
Energy-rich	Slight improvement	Slight worsening	Slight worsening	considerable improvement	Modest worsening	Modest worsening	Slight worsening	Modest improvement
Energy-Poor	Slight improvement	Slight worsening	Slight worsening	Significant improvement	Considrable worsening	Considrable worsening	Slight worsening	Slight worsening
Water availability(less than 500 m3/person/yr)	Modest improvement	Negligible impact	Negligible impact	Significant improvement	Considrable worsening	Considrable worsening	Slight worsening	Slight worsening
Water availability(more than500 m3/person/yr)	Slight improvement	Slight worsening	Slight worsening	considerable improvement	Modest worsening	Modest worsening	Modest worsening	considerable improvement

Country grouping	Energy Security				water Security				Food Security			
	ESC	WSC	FSC	NSC	ESC	WSC	FSC	NSC	ESC	WSC	FSC	NSC
High-income	Substantial improvement	Significant improvement	Significant improvement	Substantial improvement	Modest improvement	considerable improvement	Slight improvement	Substantial improvement	Modest improvement	Modest improvement	considerable improvement	considerable improvement
Upper/Low middle-income	Significant improvement	considerable improvement	Negligible impact	Substantial improvement	considerable improvement	Significant improvement	Modest improvement	Substantial improvement	considerable improvement	considerable improvement	Significant improvement	Significant improvement
Energy-rich	Significant improvement	Significant improvement	considerable improvement	Substantial improvement	Modest improvement	Significant improvement	Slight improvement	Substantial improvement	considerable improvement	considerable improvement	considerable improvement	considerable improvement
Energy-Poor	Significant improvement	considerable improvement	Modest improvement	Significant improvement	Modest improvement	Significant improvement	Slight worsening	Substantial improvement	Modest improvement	Modest improvement	considerable improvement	Significant improvement
Water availability(less than 500 m3/person/yr)	Modest improvement	Modest improvement	Modest worsening	Significant improvement	considerable improvement	Significant improvement	Slight improvement	Substantial improvement	considerable improvement	considerable improvement	Significant improvement	Significant improvement
Water availability(more than500 m3/person/yr)	Substantial improvement	Significant improvement	considerable improvement	Substantial improvement	Modest improvement	considerable improvement	Slight improvement	Substantial improvement	Slight improvement	Slight improvement	Slight improvement	considerable improvement

Table 8.9: Change in economic, social and EWF securities trade-offs, by country

a) BAU scenarios (2030 and 2050) as compared to 2015

	Changes in BAU scenario in 2030 and 2050 as compared to 215												
Country	Economic Outcomes (GDP)		Social outcomes (Jobs)		Energy Security		water Security		Food Security		Characteristics		
	2030	2050	2030	2050	2030	2050	2030	2050	2030	2050	I	E	W
Israel											H	P	SC
Kuwait											H	R	SC
Oman											H	R	SC
Qatar											H	R	SC
Saudi Arabia											H	R	SC
UAE											H	R	SC
Iran											UM	R	ST
Egypt											LM	M	SC
Morocco											LM	P	SC
Tunisia											LM	P	SC

Notes
1. BAU represents the outcome over the period of 2015-2030 and 2015-2050.
2. ESC, WSC , FSC and NSC scenarios represents the outcome of 2030 and 2050, in comparison with BAU (2030 and 2050)
3. I denotes as income groups (HI: High-income, UM: upper middle-income and LM: lower middle-Income), E denotes as energy resources (P:poor, M: Moderate and R: rich) and W denotes water availability (SC: Scarce and ST: stress)

Legend

Substantial worsening	x ≤ -20%
Significant worsening	-20 % < x ≤ -10%
Considerable worsenir	-10 % < x ≤ -5%
Modest worsening	-5 % < x ≤ -2%
Slight worsening	-2 % < x ≤ -0.5%
Negligible impact	-0.5 % < x < 0.5%
Slight improvement	0.5 %≤ x < 2%
Modest improvement	2 %≤ x < 5%
considerable improver	5 % ≤ x < 10%
Significant improveme	10 % ≤ x < 20%
Substantial improveme	x ≥ 20%

b) Various scenarios as compared to the BAU scenario-2030

Country	Economic Outcomes (GDP)				Social outcomes (Jobs)				Energy Security				water Security				Food Security			
	ESC	WSC	FSC	NSC	ESC	WSC	FSC	NSC	ESC	WSC	FSC	NSC	ESC	WSC	FSC	NSC	ESC	WSC	FSC	NSC
Israel																				
Kuwait																				
Oman																				
Qatar																				
Saudi Arabia																				
UAE																				
Iran																				
Egypt																				
Morocco																				
Tunisia																				

c) Various scenarios as compared to the BAU scenario-2050

Country	Economic Outcomes (GDP)				Social outcomes (Jobs)				Energy Security				water Security				Food Security			
	ESC	WSC	FSC	NSC	ESC	WSC	FSC	NSC	ESC	WSC	FSC	NSC	ESC	WSC	FSC	NSC	ESC	WSC	FSC	NSC
Israel																				
Kuwait																				
Oman																				
Qatar																				
Saudi Arabia																				
UAE																				
Iran																				
Egypt																				
Morocco																				
Tunisia																				

8.3 Economic, social and security trade-offs

In this section, the focus is on the economic, social and EWF security trade-offs across the different country groups in this research (Section 8.3.1), as well as across individual countries (Section 8.3.2). The countries in the region are divided into three various groups based on level of income, energy resources and the availability of water (see Chapter 3, Table 2).

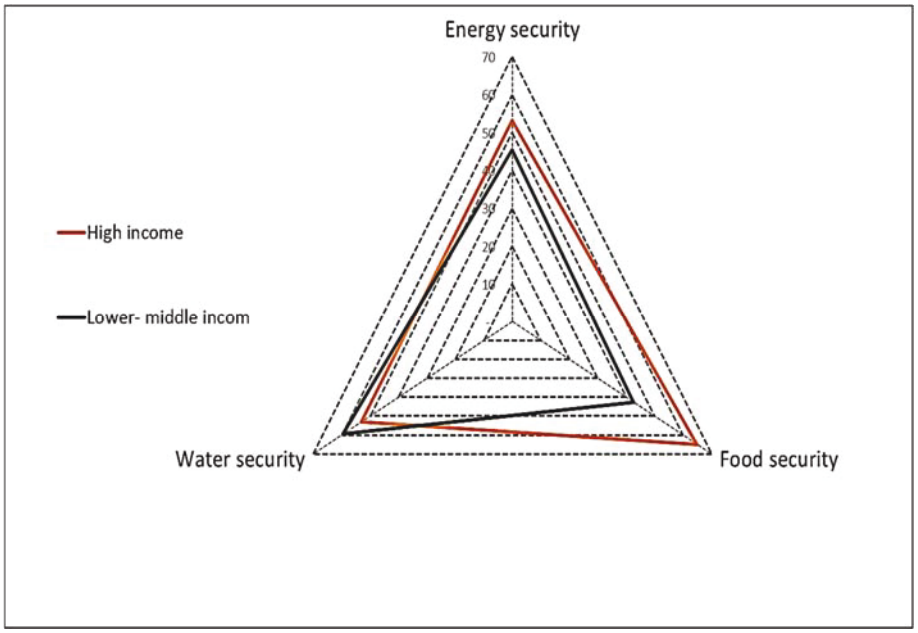
8.3.1 Trade-offs for the country grouping

Tables 8.8 (consists of three parts: a, b and c) shows the major trade-offs among the different country groupings, which are discussed as follows:

Low/middle versus high-income countries

- The high-income countries were more secure in energy and food in 2015 compared with the low/middle-income countries in this research. However, the low/middle-income countries are more water secure than the high-income countries (Figure 8.16a).

Table 8.16a: Composite EWF security in 2015, by country groupings



Source: See Appendix B, Section E, Tables E7 to E9

- By 2050 in the BAU scenario, the high-income countries would face a decrease in their EWF security indices and an increase in their EWF security risks (Table 8.8a). In contrast, the low/middle-income countries are likely to expect modest improvement in their energy security. The improvement in energy security for the low/middle-income countries could be due to regional integration. A shift in the regional trade pattern could improve, for example, the security of energy in low/middle-income countries while impacting

positively on the economy and employment in the high-income countries. In the short term, while both of the income groups would expect improvement in their energy security, a substantial decline would expect for water security for both income groups.

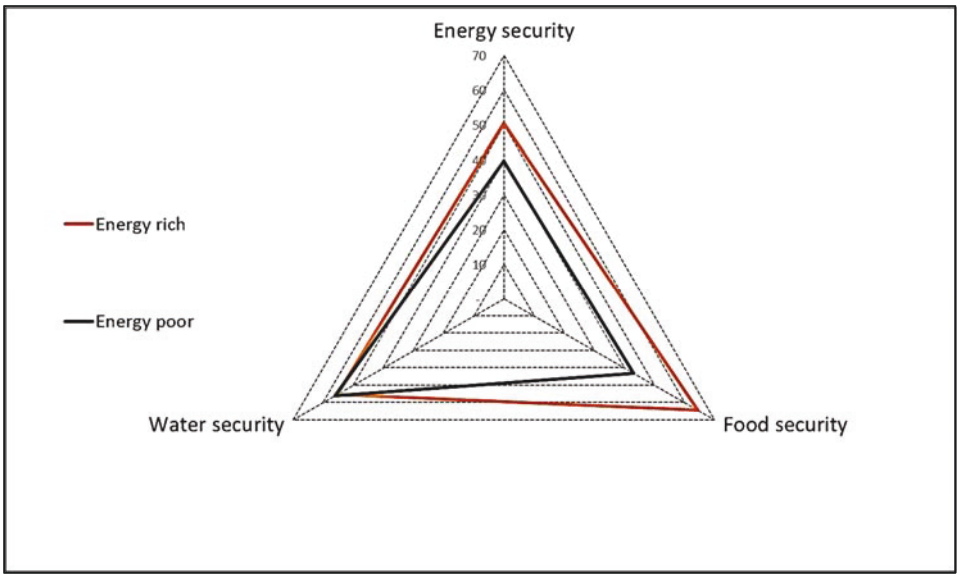
- High-income countries would face a better energy, water and food situation in the ESC, WSC and FSC scenarios than in the BAU scenario in both short term and long term. However, the improvement in energy security will be more than in water and food security. The EWF security improvement in the ESC, WSC and FSC scenarios will, however, involve sacrifices in job opportunities. In the NSC scenario, the economic and employment (only for high-income countries) outcomes would improve in the short term and long term, but the EWF security is likely to experience the most significant results compared with the other scenarios. This would be due to the introduction of efficient technologies and better agricultural practices while taking into consideration the EWF nexus (see Table 8.8 b and c).

- Low/middle-income countries would achieve better energy, water and food outcomes in the ESC, WSC, FSC and NSC scenarios compared with the BAU scenario (Table 8.8 b and c). However, the EWF securities improvement in the ESC, WSC and FSC scenarios would be accompanied by a loss in jobs, while the economic and employment conditions in the NSC scenario would show greater benefits. Such improvements would impact job opportunities less than in the ESC, WSC and FSC scenarios in both short term and long term.

Energy-rich versus energy-poor countries

- Countries with an abundant source of energy (fossil fuels) were generally more secure in energy and food in 2015 than the energy-poor countries in this research. However, both the energy-rich and energy-poor countries would have similar circumstances in terms of water security in 2015 (Figure 8.16b).

Table 8.16b: Composite EWF security in 2015, by country groupings



Source: See Appendix B, Section E, Tables E7 to E9

- By 2050, the energy-rich nations in this research will be in a worse situation in terms of their EWF security compared to 2015, while the energy security for the energy-poor countries would have improved slightly (see Table 8.8c). The economy and employment in both groups would have improved by 2050. Regional trade integration between the energy-rich (mostly high-income) and the poor (mostly low/middle-income) countries could improve the energy security in the low/middle-income countries while impacting positively on the economic and employment status of the high-income countries by 2050.

- Due to the implementation of large-scale, energy-efficient technologies (as in the ESC scenario) and considering seawater desalination (as in the WSC scenario), energy and water security would improve for the energy-rich countries compared with the BAU scenario. The security benefits of the energy-rich counties could be transferred to the energy-poor nations in terms of enhancing the security of food, as more fertilisers are available. The security improvement in these scenarios, however, will come at the expense of both groups losing jobs in all the scenarios in both short term and long term. The economic outcomes of both groups will deteriorate slightly in the WSC and FSC scenarios in the long term (Table 8.8 b and c).

- In the NSC scenario, the EWF security would increase compared with the BAU scenario for both groups in this research. In addition, the NSC scenario would deliver greater EWF security benefits for both groups compared with the ESC, WSC and FSC scenarios. However, energy-poor countries would achieve better water security in the WSC scenario

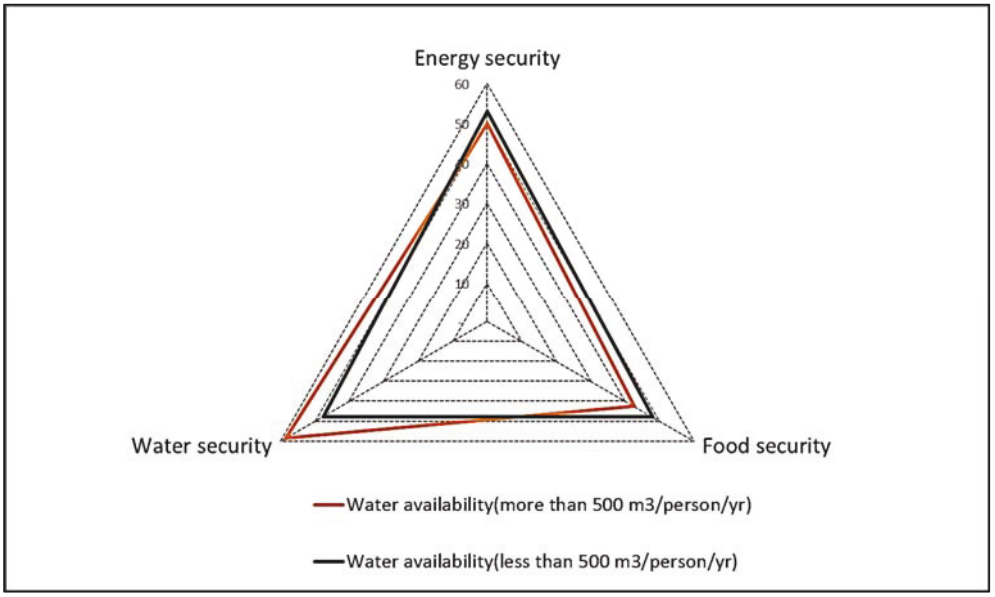
in the long term. However, in the short term, both groups would achieve better results in their EWF security in the ESC, WSC and FSC scenarios as compared to the NSC scenarios. In terms of socio-economic outcomes, the NSC scenario is likely to improve the economics and job opportunities of both groups of countries as compared with the ESC, WSC and FSC scenarios in both short term and long term.

Water-rich vs water-poor countries[27]

- Water-rich countries are generally more water secure than the water-poor countries. As the majority of the countries in the water-poor group are high-income with energy-rich resources, they are slightly more secure in terms of energy and food than the water-rich nations (see Figure 8.16c).

- Improvements in soco-economic conditions in both groups in the BAU scenario would have substantial negative impact on their water security and modestly improve the energy security of the water-rich counties in both short term and long term. In terms of food security,while water-rich countries are likely to experience slight improvement from short term to long term, water-poor countries would expect the reverse situation in this scenario.

Table 8.16c: Composite EWF security in 2015, by country groupings



Source: See Appendix B, Section E, Tables E7 to E9

[27] Water-rich countries in this research means those with water availability of 500m^3/person/year. The water-poor countries are those with less than 500m^3/person/year.

- In the ESC, WSC, FSC and NSC scenarios, water security would be enhanced in both groups compared with the BAU scenario. Energy security would also improve for both groups in the ESC, WSC and NSC scenarios , however, FSC scenario would slightly reduce the level of energy security in water-rich countries both in short term ang long term (as compared to the BAU scenario). Food security would also improve for both groups while the impact of the NSC scenario would make conditions worse in the water-rich countries in the short term. These EWF security outcomes would be accompanied by contrasting the economic and employment situations. For example, in the water-rich countries, there will be negligible economic impact in the WSC and FSC scenarios while employment will be negatively impacted in the long term. In the water-poor countries, the economic situation would be slightly worse than in the BAU scenario and job opportunities will mostly deteriorate in the WSC and FSC scenarios. In the NSC scenario, however, the economic outcome will improve appreciably while the social outcome is likely to improve only for the water-poor countries (see Table 8.8c).

8.3.2 Trade-offs for the individual countries

The major trade-offs for the individual countries are presented in Table 8.9 (consists of three parts: a, b and c) and are explained as follows.

BAU Scenario

- The majority of the countries in this research could expect significant development in terms of economic and social developments over the research period. However, such developments would be accompanied by worsening water conditions both in short term and long term. For example, the impacts of BAU scenario will substantial diminish the water security of the water-rich countries in this research, namely Iran, an upper/middle-income country, and Egypt and Morocco, which are low/middle-income countries. The impacts would be worse for the high-income countries of Israel, Oman Qatar, Saudi Arabia and the UAE and low/middle-income Tunisia, which are water-poor countries.

- Energy and food security, however, will vary across the countries. For example, both in short term and long term, Kuwait Oman and Qatar (energy-rich countries) are likely to face improvement in their energy security while Saudi Arabia, the UAE and Iran (also energy-rich countries) would be less energy secure. In contrast, Egypt, Morocco, Tunisia and Israel (energy-poor countries) could expect improvements in their energy security. When it comes to food security, Qatar, Saudi Arabia and Morocco could expect slight

improvement while Israel, Oman, the UAE, Iran, Egypt and Tunisia are likely to experience greater risk. Kuwait is the only country whose food security would decline slightly in the short term but improve modestly in the long term.

- Further, developments in the economic and social aspects of the countries will not necessarily improve the level of EWF security uniformly across the Middle East and North Africa regions. For example, while the socio-economic development in Egypt, Morocco and Tunisia (low/middle-income countries) would improve the energy security of these countries, energy security will be negatively impacted in some of the energy rich countries such as Saudi Arabia, Iran and the UAE.

- In addition to the contrasts between individual countries in the different country groupings (as discussed in Section 8.3.1) in this research, countries in the same country groupings would have significant difference in their EWF securities in this scenario. For example, Kuwait's socio-economic conditions will improve and will be accompanied by increasing EWF security, while the UAE, in the same country grouping (high-income, energy-rich and water-poor), will face increased EWF security risk by 2050.

- Similarly, while the socio-economic developments in Egypt (low/middle-income, energy-poor and water-rich) would show a decline in its water and food securities, Tunisia, in the same condition, would also expect a deterioration in both its water and food securities. While both of the countries are likely to experience a decline in their food security (as compared to 2015), the magnitude of deterioration will be different: Egypt could expect a significant worsening (between 10% and 20%) while Tunisia could expect modest deterioration (between 2% and 5%).

ESC, WSC and FSC Scenarios

- Overall, the region could expect different achievements in socio-economic conditions in the ESC, WSC and FSC scenarios. While the countries could experience slight economic improvement in the ESC scenario, the WSC and FSC scenarios would impact their economics negatively. The outcomes would be accompanied by mostly worse social conditions while negative impact on employment would be slightly less in the FSC scenario compared with the ESC and WSC scenarios across the countries compared with the BAU scenario. However, the results are not uniform across the countries.

- In the ESC scenario, for example, Morocco and Egypt, both low/middle-income countries, are energy-poor and water-rich. In this scenario compared with the BAU, scenario, Egypt would expect negligible economic improvement, significant worsening in its employment and significant improvement in its EWF security by 2050. On the other hand, Morocco is likely to experience moderate economic improvement, moderately worse employment, moderate decline in energy security, significant improvement in water security and moderate enhancement in food security by 2050.

- Similarly, in the WSC scenario, Kuwait, Qatar, Oman and the UAE (all high-income countries, energy-rich and water-poor), will see their EWF security improve in the long term. However, the economic outcome will deteriorate slightly in Kuwait, Oman and Qatar and negligible decline in the UAE. In terms of employment conditions, Kuwait will experience moderate worsening in their employment while Oman, Qatar and the UAE would expect negligible changes.

- In the short term, in the WSC scenario, the economic outcomes for Kuwait, Qatar, Saudi Arabia and the UAE would improve slightly which would be accompanied by worsening employment conditions for Kuwait and Saudi Arabia and negligible changes for Qatar and the UAE. During this period (2015-2030), the overall, EWF security would improve while some exceptions would be observed. For example, the energy security for Kuwait would deteriorate slightly and Saudi Arabia would experience the moderate decline in its food security.

- Employment is likely to be the challenging issue for the ESC, WSC and FSC scenarios for the majority of the countries in this research. Israel is the only country likely to experience a slight improvement in its socio (employment) condition compared to the BAU scenario in all three scenarios in the long term. Its economic condition, however, will not be uniform across the scenarios: Israel will experience a slight decline in the WSC and FSC scenarios but an improvement in the ESC scenario in the long term. In contrast, in the high-income, energy-rich and water-poor countries, job opportunities will drop for Kuwait, Saudi Arabia and the UAE in ESC, WSC and FSC scenarios. Of these, Kuwait and the UAE are likely to experience improvement in their EWF security in all three scenarios in the long term.

- By 2030, Oman would be the only country, which the improvement in socio-economic conditions would be accompanied by considerable improvement in EWF security in all

three scenarios (ESC, WSC and FSC). Iran and the UAE would experience similar conditions as Oman only in ESC and WSC scenarios.

NSC Scenario

- Overall, in the NSC scenario, the countries would expect considerable improvement in economic, EWF security with moderate increases in job opportunities compared with the BAU scenario by 2050. However, the magnitude of improvement is varied across the countries.

- In this scenario, all the countries except Qatar would experience considerable improvement in their economic outcomes compared with the BAU scenario in the long term. However, in the short term the slight change in the economic conditions is expected for most of the countries except Oman, Saudi Arabia, the UAE and Tunisia.

- In terms of employment, while the condition would improve in the short term, countries would expect faster growth in their job opportunities in the long term as the result of NSC scenario. The only exception would be Morocco (in the short term) and Egypt (both short term and long term), which the countries would face a deterioration in their employment rate in this scenario.

- Although the NSC scenario suggests improvements in the socio-economic condition for majority of the countries, EWF security outcomes will not be uniform in the short term and long term. For instance, in the short term, the majority of the countries in this research would expect improvement in their EWF security, however, few are likely to experience deterioration. For example, Kuwait is likely to experience considerable decline in its energy security while the rest of the countries are likely to expect considerable improvement compared with the BAU scenario. Another example is Iran, which could expect considerable decline in its food security in the NSC scenario in the short term.

- In the long term, all countries would expect improvement in EWF security in this scenario, while improvements will not be uniform. For example, Oman and Saudi Arabia are high-income, energy-rich and water-poor countries. In this scenario, Oman would expect significant improvement in its water security while Saudi Arabia will experience slight enhancement in its water security compared with the BAU scenario. In both low/middle-income countries, Tunisia would expect substantial improvement in its energy security while the improvement for Morocco would be considerable.

- In comparison with the other scenarios, the NSC scenario would present better outcomes in terms of EWF security by 2050. For example, while the energy security for Qatar and Iran (both rich countries) would be expected to improve considerable in the ESC scenario, it is likely the countries will experience significant improvement in the NSC scenario in the long term. The same trend would be observed in water and food security. For example, in the FSC scenario, Qatar and Israel (high-income countries but water-poor) would face a decline in their food security, but in the NSC scenario, both countries are likely to show modest improvement in their food security in both the short term and the long term.

- Unlike in the other scenarios, in the NSC scenario, the socio-economic and EWF security levels reinforce each other. For example, while improvements in EWF security in Kuwait, Qatar, the UAE, Iran and Egypt would cause a decline in economic and job opportunities in the WSC scenario in the long term, they would have positive impacts on GDP and job levels in the NSC scenario.

8.4 Some further discussion: policy trade-offs

The discussion in the previous section of this chapter (and the discussion in Chapters 6 and 7) shows the nature of policy trade-offs that policymakers in the countries in this research might like to consider while developing sectoral (energy, water and food) and economic and social policies. The following examples show the strength of this claim:

- The ESC, WSC and FSC scenarios indicate worsening employment in both the short and long terms for the majority of the countries in this research. There are few exceptions: for example, in the Middle East region, only the UAE (in the ESC scenario), and Iran and Qatar (in the FSC scenario) could expect better employment conditions compared to the BAU scenario by 2030. In addition to Iran and Qatar (in the FSC scenario), Israel is likely to have higher rates of employment in the long term in all the three scenarios (ESC, WSC and FSC). As the countries in this research are likely to grow fast in the coming years, employment will be one of the main challenges for the whole region (see Chapter 3, Section 3.2.4.3) and job creation will become a very important policy priority for all the countries in this research. In this situation, some countries would accept to sacrifice improvements in EWF securities in favour of policies that create new job opportunities for the young. Iranian policymakers, for example, may prefer the FSC scenario (because it has the fewest job losses of all the scenarios in both the short and long term), even though this may impact the economic and energy security negatively (see Table 8.9).

- The GCC countries and North African countries in this research could face a reduction in their job opportunities in the ESC, WSC and FSC scenarios. In this case, these countries may need to implement strong technological interventions to address the EWF security challenge while at the same time improving job opportunities. Morocco, for example, is likely to experience modest job losses in the ESC and WSC scenarios and a slight decrease in the FSC scenario in the long term. The country could apply the NSC scenario, which could include strong policy interventions such as accelerating electrification, greater investment in energy efficient electricity generation technologies, higher investment in seawater desalination and higher levels of agriculture productivity by applying additional fertilisers. This would not only improve EWF security but also increase job opportunities (see Chapter 6, Table 6.4) and boost GDP (see Chapter 6, Table 6.1).

- The four pathways (ESC, WSC, FSC and NSC) developed in this research provide policymakers with the basis for considering specific policy trade-offs. For example, Saudi Arabia could achieve the highest level of water security in the WSC scenario both in the short term and long term, but at the expense of GDP and job opportunities (see Table 8.9). In the NSC scenario, however, the GDP and job opportunities are likely to improve, but at the expense of its water security. This could suggest to Saudi Arabia's policymakers a choice of pathway, for example, improved GDP and higher job opportunities, or enhanced water security. If it is the former (i.e., improved GDP and higher job opportunities), they should follow policies that underpin the NSC scenario. However, if they have a preference for improved water security, they should follow the WSC scenario.

- In addition, different countries may adopt different policies to achieve the same objectives. For example, Kuwait and Oman are similar in that they are both high-income, energy-rich and water-poor countries in the GCC region. In the FSC scenario (compared with the BAU scenario), both countries are likely to observe relatively similar socio-economic and EWF security results (see Tables 8.6 and 8.9) in both the short and long term. However, improved energy security in each country would come from different sources (see Chapter 6). Kuwait's energy security, for example, would improve mainly due to its improved energy efficiency and the increased diversity of its energy base. Oman's energy security, however, will improve due to its reduced import dependency and improved energy affordability.

8.5 Summary and conclusion

In summary, the aim of this chapter was to investigate socio-economic and EWF security trade-offs. The outcomes presented in this chapter are as follows:

EWF security trade-offs

- EWF security will deteriorate in the BAU scenario over the research period. Water security is likely to worsen in all the countries in this research, followed by food and energy security concerns. While water security would deteriorate in all countries, the food and energy security situation would differ from country to country. For example, the energy-poor countries could expect an improvement in their energy security both in the short term and the long term but the energy security in some of the energy-rich countries would worsen in the long term.

- The overall EWF security would improve in comparison with the BAU scenario in the selected countries in this research by applying any of the ESC, WSC, FSC and NSC scenarios. However, the relative improvements would vary across the countries and vary over the short or long term. For example, in the ESC and WSC scenarios, while food security is improving compared with the BAU scenario by 2050, the level of food security will be lower in the ESC scenario or slightly more in the WSC scenario than the level of food security in 2015. This suggests that food security should become a priority for policymakers in these scenarios. Further, in the ESC, WSC, FSC and NSC scenarios, while water security may improve compared to the BAU scenario, it would still be lower than the water security in 2015 over the short or long term. This emphasises further that water security is the main challenge and policies should be developed to reduce the severity of the water security challenge in all the countries in this research.

Socio-economic and EWF security trade-offs

- In general, the high-income, energy-rich and water-poor countries in this research were in 2015 more secure in terms of energy and food compared with the countries in different groupings. In response to the socio-economic development in the BAU scenario, the EWF security risks are likely to increase in all the countries by 2050.

- Overall, the region could expect different results in the ESC, WSC and FSC scenarios. While all the countries could experience a slight economic improvement in the ESC scenario, GDP will be moderately worse in the WSC and FSC scenarios compared to the BAU scenario) by 2050. Employment opportunities will deteriorate in the ESC, WSC

and FSC scenarios for the majority of the countries in this research, while EWF security outcomes will improve considerably both in the short term and the long term. However, the results within the same scenario are not uniform across the countries. For example, in ESC scenario, Tunisia is likely to experience improved EWF security but adverse economic and employment outcomes. In the same income group, Egypt will also experience improved EWF security, adverse employment but negligible improvement in economic outcomes by 2050.

- Similarly, in the WSC scenario, for example, Qatar and Oman could experience improvement in its EWF security both in the short term and in the long term. However, in Oman, the improvement would be at the expense of a decline in economic condition while in Qatar, both GDP and the number of jobs will deteriorate in the long term.

- In the NSC scenario, the socio-economic and EWF security outcomes appear to reinforce each other; the improvement in EWF security is accompanied by improvements in the socio-economic condition of most of the countries in this research. Egypt is the only exception: it is likely to enjoy an increase in GDP and EWF security but a lower employment rate compared to the BAU scenario both in the short term and in the long term.

Policy trade-offs: concluding comments

The analyses in this research present the nature of trade-offs that policymakers might like to consider while developing sectoral (energy, water and food) and economic and social policies for the countries in this research. The following examples show the strength of this claim:

- In the ESC, WSC and FSC scenarios, the outcomes present worse employment levels in both the short and long term for most of the countries in this research. There are few exceptions in terms of impacts on employment: for example, Iran and Qatar only in the FSC scenario and Israel in the ESC, WSC and FSC scenarios in the long term. As the countries in this research are likely to grow fast in the coming years, employment will be one of the main challenges for the whole region and thus job creation will become a very important policy priority for all the countries in this research. Some countries would accept to sacrifice improvements in EWF securities in favour of policies that would create new job opportunities for the young. Iranian policymakers, for example, may prefer the FSC scenario, which could impact its economic (in the long term) and energy security (both in the short term and in the long term) negatively.

- Other countries, such as the GCC countries and North African countries in this research, could face a reduction in their job opportunities in the ESC, WSC and FSC scenarios. In this case, these countries may need to implement strong technological interventions to address their EWF security challenge while at the same time improving job opportunities.

- The four pathways (ESC, WSC, FSC and NSC) developed in this research provide policymakers with the basis for considering specific policy trade-offs. The discussion in chapter 8 suggests that there is no distinctive pathway, which could overcome all the challenges in this region. However, the selection of the appropriate scenario depends on the matter of context and priorities of the policymakers in each country. It is essential that the policymakers of the MENA region consider the trade-offs across various scenarios and deeply understand the positive and negative aspects of the selected scenario in the short term and the long term for their future developments.

- It is also recommended that the selected countries in this research require to adopt the new socio-economic development strategic policies that would taking into account the underlying EWF nexus. Such strategic policies will assist to reduce (or in some cases even avoid) the adverse consequences on the scarce resources (energy, water and land) as the results of the continuity of the current socio-economic trends as observed in the BAU scenario in the short and long term.

Chapter 9: Conclusion and recommendations for further research

EWF resources are highly inter-linked at various levels and scales of an economy. Major concerns have emerged about the interconnectedness of EWF security (i.e. the ***energy-water-food nexus***) and its geopolitical consequences in the MENA region. This research aimed to develop a multidimensional framework on the EWF nexus, using IO general equilibrium models in the context of MENA countries. It developed a multidimensional framework that could help to enhance the capacity of the MENA nations' policymakers and planners to address such a vital security challenge.

Further, using its unique set of context-oriented IO general equilibrium models, this research presented a robust scenario analysis across a selection of 10 MENA member countries, including seven countries from Middle East (Qatar, Kuwait, Iran, Israel, Oman, Saudi Arabia and the UAE) and three North Africa (i.e. Egypt, Morocco and Tunisia). Five scenarios were carefully designed for this purpose to demonstrate alternative economic and technological developmental pathways. The scenario impacts were assessed based on some key attributes or dimensions of each individual economy, including ***economic*** (GDP, trade balance and infrastructure investment), ***social*** (employment), ***energy security*** (energy intensity, energy conversion efficiency, energy diversity, energy-import dependency and energy affordability), ***water security*** (water availability, water stress and water intensity) and ***food security*** (food accessibility, food-import dependency and food affordability).

Against the background above, this chapter has two sections. Section 9.1 presents the salient conclusions of this research on the basis of the findings and policy implications described in the previous chapters. Section 9.2 aims to provide key recommendations for future research on the EWF nexus.

9.1 Conclusions

The conclusions below are based on the outcomes of the scenario analysis and policy recommendations in Chapters 6, 7 and 8. The results of the implemented scenarios provider the integration of energy, water and food policies in the selected countries in this research.

Economic Outcomes

Gross Domestic Product (GDP)

- If current trends continue (**BAU scenario**), the size of the economy in the selected countries would increase by an average 1.8-fold in the BAU scenario by 2050. This is equivalent to an average annual growth of 1.7%. The per-capita income of the selected countries over this period will increase by 0.7% annually. While this increase in overall and per-capita GDP will be consistent across the countries, the most notable beneficiaries include the low/middle-income countries of Egypt, Morocco and Tunisia, the GDP of which will more than double. Further, the same countries could also expect an improvement of more than 1% per-capita income. Moreover, this pathway could elevate the economic status of Egypt, Morocco and Tunisia from being low/middle-income countries to upper/middle-income countries by mid-century. High-income and upper-income countries would follow the same economic status as 2015 in the BAU scenario by 2050. In the short term, in the BAU scenario, most of the countries could expect moderate increases in their GDP. The highest annual GDP growth is expected for lower-income countries over the period of 2015-2030.

- While the GDP in the **ESC, WSC and FSC scenarios** would be nearly the same as in the case of the BAU scenario, the impact across the countries would be slightly different. The GDP of Tunisia, a low/middle-income country, is likely to worsen in the ESC, WSC and FSC scenarios. In ESC some countries (except Kuwait and Tunisia) expect a slight improvement in their GDP by 2050. However, the GDP of the countries in the WSC scenario (except Morocco) and FSC (except Egypt and Morocco) scenarios would be worse. In the short term, most of the countries can expect only a moderate increase in their GDP in ESC, WSC and FSC scenario. In the ESC scenario, Iran, Kuwait and Oman would expect the highest rate of growth compared with the BAU scenario. The WSC scenario will give Oman a significant boost to its GDP and in the FSC scenario, Iran, Qatar and Oman could expect a slight improvement in their GDP.

- In the **NSC scenario**, **the average GDP of the al**l the countries is likely to be 9.4% higher (an increase of US$451 billion) than in the BAU scenario. Further, the GDPs are expected to be higher for all countries. Significant (more than 10%) economic gains are likely to be experienced by Egypt, Oman, Saudi Arabia, Tunisia and the UAE, while Iran, Israel, and Kuwait in the Middle East and Morocco in North Africa are expected to experience considerable (5% to 10%) economic gains. In the short term (2015-2030), the average GDP for all the countries could expect a modest economic gain in the scenarios.

Social Outcomes

- In the **BAU scenario**, an almost two-fold increase in GDP over the period 2015-2050 will create 179 million new jobs, with the number of employed increasing from 89 million in 2015 to 179 million in 2050 to 128 million in 2030 and 178 million in 2050. This is equivalent to an average growth in employment of 0.9% per year in the short term and 0.8% per year in the long term. Around 40% of these new jobs are expected to be created in the commercial and services sectors, as these sectors will continue to be major sectors of the economy in the countries in this research by 2050. The remaining new jobs are expected to be created in the water (1%), transport (7%), energy (11%), industry (15%) and agriculture (28%) sectors. Approximately two-fifths of new jobs in the region will be created in Egypt alone, which would be the third largest economy and most populous country in the region by 2050. Oman, Tunisia and Saudi Arabia would also experience significant increases in employment as a result of strong growth in industrial production.

- The employment impact in the **ESC, WSC and FSC scenarios** will be significant, and mostly negative. In the ESC scenario, total employment among all the countries in 2050 is expected to be 3% (11.6 million) lower in the ESC scenario, 2.4% (9.3 million) lower in the WSC scenario and 1% (2.6 million) lower in the FSC compared to the BAU scenario. The number of additional jobs in the industrial and energy sectors will not be sufficient to compensate for jobs lost in the agriculture sector. In fact, job losses will be experienced by all countries, except Israel, a high-income country, in all three scenarios by 2050.

- By 2030, Iran and Oman would expect an improvement in their job opportunities in the ESC, WSC and FSC scenarios while Egypt, Israel, Kuwait, Morocco, Saudi Arabia and Tunisia would face a decline in their employment levels. The UAE with 1.2% (ESC scenario), Iran with 1.4% (in FSC scenario) higher than the BAU scenario would expect the highest improvement in their employment levels among the countries in this research.

- Unlike in the other scenarios, employment levels in the **NSC scenario** are likely to be 2.4% (828 million jobs) in the short term and by 4.5% (1660 million jobs) in the long term higher than in the BAU scenario. While 6 million jobs are likely to be lost in the agriculture sector, 10 million new jobs will be created in other sectors of the economy. Significant new job opportunities are likely to arise in Oman (10.3%), the UAE (10.4%), Israel (6.7%), Tunisia (5.6%), Kuwait (5.2%) and Qatar (4.6%) and moderate extra opportunities in Iran (2.2%), with about a 1% improvement in Morocco and Saudi Arabia.

In this scenario, Egypt would be the only country to experience a moderate negative impact on employment by 2050.

- In the short term, that is, to 2030, while countries would expect improvement in their employment levels, Egypt and Morocco could face a decline in terms of job creation in the NSC scenario. Countries that would expect a significant positive impact in their employment levels include Tunisia (7.3%), the UAE (4.9%) and Oman (4.7%).

The socio-economic outcomes (as noted above) are likely to impact EWF security for the region in diverse ways. These impacts are discussed below.

Energy Security

To support the region's economy that by 2050 would be nearly twice as large as in 2015, the primary energy requirements in the **BAU scenario** will nearly double, from 1187Mtoe in 2015 to 2102Mtoe in 2050. This will have implications for energy security in the region, as discussed below.

- In 2015, the region was overly dependent on fossil fuels, particularly gas and oil, to meet its energy needs. While most countries will experience reduced reliance on energy imports by 2050, some of the energy exporting countries are likely to experience increased reliance on imported energy. Increased use of relatively expensive commercial energy (electricity, coal, gas and renewable) will result in higher energy prices. Therefore, increasing proportions of consumer incomes are likely to be spent on energy, thus affecting energy affordability.

- Different countries in the region will face different energy security outcomes. For example, energy security in Saudi Arabia and the UAE is likely to be adversely impacted. Both countries will have increased their rate of electrification by 2050 while relying strongly on fossil fuels as the only source of energy. In particular, energy affordability could become a key concern for both these countries, whose residents could be expected to spend greater proportions of their incomes on energy. Further, in the case of Saudi Arabia, the economy would become more energy intense while the choice of energy options available in the country would be limited. This would make Saudi Arabia even less energy diverse. In the case of the UAE, its energy import dependency would increase by 2050, which would result in increased energy prices.

- In 2015, the energy security risk was greatest for Kuwait, energy exporter country. However, this situation could improve in the future as Kuwait improves the energy intensity of its economy, from about 603 toe per US$ in 2015 to 564 toe per US$ in 2050. This would reduce the country's reliance on fossil fuels to support its economic growth.

- Energy security, in fact, could improve for several countries in the region by 2050 as their reliance on energy is reduced and as their energy-mix becomes more diverse. Such improvements are expected to be experienced considerably by all low/middle income countries.

- Iran and Tunisia are likely to be less energy secure by 2030 but this will have improved by 2050. The main reason for this reduction in Iran is that the country would become less energy diverse and the energy affordability for its residents would decline by 2030. In Tunisia, the intensity of the economy would increase slightly, which would rise the reliance of the country on importing energy to meet domestic demand.

- In the **ESC scenario**, energy security for the region is likely to be significantly improved by 2050. While energy affordability would become a matter of concern in Egypt and Morocco in the future, a significant reduction in energy intensity, an increase in energy diversity and reduced reliance on energy imports are likely to contribute to enhanced energy security for the region. All countries except Morocco are likely to experience improved energy security in this scenario. Tunisia, Kuwait, Saudi Arabia, the UAE, for example, are likely to experience a substantial (more than 20%) improvement in energy security. Countries likely to experience significant (more than 10%) improvement are Egypt and Israel. Morocco, in contrast, is likely to face increased energy security risk as it becomes more reliant on gas to meet its energy needs.

- In the **WSC and FSC scenarios,** energy security in the region would reduce compared to the ESC scenario but would be better than in the BAU scenario by 2050. In the WSC scenario, only Saudi Arabia and Tunisia would expect substantial (more than 20%) improvement in their energy security while the rest of the countries, apart from Morocco, would become considerably energy secure. The risk of energy insecurity would increase in the FSC scenario as compared to the ESC and WSC scenarios. Most of the countries except for Morocco and Iran would improve considerably (by less than 10%). Morocco (in the WSC and FSC scenarios) and Iran (in the FSC scenario) would become energy insecure, as both countries would increase the intensity of their economies and be more reliant on imported energy to support their economic growth.

- In the **NSC scenario**, energy security for the region would further improve (as compared to the BAU scenario) by 2050. In addition to the three main factors contributing to improved energy security in the ESC scenario, energy affordability for consumers in the selected countries is also expected to improve, except for Egypt and Kuwait, where energy security in this scenario is likely to be slightly lower than in the ESC scenario.

- In the short term, the overall energy security of the selected countries would improve in the NSC scenario compared to the BAU scenario. However, the positive impact of the NSC scenario in the long term would be much higher than in the ESC scenario for all the selected countries in the MENA region.

Water Security

Economic and population growth in the **BAU scenario** will lead to a more than two-fold increase in water demand in the region, from 187 billion cubic metres (m^3) in 2015, to 392 billion m^3 by 2050. This, combined with reduced water availability in the region, will create a high level of water insecurity. Specific examples are given below.

- The worsening in water security will be felt by all the selected countries in the region. Residents in the countries of research already face limitations in water availability; Egypt, Morocco, Tunisia, Saudi Arabia, the UAE, Israel, Oman, Qatar and Kuwait are currently water scarce countries and Iran is water vulnerable. The water situation in these countries will worsen over the period 2015-2050. In the **BAU scenario**, the water situation in these countries will worsen to the extent that by 2050, Kuwait, Qatar, Oman, Israel, the UAE, Saudi Arabia, Tunisia and Egypt will become more water insecure, with water availability of less than 300 m^3 per person per annum; this means these countries will retain their water scarce status. Morocco, another water scarce country in 2015, would expect better conditions compared with rest of the countries except Iran. However, the water availability for citizens of Morocco would still be less than 1000 m^3 per person per annum, which is defined by the UNEP as a critical level of water scarcity. Iran is the only country that is likely to maintain its status as a water stressed country.

- All countries in the region are likely to experience improved water security by 2050 in the **WSC scenario** compared with the BAU scenario. Four countries, Qatar, Kuwait, Iran, and Egypt, are likely to experience substantial (more than 20%) improvements in water security. The main reasons for such an improvement include a reduction in water intensity and an increase in water supply options, mainly seawater desalination. Oman, Morocco and the UAE are likely to experience significant (more than 10%) improvement in water security. However, no country could avoid facing chronic water shortages in this scenario. Water security will increase in the **ESC and FSC scenarios** in Kuwait, Oman, Qatar, the UAE, Iran, Egypt and Morocco by 2050. In contrast, the water security would drop in both Saudi Arabia and Israel in these scenarios compared to the BAU scenario. The higher levels of water insecurity for both countries would be attributable to a higher water intensive economy, which would increase the demand for water by 2050.

- By 2030, in the ESC, WSC and FSC scenarios, water security for almost all the countries would be at a higher level compared to the BAU scenario. The only exception would be Saudi Arabia, which is likely to experience a higher level of water security risk in the FSC scenario. Although water demand would decrease in both the short term (2015-2030) and the long term (2030-2050) in the ESC, WSC and FSC scenarios, the rate of change in the three scenarios would be faster in the long term (2030-2050). This would lead to greater water security among the countries in the short term (2015- 2030) compared to the long term (2030-2050).
- Lower water intensities and increased use of recycled water through investment in advanced wastewater technologies in the **NSC scenario** are likely to improve water security further as compared to the BAU scenario for all the selected countries in the region by 2050. In addition to Qatar, Kuwait, Iran, and Egypt (as in the WSC scenario), Morocco could expect substantial improvement in their water security. Most of the reduction in water demand (and hence water intensity) in this scenario would be a result of reduced water usage in the agriculture sector as it shifts cropping patterns from water-intensive to less water-intensive.

- In the short term (2015-2030), the NSC scenario would improve the levels of water security for all the countries in this research except Saudi Arabia. However, countries would experience greater water security in the WSC scenario. Water security would be a matter of concern for Saudi Arabia and the UAE in the NSC scenario as compared to WSC scenario by 2030.

Food Security

Food security is likely to become an issue of serious concern for most countries in the region in the **BAU scenario**. Insufficient transport infrastructure by 2050 could considerably limit physical access to food in the countries in this research. Further, the region would become more reliant on food imports. For example:

- Most of the countries in the region apart from Kuwait, Saudi Arabia, Qatar and Morocco will face increased food security risks. Oman and the UAE, high-income countries, are likely to have less access to food and hence will become more dependent on food imports (as compared to 2015). Therefore, larger proportions of export earnings will need to be spent on food imports by 2050. Further, the residents of Oman and the UAE would need to spend a higher proportion of their income on food.

- Israel, another high-income country, could also become moderately food insecure in the future as a result of increasing food-import dependency. Although, food would become

relatively more affordable in Israel by 2050 compared with 2015, its food security risk will as severe as for Oman.

- Egypt, a low/middle-income country, is currently the most food insecure country in the region. This is due mainly to its limited access to food and its reliance on food imports. While Egypt's dependency on food imports would decline by 2050, food affordability would become worse. Hence, food insecurity here is expected to increase in the future.

- Saudi Arabia, Kuwait and Qatar are likely to experience improved food security. Both are high-income countries that rely heavily on food imports to meet their domestic needs. Infrastructure improvements in these countries are expected to appreciably increase food accessibility, thus enhancing food security.

- All countries in this research except Israel are likely to experience improved food security in 2050 in the **ESC and WSC scenarios**, compared with the BAU scenario. Food security for Egypt and Iran is likely to improve significantly compared to the other countries. The food security risk would become a matter of concern for some high-income countries, particularly Israel in the ESC and WSC scenarios and Saudi Arabia in the WSC scenario. For example, while food accessibility in Israel would reduce slightly, households in this country will also need to spend a greater proportion of their incomes on food, hence they would experience higher levels of food insecurity.

- In the **FSC scenario,** most of the countries except Israel and Qatar would expect moderate improvement in their food security. Overall, improved transportation systems and a reduced reliance on food imports are the main reasons for food security improvement in these countries. Of all the selected countries in this research, Egypt, the most food insecure country in 2015, would experience the highest positive impact in its food security. The main reason for this improvement in Egypt would be an increase in food accessibility and a reduction in the proportion of income spent on food. In contrast, Qatar and Israel would expect to be less food secure as residents of the both countries would spend more on food, resulting in an increase in their level of food insecurity by 2050.

- Unlike in the FSC scenario, all the countries selected for this research are likely to experience improved food security in the **NSC scenario** by 2050. Increased investment in transport infrastructure and hence increased food accessibility would contribute to alleviating food security risks, particularly in Egypt. Food security risks in the high-income countries, in particular Kuwait and Oman, are likely to be much lower in this scenario because of increases in food accessibility and improved food affordability. However, by 2030, Kuwait and Iran would have higher levels of food insecurity in the NSC scenario due to an increase

in their dependence on food imports compared to the BAU scenario. In comparison with the FSC and NSC scenarios, overall, food security for all the countries would be slightly higher in the FSC scenario, particularly in Iran, by 2030. The improvement in food accessibility and less dependency on food imports would be the main factors for higher food security for Iran in FSC scenario (as compared to the NAS scenario) by 2030.

- In the ESC, WSC, FSC and NSC scenarios, while there will be overall improvements in EWF securities compared to the BAU scenario, relative improvements across these securities will differ considerably. For example, in the ESC and WSC scenarios, while food security will have improved compared with the BAU scenario by 2050, it will still be lower than the food security in 2015. This suggests that food security should become a policy priority for the regional policymakers in both the ESC and WSC scenarios. Further, in the ESC, WSC, FSC and NSC scenarios, while water security may improve compared to the BAU scenario, it would still be lower than the water security in 2015. This emphasises further that water security is the main challenge and policies should be developed to reduce the severity of the water security challenge in all the countries in this research.

EWF Security Trade-offs

- EWF security will deteriorate in the BAU scenario for all of the countries (except Morocco) over the research period. Water security is likely to worsen in all the countries in this research, followed by food and energy security concerns. While water security would deteriorate in all countries, the food and energy security situation would differ from country to country. For example, the energy-poor countries could expect an improvement in their energy security but the energy security in some of the energy-rich countries would worsen.

- Although on average, region-wide EWF security is likely to improve in the ESC, WSC, FSC and NSC scenarios compared with the BAU scenario, these improvements are unlikely to be uniform across countries. For example, in the FSC scenario, the trade-offs (on average) of EWF security in Israel and Morocco will be worse than in the BAU scenario by 2050.

Socio-Economic and Security Trade-offs

- The high-income, energy-rich and water-poor countries were more secure in terms of energy and food compared with their counterparts in other country groupings in 2015. By 2050, in response to the socio-economic developments in the BAU scenario, the EWF security risks are likely to increase across all the countries in this research.

- Overall, the region could expect different results in the ESC, WSC and FSC scenarios. While all the countries could experience a slight economic improvement in the ESC scenario, GDP will be moderately worse in the WSC and FSC scenarios compared to the BAU scenario. Employment opportunities will deteriorate in the ESC, WSC and FSC scenarios, while EWF security outcomes will improve considerably. However, the results within the same scenario are not uniform across the countries. For example, Tunisia is likely to experience improved EWF security but adverse economic and employment outcomes. In the same income group, Egypt will also experience improved EWF security, adverse employment but improved economic outcomes.

- Similarly, in the WSC scenario, for example, Qatar and Oman could experience improvements in their EWF security. However, in Oman, the improvement would be at the expense of reduced job opportunities, while in Qatar, both GDP and the number of jobs would deteriorate.

- In the NSC scenario, the socio-economic and EWF security outcomes appear to reinforce each other; the improvement in EWF security is accompanied by development in the socio-economic condition of most of the countries in this research. Egypt is the only exception; it is likely to enjoy an increase in GDP and EWF security but a lower employment rate compared to the BAU scenario.

Policy trade-offs: concluding comments

The analyses in this research present the nature of trade-offs that policymakers might like to consider while developing sectoral (energy, water and food) and economic and social policies for the countries in this research. The following examples show the strength of this claim:

- In the ESC, WSC and FSC scenarios, the outcomes show worse employment levels in both the short and long term for most of the countries in this research. There are a few exceptions in terms of impacts on employment, for example, Iran and Qatar in the FSC scenario and Israel in the ESC scenario. As the countries in this research are likely to grow fast in the coming years, employment will be one of the main challenges for the whole region and thus job creation will become a very important policy priority. Some countries would accept to sacrifice improvements in EWF security in favour of policies that would create new job opportunities for the young. Iranian policymakers, for example, may prefer the FSC scenario, which could impact its economic and energy security negatively.

- Other countries in this research, such as those in the GCC and North Africa, could face a reduction in their job opportunities in the ESC, WSC and FSC scenarios. In this case, these countries may need to implement strong technological interventions to address their EWF security challenge while at the same time improving job opportunities.

- The four pathways (ESC, WSC, FSC and NSC) developed in this research provide policymakers
- Policymakers with the basis for considering specific policy trade-offs. The discussion in chapter 8 suggests that there is no distinctive pathway, which could overcome all the challenges in this region. However, the selection of the appropriate scenario depends on the matter of context and priorities of the policymakers in each country. It is essential that the policymakers of the MENA region consider the trade-offs across various scenarios and deeply understand the positive and negative aspects of the selected scenario in the short term and the long term for their future developments.

- It is also recommended that the selected countries in this research require to adopt the new socio-economic development strategic policies that would taking into account the underlying EWF nexus. Such strategic policies will assist to reduce (or in some cases even avoid) the adverse consequences on the scarce resources (energy, water and land) as the results of the continuity of the current socio-economic trends as observed in the BAU scenario in the short and long term.

9.2 Recommendations

Based on the above analysis, the following future studies are recommended.

- This research investigates the inter-linkages between energy, water and food in the context of MENA countries, both at micro and macro levels, using input-output general equilibrium model and scenario analysis. It is unique in the composition of its methodology and eye-opening in its policy implications of the outcomes. Of course the outcomes are sensitive to data and assumptions, but they are well indicative about the potential impacts of alternative policies. It should however be mentioned that due to data limitations in some MENA countries, the results of scenario analysis have reflected small differences on expected trends of some variables in accordance to discussed attributes (see, Figure 5.11). This, in turn, has affected the outcomes for the composite EWF security indices in Chapter 8. Therefore, despite data limitation and sensitivity to

assumptions the conclusion of this research is very useful for policymakers in understanding the nature of the complex nexus between energy, water and food.

- This research discussed the impact of different scenarios on the various dimensions of nexus, including economic, social, technological and political. However, the environmental dimension of nexus and the damage that could cause as a result of these scenarios was not considered in this research due to the limited availability of data. It is suggested that future research should analyse all the aspects of the nexus, including the environmental dimension; this could present the wider impact of policy choices on the EWF security nexus.

- This research applies IO analysis, which is essentially a top-down modelling approach. The applied disaggregation level of the EWF sectors in this model was to quantify the links between various sectors of the economy. Applying a bottom-up model, such as material flow analysis (see Section 4.23), could complete the analysis and allow a wide range of policy options, such as supply and demand side management and material substitution, to be assessed. This is because it would consider the links between energy, water and food in end-use applications. However, such analysis would require excessive data, which is the major challenge for such an approach.

- The analysis of the linkages between energy, water and food was calculated based on monetary input-output tables. Considering the input-output model in physical units (such as kWh, ton, m^3, etc) could analyse the linkages more accurately. However, this level of detail is not currently available for the MENA countries.

- The 2011 input-output tables captured from the GTAP are static and present a snapshot of the relationship between energy, water and food. This approach was applied in this study as the original IO tables for each country were aggregated for energy, water and food. Further, including a dynamic approach requires a series of IO tables at regular time intervals (ideally on an annual basis) for each country. However, the water and food information was not available for all the selected countries in this study.

- The substitution possibilities for various input factors and the assumed values for this substitution was considered uniform for all the countries in this research. In reality,

different countries have a different nested structure for the substitution of input factors with different values for this substitution. The use of such different substitution possibilities would improve the quality of the work.

- In simulation modelling for scenario analysis, there are two approaches, namely i) deterministic approach; ii) stochastic approach. The former is implemented in this research, whereas the latter allows for point estimation with a certain confidence interval. The deterministic approach lacks this analysis because it ignores the probability distribution function of assumed variables. Nonetheless, the scenario simulation of deterministic approach are indicative too. In the design of scenarios, In this research, the umost effort made to reflect the sensitivity of assumed variables associated with uncertainties surrounding them in each country. However, due to the methodological limitations, the results have not been reflected by percentage confidence.

- The availability of data for water and food (for example, in Qatar) at a disaggregated level for individual countries in this study was limited. Hence, in some cases (for example, the amount of water needed for different sectors of an economy at disaggregated levels), this study assumed the same value for various water technology options and food sector for the countries with the same economic structure, in particular, the countries located in the GCC region (Saudi Arabia, the UAE, Kuwait, Qatar and Oman). Applying the specific data for individual countries in these sectors could result in more accurate outcomes.

- The scenarios presented in this study are based on the existing energy, water and food policies and the available information about the national strategic vision for each individual country in the energy, water and food sectors. As energy, water and food developments change rapidly, the scenarios in this study might require revisiting in the future in order to make them align with policy settings.

- The new technologies presented for energy, water and food in 2030 and 2050 were developed with the purpose of applying the most recent engineering and input-output data available to researchers at the time. The operation and maintenance of some of these technologies, such as wastewater treatment, wind power plants and nuclear power plants are either not available or the technology is still in an initial phase for the majority of the

countries in this study. Hence, the applied data in the input-output tables require to be reviewed when more accurate data becomes available.

- As this research is one of the first studies of the EWF nexus, the linear relationship applied between the variable for projecting the results for 2030 and 2050 in different scenarios in this study. This is due to the lack of sectoral energy, water and food data at disaggregated levels, and it was not possible to develop non-linear models with the resource constraints of this research. As data collection for the EWF sectors improves, there would be a greater opportunity to adopt the nonlinear functional forms.

- This study considered 10 countries from the MENA region. For more accurate analysis of the EWF security nexus for the region, one should consider all the counties included in the Middle East and North Africa. However, currently the detailed input-output tables are not available in GTAP database9 for the individual countries not included in this study. Therefore, the outcomes for the region require revision when the information for individual countries becomes available.

Appendix A: Assumed values for scenario drivers for MENA countries

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Table A-1: Egypt

Egypt	1990	2015	2030					2050				
			BAU	ESC	WSC	FSC	NSC	BAU	ESC	WSC	FSC	NSC
POPULATION (million)	57	94	120	120	120	120	120	153	153	153	153	153
ECONOMY												
GDP per capita (constant 2005 US$)	1,560	2,665	3,453					4,148				
Components of GDP (%)												
Household consumption	72	87	86	82	82	82	82	85	78	78	78	78
Government spending	11	14	14	15	15	15	15	15	15	15	15	15
Investment	29	18	18	23	23	23	22	19	28	28	28	32
Economic structure (%)												
Agriculture	18	11	14	10	10	13	10	18	8	8	15	8
Industry	27	40	41	40	40	35	36	45	40	40	28	32
Services	54	49	45	50	50	52	54	36	52	52	57	60
ENERGY												
Access to electricity (% of population)	94	100	100	100	100	100	100	100	100	100	100	100
Energy productivity growth* (% pa)		(0.38)	(0.40)	0.15	0.13	0.13	0.15	(0.40)	0.22	0.18	0.18	0.67
Electricity supply mix (%)												
Nuclear power plant												
Coal power plant												
Gas power plant	45.0	71	71	62	72	71	66	72	49	72	72	60
Oil power plant	32.0	21	20	13	20	19	16	18	3	19	17	10
Hydro power plant	24.0	7	7	6	5	6	6	7	5	4	4	5
Wind power plant		1	1	7	3	2	5	1	15	4	4	5
Solar power plant		*0*	*0*	*10*	*1*	*1*	*7*	*1*	*23*	*1*	*3*	*20*
Other Renewables			*0*	*2*				*1*	*5*			
WATER												
Water supply mix (%)												
Surface water	na	84	83	83	77	83	78	82	82	72	82	62
Groundwater	na	10	11	11	9	11	9	12	12	9	12	8
Desalination	na	0	1	1	3	1	4	1	1	5	1	9
Treated wastewater	na	2	1	2	6	1	6	1	2	9	1	15
Reused agricultural drainage water	na	4	4	3	4	4	3	4	3	5	4	6
FOOD												
Agricultural productivity growth* (% pa)		0.70	0.70	1.1	1.1	1.1	1.0	0.80	0.9	0.9	0.9	1.3
Crop selection for:												
Grains (%)												
Barley		1	1	1	1	1	1	1	1	1	1	1
Maize	90	89	89	89	89	89	90	89	89	89	90	91
Sorghum	10	1	9	9	9	8	8	1	1	1	1	1
Oats												
Millet												
Rye		9	1	1	1	1	1	9	9	9	8	7
Veg & Fruit (%)												
Potatoes	24	28	28	28	28	28	28	28	28	28	28	30
Tomatoes	62	55	55	55	55	53	53	55	55	55	51	53
Nuts and nut products	0	0	0	0	0	0	0	0	0	0	0	0
Bananas	6	8	8	8	8	9	9	8	8	8	10	8
Dates	8	9	9	9	9	9	9	9	9	9	10	9
Vegetable oil (%)												
Soybean Oil	50	81	81	81	81	82	81	81	81	81	82	80
Groundnut Oil	8	5	5	5	5	5	5	5	5	5	5	5
Sunflower seed Oil		5	5	5	5	5	5	5	5	5	5	5
Rape and Mustard Oil												-
Cottonseed Oil	31	6	6	6	6	7	6	6	6	6	7	6
Sesame seed Oil	11											
Olive Oil		2	2	2	2	3	2	2	2	2	3	3
Maize Germ Oil		1	1	1	1	-	1	1	1	1	-	1
Other oil crops												
Meat (%)												
Bovine Meat	48	48	48	48	48	50	48	48	48	48	53	47
Mutton & Goat Meat	13	8	8	8	8	8	8	8	8	8	7	8
Pig Meat	0	1	1	1	1	1	1	1	1	1	0	1
Poultry Meat	39	43	43	43	43	42	43	43	43	43	40	45
TRANSPORT												
Land transport investment* (% pa growth)	na		0.5	0.60	0.60	0.60	0.50	0.5	0.50	0.50	0.50	0.80

Table A-2: Iran

Iran	1990	2015	2030					2050				
			BAU	ESC	WSC	FSC	NSC	BAU	ESC	WSC	FSC	NSC
POPULATION (million)	56	78	89	89	89	89	89	94	94	94	94	94
ECONOMY												
GDP per capita (constant 2005 US$)	4,147	6,161	7,074					7,269				
Components of GDP (%)												
Household consumption	68	46	46	46	46	46	47	40	38	78	78	38
Government spending	11	10	14	14	14	14	14	14	14	15	15	14
Investment	33	40	35	37	37	37	37	35	41	28	28	42
Economic structure (%)												
Agriculture	12	10	10	9	9	9	9	11	7	8	7	8
Industry	33	40	27	26	25	25	37	37	32	40	32	33
Services	55	51	62	65	66	66	54	52	61	52	61	57
ENERGY												
Access to electricity (% of population)	96	100	100	100	100	100	100	100	100	100	100	100
Energy productivity growth* (% pa)	-	0.74	0.60	0.82	0.82	0.82	0.80	0.60	0.70	0.70	0.70	0.98
Electricity supply mix (%)												
Nuclear power plant	-	1	1	2	1	1	2	0	3	1	1	3
Coal power plant	0.1	0	-	1	-	-	1	0	1	0	0	2
Gas power plant	52.5	79	77	75	77	77	63	73	70	73	73	41
Oil power plant	37.1	14	16	14	16	16	13	18	13	18	18	11
Hydro power plant	10.3	5	5	4	5	5	5	5	2	5	7	6
Wind power plant	-	0	-	2	1	-	1	0	5	2	0	2
Solar power plant	-	*0*	-	*1*	-	-	*15*	*0*	*3*	*1*	*0*	*35*
Other Renewables	-	*0*	*1*	*1*	-	*1*	-	*2*	*3*	*0*	*0*	-
WATER												
Water supply mix (%)												
Surface water	na	43	44	44	43	44	42	46	46	43	46	42
Groundwater	na	57	55	55	45	55	43	54	53	35	51	28
Desalination	na	0	0	1	7	1	5	0	1	15	0	10
Treated wastewater	na	0	0	-	5	-	10	0	0	10	3	20
Reused agricultural drainage water	na	-						-	-	-	-	-
FOOD												
Agricultural productivity growth* (% pa)	na	0.60	0.72	0.9	1.0	1.7	1.1	0.70	0.8	0.9	1.3	1.7
Crop selection for:												
Grains (%)												
Barley	96	60	60	60	60	59	63	60	60	60	58	65
Maize	4	40	40	40	40	41	37	40	40	40	42	35
Sorghum												
Oats												
Millet	0											
Rye												
Veg & Fruit (%)												
Potatoes	51	37	37	37	37	38	37	37	37	37	40	30
Tomatoes	33	45	45	45	45	44	45	45	45	45	42	53
Nuts and nut products	6	8	8	8	8	8	8	8	8	8	9	8
Bananas	0	1	1	1	1	1	1	1	1	1	2	8
Dates	10	9	9	9	9	8	9	9	9	9	7	9
Vegetable oil (%)												
Soybean Oil	16	19	19	19	19	21	20	19	19	19	23	27
Groundnut Oil												
Sunflower seed Oil	24	13	13	13	13	12	12	13	13	13	12	11
Rape and Mustard Oil	-	54	54	54	54	52	55	54	54	54	50	51
Cottonseed Oil	50	5	5	5	5	5	5	5	5	5	5	0
Sesame seed Oil	9	6	6	6	6	7	6	6	6	6	7	4
Olive Oil	1	1	1	1	1	1	1	1	1	1	1	5
Maize Germ Oil		2	2	2	2	1	1	2	2	2	2	0
Other oil crops	-	-	-	-	-	1	-	-	-	-	-	
Beverages (%)												
Coffee												
Tea	100	100	100	100	100	100	100	100	100	100	100	100
Meat (%)												
Bovine Meat	na	27	27	27	27	28	26	27	27	27	30	26
Mutton & Goat Meat	na	38	38	38	38	38	37	38	38	38	38	36
Pig Meat	na											
Poultry Meat	na	35	35	35	35	37	37	35	35	35	38	38
TRANSPORT												
Land transport investment* (% pa growth)	na		0.3	0.30	0.30	0.30	0.30	0.0	1.30	1.30	1.30	1.50

Table A-3: Israel

Israel	1990	2015	2030					2050				
			BAU	ESC	WSC	FSC	NSC	BAU	ESC	WSC	FSC	NSC
POPULATION (million)	5	8	10	10	10	10	10	13	13	13	13	13
ECONOMY												
GDP per capita (constant 2005 US$)	21,141	32,661	37,051					41,539				
Components of GDP (%)												
Household consumption	57	56	57	57	57	57	57	59	58	58	58	58
Government spending	27	23	17	17	17	17	17	10	10	10	10	10
Investment	20	20	19	21	21	21	22	17	21	21	21	25
Economic structure (%)												
Agriculture	na	1	1	1	1	1	1	1	1	1	1	1
Industry	na	20	20	21	22	21	18	21	23	23	23	15
Services	na	79	79	78	77	78	81	78	76	76	76	84
ENERGY												
Access to electricity (% of population)	100	100	100	100	100	100	100	100	100	100	100	100
Energy productivity growth* (% pa)		0.17	0.13	0.40	0.38	0.38	0.40	0.12	0.40	0.36	0.36	0.50
Electricity supply mix (%)												
Nuclear power plant												
Coal power plant	50.1	46	34	29	32	34	24	30	20	25	30	6
Gas power plant		52	63	54	61	63	52	67	45	60	65	40
Oil power plant	49.9	1	0	1	0	0	1	0	1	0	0	1
Hydro power plant	0.0	0										
Wind power plant		0										
Solar power plant		*2*	*2*	*14*	*7*	*3*	*19*	*2*	*30*	*14*	*3*	*44*
Other Renewables		*0*	*0*	*2*	*0*	*1*	*4*	*1*	*4*	*1*	*2*	*9*
WATER												
Water supply mix (%)												
Surface water	na	20	20	20	18	20	19	19	19	15	19	17
Groundwater	na	26	28	28	17	28	21	30	30	5	30	15
Desalination	na	24	20	20	29	20	22	14	14	35	14	20
Treated wastewater	na	30	33	33	37	33	38	37	37	45	37	48
Reused agricultural drainage water	na	-										
FOOD												
Agricultural productivity growth* (% pa)	-	0.70	0.05	0.1	0.1	0.1	0.2	0.05	0.1	0.1	0.1	0.5
Crop selection for:												
Grains (%)												
Barley	8	10	10	10	10	13	13	10	10	10	15	15
Maize	91	70	70	70	70	72	70	70	70	70	75	70
Sorghum	1	20	20	20	20	15	18	20	20	20	10	15
Oats	1											
Millet												
Rye												
Veg & Fruit (%)												
Potatoes	26	49	49	49	49	46	47	49	49	49	42	44
Tomatoes	64	35	35	35	35	35	37	35	35	35	35	40
Nuts and nut products	1	1	1	1	1	1	1	1	1	1	1	1
Bananas	7	11	11	11	11	11	11	11	11	11	11	11
Dates	1	4	4	4	4	7	4	4	4	4	11	4
Vegetable oil (%)												
Soybean Oil	57	56	55	55	55	58	56	55	55	55	60	56
Groundnut Oil												
Sunflower seed Oil	7	4	4	4	4	3	5	4	4	4	3	6
Rape and Mustard Oil	24	21	21	21	21	20	20	21	21	21	20	20
Cottonseed Oil	10	3	3	3	3	2	3	3	3	3	2	3
Sesame seed Oil												
Olive Oil		13	13	13	13	12	12	13	13	13	10	11
Maize Germ Oil	3	1	1	1	1	1	1	1	1	1	1	1
Other oil crops	-	2	4	4	4	4	3	4	4	4	4	3
Meat (%)												
Bovine Meat	15	48	46	46	46	46	45	46	46	46	46	45
Mutton & Goat Meat	3	8	5	5	5	5	4	5	5	5	5	4
Pig Meat	4	1	1	1	1	1	1	1	1	1	1	1
Poultry Meat	78	43	48	48	48	48	49	48	48	48	48	50
TRANSPORT												
Land transport investment* (% pa growth)	na		0.4	0.50	0.50	0.50	0.50	0.4	0.50	0.50	0.50	0.70

Table A-4: Kuwait

Kuwait	1990	2015	2030					2050				
			BAU	ESC	WSC	FSC	NSC	BAU	ESC	WSC	FSC	NSC
POPULATION (million)	2	4	5	5	5	5	5	6	6	6	6	6
ECONOMY												
GDP per capita (constant 2005 US$)	8,777	36,260	34,709					34,062				
Components of GDP (%)												
Household consumption	57	29	34	33	33	33	33	40	38	38	38	38
Government spending	39	18	22	17	17	17	17	28	15	15	15	15
Investment	18	16	16	22	22	22	25	15	30	30	30	35
Economic structure (%)												
Agriculture	na	0	1	1	1	1	1	1	1	1	1	1
Industry	na	71	66	66	66	66	63	61	60	60	60	53
Services	na	29	33	34	34	34	37	38	39	39	39	46
ENERGY												
Access to electricity (% of population)	100	100	100	100	100	100	100	100	100	100	100	100
Energy productivity growth* (% pa)	-	0.70	0.14	0.34	0.34	0.34	0.30	0.13	0.32	0.32	0.32	0.97
Electricity supply mix (%)												
Nuclear power plant												
Coal power plant												
Gas power plant	45.0	36	38	47	38	38	44	40	60	40	40	54
Oil power plant	55.0	64	62	43	56	58	40	60	16	46	50	10
Hydro power plant												
Wind power plant	-	-	-	0	-	-	0	-	1	-	-	1
Solar power plant	-	-	-	*10*	*6*	*4*	*15*	-	*23*	*14*	*10*	*33*
Other Renewables	-	*0*	*0*	*0*	*0*	*0*	*1*					
WATER												
Water supply mix (%)												
Surface water	na	1	1	1	1	1	1	2	2	2	2	2
Groundwater	na	45	44	44	30	43	32	42	42	12	40	15
Desalination	na	46	47	47	58	47	48	48	48	72	48	50
Treated wastewater	na	8	8	8	11	9	19	8	8	14	10	33
Reused agricultural drainage water	na											
FOOD												
Agricultural productivity growth* (% pa)	-	0.70	0.18	0.9	0.9	0.9	0.9	0.18	0.8	0.8	0.8	1.1
Crop selection for:												
Grains (%)												
Barley	50	7	7	7	7	9	7	7	7	7	10	7
Maize	50	74	74	74	74	73	74	74	74	74	71	74
Sorghum												
Oats												
Millet												
Rye												
Veg & Fruit (%)												
Potatoes	4	31	31	31	31	33	33	31	31	31	35	34
Tomatoes	53	48	48	48	48	46	47	48	48	48	44	45
Nuts and nut products	7											
Bananas	33											
Dates	2	21	21	21	21	21	21	21	21	21	21	21
Vegetable oil (%)												
Soybean Oil												
Groundnut Oil		100	100	100	100	100	100	100	100	100	100	100
Sunflower seed Oil												
Rape and Mustard Oil												
Cottonseed Oil												
Sesame seed Oil	14											
Olive Oil	14											
Maize Germ Oil	71											
Other oil crops	-											
Meat (%)												
Bovine Meat	2	4	4	4	4	4	4	4	4	4	4	5
Mutton & Goat Meat	36	53	53	53	53	51	49	53	53	53	50	45
Pig Meat												
Poultry Meat	62	43	43	43	43	45	47	43	43	43	46	50
TRANSPORT												
Land transport investment* (% pa growth)	na	0.1	0.1	0.30	0.30	0.30	0.30	0.1	0.30	0.30	0.30	0.70

Table A-5: Morocco

Morocco	1990	2015	2030					2050				
			BAU	ESC	WSC	FSC	NSC	BAU	ESC	WSC	FSC	NSC
POPULATION (million)	25	34	41	41	41	41	41	46	46	46	46	46
ECONOMY												
GDP per capita (constant 2005 US$)	1,721	3,114	3,825					4,645				
Components of GDP (%)												
Household consumption	59	61	54	54	54	54	54	48	46	46	46	46
Government spending	16	20	20	18	18	18	18	20	15	15	15	15
Investment	31	32	33	35	35	35	37	33	38	38	38	42
Economic structure (%)												
Agriculture	15	12	12	11	11	11	11	11	9	9	9	9
Industry	28	26	25	28	28	28	27	25	32	32	32	28
Services	57	62	62	60	60	60	62	64	59	59	59	63
ENERGY												
Access to electricity (% of population)	48	95	100	100	100	100	100	100	100	100	100	100
Energy productivity growth* (% pa)	-	0.05	0.10	0.15	0.15	0.15	0.13	0.01	0.10	0.10	0.10	0.40
Electricity supply mix (%)												
Nuclear power plant												
Coal power plant	23.0	57	43	41	43	54	35	24	19	24	50	5
Gas power plant	-	19	19	22	19	19	20	18	25	18	18	20
Oil power plant	64.0	7	6	5	6	7	5	3	2	3	7	2
Hydro power plant	13.0	8	9	8	9	9	8	10	8	10	10	8
Wind power plant		8	14	15	14	9	11	22	23	22	10	14
Solar power plant		*0*	*9*	*10*	*9*	*2*	*21*	*22*	*23*	*22*	*5*	*50*
Other Renewables			*0*	-	*0*	-	*0*	*1*	-	*1*	-	*1*
WATER												
Water supply mix (%)												
Surface water	na	75	73	68	59	73	59	70	60	40	70	40
Groundwater	na	25	23	21	21	23	21	20	15	15	20	15
Desalination	na	0	2	6	10	2	11	5	13	23	5	25
Treated wastewater	na	0	2	6	10	2	9	5	13	22	5	20
Reused agricultural drainage water	na	-										
FOOD												
Agricultural productivity growth* (% pa)	-	0.70	0.38	0.6	0.6	0.6	0.6	0.35	0.6	0.6	0.6	0.8
Crop selection for:												
Grains (%)												
Barley	91	93	93	93	93	90	90	93	93	93	87	87
Maize	6	4	4	4	4	7	7	4	4	4	10	10
Sorghum	1	0	1	1	1	1	1	1	1	1	1	1
Oats	2	2	2	2	2	2	2	2	2	2	2	2
Millet	0	1	0	0	0	0	0	0	0	0	0	0
Rye												
Veg & Fruit (%)												
Potatoes	44	52	52	52	52	47	47	52	52	52	42	42
Tomatoes	44	35	35	35	35	39	39	35	35	35	44	44
Nuts and nut products	3	3	3	3	3	3	3	3	3	3	3	3
Bananas	3	8	8	8	8	8	8	8	8	8	8	8
Dates	6	3	3	3	3	3	3	3	3	3	3	3
Vegetable oil (%)												
Soybean Oil	1	6	6	6	6	7	7	6	6	6	8	8
Groundnut Oil	5	6	6	6	6	6	6	6	6	6	6	6
Sunflower seed Oil	36	7	7	7	7	8	8	7	7	7	9	9
Rape and Mustard Oil	1											
Cottonseed Oil	2											
Sesame seed Oil												
Olive Oil	53	79	79	79	79	75	75	79	79	79	70	70
Maize Germ Oil	1	1	1	1	1	3	3	1	1	1	5	5
Other oil crops	-	2	2	2	2	2	2	2	2	2	2	2
Meat (%)												
Bovine Meat	34	40	40	40	40	39	39	40	40	40	38	38
Mutton & Goat Meat	28	8	22	22	22	21	21	22	22	22	20	20
Pig Meat	0	1	0	0	0	0	0	0	0	0	0	0
Poultry Meat	38	43	38	38	38	40	40	38	38	38	42	42
TRANSPORT												
Land transport investment* (% pa growth)	na		0.1	0.30	0.30	0.30	0.35	0.1	0.30	0.30	0.30	1.04

Table A-6: Oman

Oman	1990	2015	2030					2050				
			BAU	ESC	WSC	FSC	NSC	BAU	ESC	WSC	FSC	NSC
POPULATION (million)	2	4	5	5	5	5	5	6	6	6	6	6
ECONOMY												
GDP per capita (constant 2005 US$)	14,903	17,132	21,687					28,743				
Components of GDP (%)												
Household consumption	46	28	30	30	30	30	30	34	32	32	32	32
Government spending	22	25	20	21	21	21	21	15	17	17	17	17
Investment	12	25	24	26	26	26	26	24	27	27	27	28
Economic structure (%)												
Agriculture	na	1	2	1	1	1	2	2	1	1	1	2
Industry	na	63	63	64	64	64	59	64	65	65	65	55
Services	na	36	35	35	35	35	39	34	34	34	34	43
ENERGY												
Access to electricity (% of population)	100	100	100	100	100	100	100	100	100	100	100	100
Energy productivity growth* (% pa)	-	0.47	0.54	0.90	0.90	0.90	0.72	0.41	0.70	0.70	0.70	0.98
Electricity supply mix (%)												
Nuclear power plant												
Coal power plant												
Gas power plant	82.0	97	91	86	88	88	80	81	70	75	75	55
Oil power plant	18.0	3	9	6	8	8	2	19	10	15	15	2
Hydro power plant												
Wind power plant	-	-	-	2	2	2	6	-	6	5	5	15
Solar power plant	-	-	-	*6*	*2*	*2*	*11*	-	*14*	*5*	*5*	*28*
Other Renewables												
WATER	-	-										
Water supply mix (%)	-	-										
Surface water	na	4	16	15	13	15	13	30	29	24	29	24
Groundwater	na	80	46	46	45	46	45	4	4	1	4	1
Desalination	na	14	32	33	34	33	29	56	57	60	57	50
Treated wastewater	na	3	6	6	8	6	13	10	10	15	10	25
Reused agricultural drainage water	na	-										
FOOD	-	-										
Agricultural productivity growth* (% pa)	-	0.70	0.48	1.0	1.0	1.0	0.9	0.44	0.8	0.8	0.8	1.5
Crop selection for:												
Grains (%)												
Barley	-	7	7	7	7	17	12	7	7	7	28	18
Maize	79											
Sorghum	4	90	91	91	91	81	86	91	91	91	70	80
Oats	17	-										
Millet												
Rye												
Veg & Fruit (%)	3	3	3	3	3	4	4	3	3	3	5	5
Potatoes	16	12	12	12	12	11	11	12	12	12	10	10
Tomatoes												
Nuts and nut products	13	17	17	17	17	21	21	17	17	17	25	25
Bananas	67	68	68	68	68	64	64	68	68	68	60	60
Dates												
Vegetable oil (%)												
Soybean Oil												
Groundnut Oil												
Sunflower seed Oil	33											
Rape and Mustard Oil												
Cottonseed Oil												
Sesame seed Oil												
Olive Oil												
Maize Germ Oil	67	100	100	100	100	100	100	100	100	100	100	100
Meat (%)												
Bovine Meat	14	25	25	25	25	23	22	25	25	25	22	20
Mutton & Goat Meat	71	43	43	43	43	42	42	43	43	43	40	40
Pig Meat												
Poultry Meat	14	32	32	32	32	35	36	32	32	32	38	40
TRANSPORT												
Land transport investment* (% pa growth)	na	-	0.1	0.34	0.34	0.34	0.34	0.1	0.32	0.32	0.32	0.57

Table A-7: Qatar

Qatar	1990	2015	2030					2050				
			BAU	ESC	WSC	FSC	NSC	BAU	ESC	WSC	FSC	NSC
POPULATION (million)	1	2	3	3	3	3	3	4	4	4	4	4
ECONOMY												
GDP per capita (constant 2005 US$)	15,449	67,901	67,995					68,112				
Components of GDP (%)												
Household consumption	30	16	17	15	15	15	15	18	14	14	14	14
Government spending	34	15	17	17	17	17	17	19	19	19	19	19
Investment	25	32	32	33	33	33	35	33	35	35	35	38
Economic structure (%)												
Agriculture	na	0	0	0	0	0	0	0	0	0	1	0
Industry	na	70	65	65	65	65	61	60	60	60	60	51
Services	na	30	34	34	34	34	39	40	40	40	40	49
ENERGY												
Access to electricity (% of population)	100	100	100	100	100	100	100	100	100	100	100	100
Energy productivity growth* (% pa)	-	0.1	0.1	0.5	0.5	0.5	0.5	0.1	0.5	0.5	0.5	0.6
Electricity supply mix (%)												
Nuclear power plant												
Coal power plant												
Gas power plant	100.0	100	100	99	98	98	91	100	98	95	95	80
Oil power plant												
Hydro power plant												
Wind power plant												
Solar power plant	-	-	-	*4*	*2*	*2*	*9*	-	*10*	*5*	*5*	*20*
Other Renewables												
WATER												
Water supply mix (%)												
Surface water	na	1	8	8	7	8	7	16	16	15	16	15
Groundwater	na	15	14	14	11	14	13	13	13	6	13	10
Desalination	na	74	68	68	71	68	68	61	61	67	61	60
Treated wastewater	na	10	10	10	11	10	12	10	10	12	10	15
Reused agricultural drainage water	na											
FOOD												
Agricultural productivity growth* (% pa)		0.60	0.7	1.4	1.4	1.4	1.5	0.6	1.1	1.1	1.1	2.1
TRANSPORT												
Land transport investment* (% pa growth)			0.0	0.2	0.2	0.2	0.3	0.0	0.2	0.2	0.2	0.4

Table A-8:Saudi Arabia

Saudi Arabia	1990	2015	2030					2050				
			BAU	ESC	WSC	FSC	NSC	BAU	ESC	WSC	FSC	NSC
POPULATION (million)	16	31	39	39	39	39	39	45	45	45	45	45
ECONOMY												
GDP per capita (constant 2005 US$)	18,003	21,183	21,707					22,362				
Components of GDP (%)												
Household consumption	46	32	37	36	36	36	36	43	40	40	40	40
Government spending	29	26	28	28	28	28	28	31	31	31	31	31
Investment	16	29	31	32	32	32	34	33	35	35	35	40
Economic structure (%)												
Agriculture	6	2	3	2	2	2	2	4	2	2	2	2
Industry	49	57	50	53	53	53	50	41	47	47	47	40
Services	45	41	47	45	45	45	48	55	51	51	51	58
ENERGY												
Access to electricity (% of population)	100	100	100	100	100	100	100	100	100	100	100	100
Energy productivity growth* (% pa)	-	0.19	0.20	0.39	0.39	0.39	0.34	0.19	0.36	0.36	0.36	0.68
Electricity supply mix (%)												
Nuclear power plant												
Coal power plant												
Gas power plant	51.0	56	64	55	60	64	47	75	54	65	75	35
Oil power plant	49.0	44	35	33	34	35	32	22	17	20	22	15
Hydro power plant												
Wind power plant	-	-	-	2	-	-	2	-	5	-	-	5
Solar power plant	-	*0*	*1*	*10*	*6*	*1*	*19*	*3*	*23*	*15*	*3*	*45*
Other Renewables	-	-	-	*0*	-	-	-	-	*1*	-	-	-
WATER												
Water supply mix (%)												
Surface water	na	28	26	26	23	26	23	23	23	17	23	17
Groundwater	na	52	40	40	38	40	36	25	25	20	25	15
Desalination	na	18	30	30	34	30	30	45	45	55	45	45
Treated wastewater	na	2	4	4	5	4	11	7	7	8	7	23
Reused agricultural drainage water	na											
FOOD												
Agricultural productivity growth* (% pa)	-	0.70	1.20	1.4	1.4	1.4	1.5	1.00	1.1	1.1	1.1	2.1
Crop selection for:												
Grains (%)												
Barley	75	5	5	5	5	7	8	5	5	5	10	11
Maize	1	43	43	43	48	48	48	43	43	53	53	53
Sorghum	23	50	50	50	45	43	43	50	50	40	35	35
Oats												
Millet	1	2	2	2	2	2	1	2	2	2	2	1
Rye												
Veg & Fruit (%)												
Potatoes	5	19	19	19	19	21	21	19	19	19	23	23
Tomatoes	38	27	27	27	27	25	25	27	27	27	23	23
Nuts and nut products	1											
Bananas	11											
Dates	45	54	54	54	54	54	54	54	54	54	54	54
Vegetable oil (%)												
Soybean Oil	-	71	71	71	71	72	73	71	71	71	73	75
Groundnut Oil	-	1	1	1	1	1	1	1	1	1	1	1
Sunflower seed Oil												
Rape and Mustard Oil												
Cottonseed Oil	1	11	11	11	12	11	11	11	11	13	11	11
Sesame seed Oil	10	17	17	17	16	16	15	17	17	15	15	13
Olive Oil	9											
Maize Germ Oil	79											
Meat (%)												
Bovine Meat	7	8	8	8	8	8	8	8	8	8	8	8
Mutton & Goat Meat	22	23	23	23	23	22	22	23	23	23	20	20
Pig Meat												
Poultry Meat	70	69	69	69	69	70	70	69	69	69	72	72
TRANSPORT												
Land transport investment* (% pa growth)	na		0.1	0.3	0.3	0.3	0.3	0.1	0.3	0.3	0.3	0.5

Table A-9: Tunisia

Tunisia	1990	2015	2030					2050				
			BAU	ESC	WSC	FSC	NSC	BAU	ESC	WSC	FSC	NSC
POPULATION (million)	16	31	39	39	39	39	39	45	45	45	45	45
ECONOMY												
GDP per capita (constant 2005 US$)	2,227	4,271	5,233					6,436				
Components of GDP (%)												
Household consumption	64	69	69	64	64	64	64	69	58	58	58	58
Government spending	16	19	19	19	19	19	19	20	20	20	20	20
Investment	27	24	22	24	24	24	26	21	25	25	25	29
Economic structure (%)												
Agriculture	16	9	9	8	8	8	8	8	6	6	6	6
Industry	30	27	29	31	31	30	27	31	35	35	33	28
Services	54	64	62	62	62	63	65	60	59	59	61	66
ENERGY												
Access to electricity (% of population)	100	100	100	100	100	100	100	100	100	100	100	100
Energy productivity growth* (% pa)	-	0.19	0.19	0.79	0.79	0.79	0.75	0.18	0.69	0.69	0.69	1.02
Electricity supply mix (%)												
Nuclear power plant												
Coal power plant												
Gas power plant	64.0	94	92	82	87	92	79	90	66	79	90	60
Oil power plant	35.0	4	4	3	4	4	3	5	3	5	5	1
Hydro power plant	1.0	0	0	0	0	0	0	1	1	1	1	1
Wind power plant	-	2	2	7	2	2	6	3	14	3	3	12
Solar power plant	-	*0*	*1*	*7*	*5*	*1*	*12*	*1*	*16*	*12*	*1*	*26*
Other Renewables	-	*0*	*0*	*0*	*0*	*0*	*0*	-	-	-	-	-
WATER												
Water supply mix (%)												
Surface water	na	36	44	44	28	44	28	54	54	20	54	20
Groundwater	na	60	50	50	46	46	46	37	37	30	30	30
Desalination	na	1	2	2	19	2	13	3	3	38	3	25
Treated wastewater	na	2	4	4	7	7	13	6	6	12	13	25
Reused agricultural drainage water	na											
FOOD												
Agricultural productivity growth* (% pa)	-	0.70	0.30	0.7	0.7	0.7	0.6	0.28	0.6	0.6	0.6	1.0
Crop selection for:												
Grains (%)												
Barley	62	82	82	82	82	83	83	82	82	82	85	85
Maize	38	-	-	-	-	-	-	-	-	-	-	-
Sorghum	0	0	0	0	0	0	0	0	0	0	0	0
Oats	0	1	1	1	1	1	1	1	1	1	1	1
Millet												
Rye												
Veg & Fruit (%)												
Potatoes	25	21	21	21	21	25	22	21	21	21	30	24
Tomatoes	60	65	65	65	65	61	63	65	65	65	56	60
Nuts and nut products	6	3	3	3	3	3	3	3	3	3	3	3
Bananas												
Dates	9	11	11	11	11	11	11	11	11	11	11	11
Vegetable oil (%)												
Soybean Oil	27	26	26	26	28	28	31	26	26	30	30	36
Groundnut Oil	-	-	-	-	-	-	-	-	-	-	-	-
Sunflower seed Oil	1	2	2	2	2	2	2	2	2	2	2	2
Rape and Mustard Oil	15	1	1	1	1	1	1	1	1	1	1	1
Cottonseed Oil												
Sesame seed Oil	0	-	-	-	-	-	-	-	-	-	-	-
Olive Oil	58	70	70	70	68	68	65	70	70	66	66	60
Maize Germ Oil												
Meat (%)												
Bovine Meat	21	31	31	31	30	30	30	31	31	30	30	30
Mutton & Goat Meat	24	32	32	32	31	31	31	32	32	30	30	30
Pig Meat	28	-	-	-	-	-	-	-	-	-	-	-
Poultry Meat	28	38	38	38	39	39	39	38	38	40	40	40
TRANSPORT												
Land transport investment* (% pa growth)	na		0.4	0.8	0.8	0.8	0.7	0.3	0.7	0.7	0.7	1.3

Table A-10: UAE

UAE	1990	2015	2030					2050				
			BAU	ESC	WSC	FSC	NSC	BAU	ESC	WSC	FSC	NSC
POPULATION (million)	16	31	39	39	39	39	39	45	45	45	45	45
ECONOMY												
GDP per capita (constant 2005 US$)	67,607	39,146	40,209					41,539				
Components of GDP (%)												
Household consumption	na	37	40	39	39	39	39	45	42	42	42	42
Government spending	na	11	13	12	12	12	12	15	13	13	13	13
Investment	na	22	23	27	27	27	30	25	32	32	32	40
Economic structure (%)												
Agriculture	1	1	1	1	1	1	1	1	1	1	1	1
Industry	59	55	52	53	53	53	48	48	50	50	50	40
Services	40	45	47	46	46	46	51	51	49	49	49	59
ENERGY												
Access to electricity (% of population)	100	100	100	100	100	100	100	100	100	100	100	100
Energy productivity growth* (% pa)	-	0.06	0.11	0.33	0.33	0.33	0.30	0.13	0.41	0.41	0.41	0.58
Electricity supply mix (%)												
Nuclear power plant	-	-	-	4	-	-	-	-	8	-	-	-
Coal power plant												
Gas power plant	96.0	99	99	82	93	95	79	99	60	85	90	55
Oil power plant	4.0	1	1	1	1	1	1	1	1	1	1	1
Hydro power plant												
Wind power plant	-	-	-	0	-	-	0	-	1	-	-	1
Solar power plant	-	*0*	*0*	*13*	*6*	*4*	*19*	*1*	*30*	*13*	*8*	*43*
Other Renewables	-	-	-	-	*0*	*0*	-	-	-	*1*	*1*	-
WATER												
Water supply mix (%)												
Surface water	na	1	4	4	4	4	4	8	8	8	8	8
Groundwater	na	42	32	32	27	32	27	20	20	10	20	10
Desalination	na	43	48	48	56	48	51	54	54	70	54	60
Treated wastewater	na	14	16	16	13	16	18	18	18	12	18	22
Reused agricultural drainage water	na											
FOOD												
Agricultural productivity growth* (% pa)			0.18	0.4	0.4	0.4	0.5	0.22	0.5	0.5	0.5	1.1
Crop selection for:												
Grains (%)												
Barley												
Maize		2	2	2	6	6	6	2	2	10	10	10
Sorghum		98	98	98	94	94	94	98	98	90	90	90
Oats	100											
Millet												
Rye												
Veg & Fruit (%)												
Potatoes	2	4	4	4	4	6	6	4	4	4	8	8
Tomatoes	22	12	12	12	12	10	10	12	12	12	8	8
Nuts and nut products		0	0	0	0	0	0	0	0	0	0	0
Bananas												
Dates	76	84	84	84	84	84	84	84	84	84	83	83
Vegetable oil (%)												
Soybean Oil		10	10	10	13	15	15	10	10	15	20	20
Groundnut Oil												
Sunflower seed Oil	16											
Rape and Mustard Oil		90	90	90	87	80	80	90	90	85	70	70
Cottonseed Oil												
Sesame seed Oil												
Olive Oil	5											
Maize Germ Oil	79											
Meat (%)												
Bovine Meat	11	10	10	10	10	9	9	10	10	10	8	8
Mutton & Goat Meat	55	32	32	32	31	31	31	32	32	30	30	30
Pig Meat												
Poultry Meat	34	58	58	58	59	60	60	58	58	60	62	62
TRANSPORT												
Land transport investment* (% pa growth)	na		0.18	0.3	0.3	0.3	0.3	0.22	0.3	0.3	0.3	0.5

Table A-11: Elasticity values between domestic (ESUBD) and import (ESUBM) for each sector

Sector	ESUBD	ESUBM
Rice	5.05	10.1
Wheat	4.45	8.9
Grains	1.3	2.6
Vegetable& fruits	1.85	3.7
Oil seed	2.45	4.9
Cane & Beet	2.7	5.4
Other Crops	3.25	6.5
Cattle	2	4
Animal products	1.3	2.6
Milk	3.65	7.3
Cattle meat	3.85	7.7
Fish	1.25	2.5
Other meats	4.4	8.8
Vegetable oils	3.3	6.6
Dairy products	3.65	7.3
Processed rice	2.6	5.2
Sugar	2.7	5.4
Other food	2	4
Beverages and tobacco	1.15	2.3
Plant fibres	2.5	5
wool	6.45	12.9
Forestry	2.5	5
Textiles	3.75	7.5
Clothing	3.7	7.4
Leather	4.05	8.1
Wood	3.4	6.8
Paper products	2.95	5.9
Fabric metal	3.75	7.5
Motor vehicle	2.8	5.6
Other equipment's	4.3	8.6
Other manufacturing	3.75	7.5
Chemical products	3.3	6.6
Non-metallic	2.9	5.8
Iron &Steel	2.95	5.9
Nonferrous	4.2	8.4
Electronic equipment's	4.4	8.8
Other machinery	4.05	8.1
Other mining	0.9	1.8
Oil	5.2	10.4
Coal	3.05	6.1
Gas	17.2	34.4
Gas distribution	2.8	5.6
Petroleum	2.1	4.2
Transmission & Distribution	2.8	5.6
Nuclear Power	2.8	5.6
Coal power	2.8	5.6
Gas Power	2.8	5.6
Oil Power	2.8	5.6
Hydropower	2.8	5.6
Wind power	2.8	5.6
Solar power	2.8	5.6
Other renewables	2.8	5.6
Water	2.8	5.6
Construction	1.9	3.8
Land transport	1.9	3.8
Sea transport	1.9	3.8
Air transport	1.9	3.8
Communication services	1.9	3.8
Other services	1.9	3.8

Appendix B: Data sets Applies for This Research

This appendix presents all the outcome of applying different scenarios in this research. The methodology and the sources used for the following data sets has been discussed in chapter5. This appendix contains of four sections, which present the following tables:

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Section A: Economic and Social

Table A1: Population for each country

Table A1	2015	2020	2025	2030	2035	2040	2045	2050
	Total population (Mn)							
Egypt	94	103	111	120	128	137	146	153
Iran	79	84	87	89	90	92	93	94
Israel	8	9	10	10	11	12	12	13
Kuwait	4	4	5	5	5	5	6	6
Morocco	35	37	39	41	42	44	45	46
Oman	4	5	5	5	5	5	5	6
Qatar	2	3	3	3	3	4	4	4
Saudi Arabia	31	35	37	39	41	43	44	45
Tunisia	11	12	12	13	13	13	14	14
UAE	9	10	10	11	12	12	13	13

Table A2: GDP ($US bn, 2010) for each country

Table A2	2015	2020					2030					2040					2050				
		BAU	ESC	WSC	FSC	NSC	BAU	ESC	WSC	FSC	NSC	BAU	ESC	WSC	FSC	NSC	BAU	ESC	WSC	FSC	NSC
	GDP ($US bn, 2010)																				
Egypt	255	324	322	327	323	318	418	425	421	421	422	525	527	523	525	573	639	641	637	641	725.1
Iran	486	572	575	574	574	572	596	611	607	607	604	602	631	600	599	654	609	641	608	607	668
Israel	264	299	306	303	303	300	367	370	368	368	369	432	439	439	438	456	494	497	487	486	540
Kuwait	127	139	142	140	139	138	163	167	165	164	165	190	190	191	190	206	219	219	216	208	241
Morocco	105	121	122	121	121	120	148	150	149	149	150	175	178	177	177	182	202	207	205	204	213
Oman	75	87	88	88	88	87	112	114	116	113	115	135	138	139	137	144	156	160	154	152	172
Qatar	190	206	206	206	206	205	235	235	235	237	238	253	254	254	254	260	265	267	262	259	276
Saudi Arabia	659	723	726	726	726	722	857	870	872	865	899	1,000	1,020	1,005	994	1,076	1,152	1,162	1,151	1,150	1,268
Tunisia	47	53	53	53	53	52	66	66	66	66	69	80	78	78	78	88	94	91	91	90	104
UAE	424	478	479	480	479	480	553	556	558	556	569	627	633	628	626	677	693	704	690	688	768.5

Table A3: GDP (per-capita) for each country

Table A3	2015	2020					2030					2040					2050				
		BAU	ESC	WSC	FSC	NSC	BAU	ESC	WSC	FSC	NSC	BAU	ESC	WSC	FSC	NSC	BAU	ESC	WSC	FSC	NSC
	Per-capita GDP (constant 2010US$)																				
Egypt	2,710	3,152	3,124	3,174	3,136	3,091	3,492	3,552	3,513	3,519	3,523	3,829	3,843	3,819	3,830	4,183	4,163	4,179	4,153	4,175	4,726
Iran	6,120	6,841	6,880	6,866	6,862	6,849	6,701	6,871	6,834	6,827	6,792	6,555	6,861	6,529	6,518	7,117	6,508	6,853	6,499	6,483	7,140
Israel	31,483	32,756	33,560	33,249	33,243	32,877	35,077	35,387	35,217	35,196	35,343	36,595	37,167	37,154	37,117	38,601	37,490	37,734	36,980	36,927	41,041
Kuwait	32,824	32,191	33,014	32,530	32,300	32,166	33,507	34,301	33,794	33,592	33,827	35,724	35,774	35,945	35,765	38,628	38,858	38,845	38,249	36,921	42,672
Morocco	3,017	3,270	3,281	3,277	3,276	3,227	3,627	3,662	3,650	3,648	3,671	4,008	4,067	4,048	4,049	4,162	4,426	4,530	4,484	4,478	4,662
Oman	18,396	19,102	19,197	19,200	19,190	19,063	22,427	22,913	23,386	22,681	23,195	25,727	26,436	26,504	26,200	27,586	28,170	28,890	27,799	27,450	31,014
Qatar	77,719	73,625	73,682	73,685	73,702	73,296	72,573	72,780	72,787	73,476	73,739	71,497	71,847	71,859	71,904	73,412	70,346	70,858	69,458	68,768	73,041
Saudi Arabia	20,968	20,829	20,903	20,904	20,902	20,799	21,717	22,027	22,075	21,915	22,770	23,388	23,839	23,491	23,243	25,154	25,579	25,791	25,543	25,528	28,140
Tunisia	4,183	4,490	4,468	4,467	4,468	4,387	5,171	5,107	5,104	5,106	5,371	5,949	5,831	5,827	5,830	6,549	6,768	6,588	6,582	6,512	7,504
UAE	46,118	48,720	48,805	48,918	48,828	48,903	50,019	50,338	50,434	50,305	51,463	51,341	51,892	51,451	51,291	55,436	52,668	53,455	52,451	52,255	58,379

Table A4: Trade balance (net exports) US$ billion by each country

Table A4	2015	2020					2030					2040					2050				
		BAU	ESC	WSC	FSC	NSC	BAU	ESC	WSC	FSC	NSC	BAU	ESC	WSC	FSC	NSC	BAU	ESC	WSC	FSC	NSC
	Trade balance (net exports) US$ billion																				
Egypt	-49.0	-68.1	-61.2	-60.5	-60.5	-61.3	-83.2	-82.5	-80.6	-78.5	-81.2	-98.8	-108.1	-103.2	-99.1	-104.0	-114.5	-108.1	-129.0	-120.8	-111.4
Iran	2.1	4.0	3.4	3.5	6.4	-2.0	5.0	4.1	3.6	14.1	2.9	4.5	3.4	1.9	20.3	6.2	-0.9	2.5	-0.3	2.3	9.2
Israel	-16.6	-17.1	-18.0	-17.4	-17.4	-17.9	-16.4	-17.2	-16.8	-16.6	-16.4	-13.8	-15.1	-15.0	-14.7	-8.4	-8.9	-11.4	-11.4	-10.9	-6.6
Kuwait	33.4	35.7	36.1	36.5	36.0	36.4	39.5	40.1	39.8	40.4	40.7	45.7	44.1	42.9	44.8	50.1	51.4	48.1	45.9	49.6	55.9
Morocco	-20.8	-21.0	-20.6	-20.7	-20.2	-21.4	-21.9	-20.2	-20.4	-18.4	-23.6	-21.2	-17.9	-18.2	-14.0	-19.5	-19.0	-13.9	-14.3	-6.9	-13.4
Oman	20.1	22.4	21.7	21.8	21.7	20.5	26.6	23.7	23.9	23.8	25.7	26.5	23.4	23.9	23.7	27.4	26.2	21.8	21.7	21.3	30.4
Qatar	74.8	77.7	78.1	78.1	78.1	75.3	81.5	82.8	82.8	82.9	80.6	80.0	82.2	78.6	79.2	83.6	75.2	78.6	76.4	75.7	80.5
Saudi Arabia	79.8	85.6	86.9	87.3	87.3	84.1	98.9	102.0	103.1	103.4	101.8	114.5	117.8	119.8	120.6	123.0	134.3	134.2	137.6	138.8	139.1
Tunisia	-20.8	-21.0	-20.6	-20.7	-20.2	-21.4	-21.9	-20.2	-20.4	-18.4	-23.6	-21.2	-17.9	-18.2	-14.0	-19.5	-19.0	-13.9	-14.3	-6.9	-13.4
UAE	164.9	180.5	178.3	180.1	179.1	178.1	196.8	191.2	193.9	192.5	194.8	210.3	200.7	205.4	202.6	211.1	219.1	205.2	211.4	207.5	224.1

Table A5: Investment in power plants infrastructure

Table A5	2015-2030					2030-2050				
	BAU	ESC	WSC	FSC	NSC	BAU	ESC	WSC	FSC	NSC
	Investment in power plants infrastructure (US$bn, 2010)									
Egypt	32	57	26	28	36	97.7	205.1	72.7	109.2	136.9
Iran	77	128	94	71	87	152	235	169	178	224
Israel	28	51	42	33	38	76	220	180	120	215
Kuwait	20	52	37	32	24	54	148	57	80	161
Morocco	11	44	31	25	21	31	106	78	83	40
Oman	14	18	17	16	18	38	38	37	34	47
Qatar	29	23	32	35	73	65	64	111	108	95
Saudi Arabia	84	91	89	88	90	225	308	300	297	302
Tunisia	5	8	4	5	11	14	12	7	8	22
UAE	68	60	67	37	68	170	323	174	197	306

Table A6: Investment in water system infrastructure

Table A6	2015-2030					2030-2050				
	BAU	ESC	WSC	FSC	NSC	BAU	ESC	WSC	FSC	NSC
	Investment in water system infrastructure (US$bn, 2010)									
Egypt	8	8	9	8	8	16	17	18	18	16
Iran	29	33	34	30	34	40	33	83	43	52
Israel	7	8	8	7	8	12	17	14	14	16
Kuwait	3	4	4	4	5	5	11	14	10	14
Morocco	3	2	4	2	5	5	8	10	3	10
Oman	2	2	2	2	2	3	4	4	4	4
Qatar	4	4	5	4	6	6	7	9	7	6
Saudi Arabia	14	13	15	12	15	25	26	32	25	35
Tunisia	1	1	1	1	1	2	2	2	2	3
UAE	9	12	15	11	17	15	22	30	21	39

Table A7: Investment in transportation system infrastructure

Table A7	2015-2030					2030-2050				
	BAU	ESC	WSC	FSC	NSC	BAU	ESC	WSC	FSC	NSC
	Investment in transportation system infrastructure (US$bn, 2010)									
Egypt	28	44	50	54	54	86.0	152.2	160.5	179.9	237.0
Iran	63	78	77	52	73	128	159	152	61	170
Israel	25	28	28	28	30	66	79	79	79	104
Kuwait	20	25	32	25	25	54	80	104	78	91
Morocco	10	9	10	10	11	27	24	24	25	39
Oman	14	18	17	17	15	38	58	56	56	58
Qatar	29	32	32	31	57	65	74	74	72	68
Saudi Arabia	73	110	109	108	128	225	351	345	342	355
Tunisia	4	6	6	6	6	13	18	18	19	22
UAE	68	71	70	71	89	170	185	182	184	202

Table A8: Economy-investment indices

Table A8	2015-2050				
	BAU	ESC	WSC	FSC	NSC
	GDP-investment index ($GDP/$investment)				
Egypt	0.031	0.038	0.054	0.046	0.042
Iran	0.024	0.027	0.029	0.040	0.030
Israel	0.034	0.035	0.040	0.049	0.038
Kuwait	0.021	0.019	0.025	0.026	0.022
Morocco	0.034	0.031	0.038	0.039	0.048
Oman	0.020	0.033	0.033	0.034	0.034
Qatar	0.024	0.037	0.028	0.029	0.026
Saudi Arabia	0.026	0.037	0.037	0.038	0.039
Tunisia	0.041	0.055	0.070	0.063	0.045
UAE	0.022	0.030	0.037	0.038	0.030

Table A9: Total employment in each country

Table A9	2015	2020					2030					2040					2050				
		BAU	ESC	WSC	FSC	NSC	BAU	ESC	WSC	FSC	NSC	BAU	ESC	WSC	FSC	NSC	BAU	ESC	WSC	FSC	NSC
	Total employment (Mn person)																				
Egypt	28,226	36,516	35,248	35,439	35,891	35,817	48,021	44,983	45,463	47,280	47,001	61,479	55,927	57,007	60,657	60,151	76,287	67,400	69,192	74,865	74,436
Iran	20,914	24,164	24,155	24,206	24,261	24,841	25,224	25,270	25,290	25,576	26,086	25,532	25,733	25,733	26,245	26,647	25,873	25,811	25,788	26,508	26,430
Israel	3,728	4,209	4,260	4,260	4,259	4,290	5,139	5,114	5,118	5,115	5,181	6,027	6,029	6,040	6,034	6,236	6,871	6,989	7,006	6,997	7,333
Kuwait	1,581	1,753	1,745	1,751	1,748	1,801	2,130	2,086	2,091	2,105	2,198	2,548	2,462	2,466	2,499	2,646	3,022	2,904	2,909	2,963	3,181
Morocco	11,542	13,377	13,317	13,329	13,373	13,382	16,132	15,895	15,929	16,024	16,073	18,800	18,379	18,422	18,717	18,857	21,385	20,823	20,833	21,269	21,617
Oman	1,323	1,547	1,549	1,551	1,549	1,580	1,985	1,988	1,990	1,986	2,078	2,408	2,397	2,413	2,406	2,587	2,815	2,792	2,818	2,807	3,106
Qatar	1,269	1,380	1,380	1,380	1,386	1,391	1,594	1,595	1,593	1,612	1,627	1,739	1,736	1,738	1,770	1,797	1,848	1,845	1,847	1,895	1,933
Saudi Arabia	11,236	12,619	12,454	12,472	12,472	12,641	15,679	15,164	15,223	15,226	15,738	19,080	18,113	18,230	18,239	19,210	22,839	21,306	21,500	21,514	23,072
Tunisia	3,349	3,804	3,776	3,777	3,772	4,119	4,752	4,664	4,665	4,650	5,098	5,749	5,579	5,582	5,554	6,116	6,794	6,524	6,527	6,509	7,175
UAE	6,102	6,940	6,898	6,959	6,926	7,075	8,183	8,278	8,192	8,125	8,588	9,456	9,268	9,447	9,335	10,194	10,659	10,371	10,624	10,457	11,767

Table A10: Employment in major sectors of the economy for each country

Egypt	2015	2020					2030					2040					2050				
		BAU	ESC	WSC	FSC	NSC	BAU	ESC	WSC	FSC	NSC	BAU	ESC	WSC	FSC	NSC	BAU	ESC	WSC	FSC	NSC
Agriculture	9,678	13,108	11,625	11,743	12,198	11,719	18,592	14,187	14,357	17,944	14,436	25,454	16,828	17,472	20,788	17,317	33,545	19,394	20,315	25,925	19,526
Industry	3,886	4,977	4,979	5,006	4,859	5,024	6,567	6,622	6,704	6,193	6,748	8,432	8,568	8,690	7,660	8,769	10,492	10,766	10,937	9,147	10,878
Commercial services	10,488	*13,152*	*13,373*	*13,433*	*13,582*	*13,821*	*16,267*	*17,154*	*17,707*	*16,420*	19,041	19,599	22,429	22,573	23,800	25,461	22,897	27,850	27,986	29,559	32,412
Transport services	1,969	*2,495*	*2,498*	*2,538*	*2,555*	*2,650*	*3,040*	*3,270*	*3,366*	*3,453*	3,793	3,585	4,170	4,323	4,547	5,264	4,069	5,171	5,402	5,811	6,975
Energy	2,195	2,771	2,762	2,707	2,685	2,591	3,540	3,733	3,314	3,254	2,968	4,390	3,912	3,930	3,841	3,321	5,261	4,194	4,529	4,396	4,624
Water	9	12	12	12	12	12	15	16	15	16	15	19	20	19	21	19	24	25	22	26	22

Iran	2015	2020					2030					2040					2050				
		BAU	ESC	WSC	FSC	NSC	BAU	ESC	WSC	FSC	NSC	BAU	ESC	WSC	FSC	NSC	BAU	ESC	WSC	FSC	NSC
Agriculture	4,257	4,326	4,233	4,229	4,219	5,247	4,654	4,236	4,222	4,670	5,082	4,835	4,108	4,084	4,015	4,776	5,098	3,893	3,860	3,754	4,355
Industry	3,436	2,892	2,895	2,897	2,894	3,868	3,428	3,468	3,462	3,453	4,247	3,879	3,998	3,983	3,962	4,526	4,288	4,480	4,455	4,419	4,722
Commercial services	7,712	*10,588*	*10,702*	*10,698*	*10,671*	*9,362*	*10,505*	*10,838*	*10,959*	*10,548*	10,119	10,145	10,989	10,938	10,820	10,650	9,844	10,812	10,742	10,574	10,747
Transport services	1,511	*1,855*	*1,874*	*1,871*	*1,868*	*1,755*	*1,882*	*1,963*	*1,954*	*1,945*	1,905	1,857	2,005	1,989	1,971	2,013	1,835	2,056	2,035	2,008	2,097
Energy	3,947	4,442	4,391	4,453	4,550	4,551	4,693	4,703	4,639	4,901	4,678	4,754	4,573	4,690	5,420	4,633	4,746	4,511	4,652	5,699	4,468
Water	52	60	60	57	60	59	62	61	53	59	55	61	60	48	57	49	61	58	45	54	42

Israel	2015	2020					2030					2040					2050				
		BAU	ESC	WSC	FSC	NSC	BAU	ESC	WSC	FSC	NSC	BAU	ESC	WSC	FSC	NSC	BAU	ESC	WSC	FSC	NSC
Agriculture	132	151	158	153	153	149	190	198	192	192	176	229	245	235	235	203	267	296	282	282	227
Industry	607	700	722	720	720	715	891	927	927	925	905	1,091	1,167	1,169	1,166	1,119	1,296	1,442	1,445	1,442	1,351
Commercial services	2,549	*2,865*	*2,918*	*2,889*	*2,888*	*2,928*	*3,462*	*3,428*	*3,413*	*3,412*	3,509	4,017	3,951	3,956	3,954	4,219	4,510	4,470	4,483	4,480	4,928
Transport services	278	*318*	*322*	*322*	*322*	*325*	*399*	*396*	*397*	*396*	408	481	479	480	480	505	563	570	571	571	614
Energy	136	146	110	145	145	143	162	128	152	154	148	169	146	155	158	152	190	165	171	177	170
Water	27	30	31	31	30	30	36	36	38	35	34	41	41	45	40	38	45	46	54	45	41

Kuwait	2015	2020					2030					2040					2050				
		BAU	ESC	WSC	FSC	NSC	BAU	ESC	WSC	FSC	NSC	BAU	ESC	WSC	FSC	NSC	BAU	ESC	WSC	FSC	NSC
Agriculture	60	69	68	66	68	57	92	92	90	97	73	119	121	119	121	94	149	154	153	153	115
Industry	78	81	87	87	87	87	88	96	106	101	107	94	125	125	125	127	98	140	141	140	141
Commercial services	783	*889*	*857*	*843*	*862*	*829*	*1,125*	*1,065*	*1,052*	*1,066*	1,094	1,394	1,302	1,293	1,298	1,409	1,692	1,558	1,554	1,546	1,762
Transport services	189	*205*	*205*	*203*	*205*	*200*	*239*	*243*	*242*	*244*	247	276	287	286	286	300	339	387	387	385	420
Energy	419	453	467	492	463	566	523	524	522	516	593	596	524	542	567	607	672	543	556	618	613
Water	53	56	62	61	62	62	62	66	80	81	84	69	103	100	103	108	72	122	118	121	130

Morocco	2015	2020					2030					2040					2050				
		BAU	ESC	WSC	FSC	NSC	BAU	ESC	WSC	FSC	NSC	BAU	ESC	WSC	FSC	NSC	BAU	ESC	WSC	FSC	NSC
Agriculture	5,005	5,857	5,794	5,809	5,843	5,848	6,842	6,594	6,644	6,875	6,672	7,718	7,262	7,346	7,539	7,523	8,492	7,849	7,932	8,205	8,167
Industry	1,899	2,209	2,240	2,242	2,244	2,240	2,742	2,915	2,920	2,787	2,919	3,286	3,654	3,663	3,692	3,657	3,841	4,463	4,471	4,529	4,466
Commercial services	3,556	*4,056*	*4,006*	*4,011*	*4,013*	*4,034*	*4,998*	*4,758*	*4,776*	*4,794*	4,896	5,948	5,461	5,492	5,519	5,727	6,908	6,128	6,161	6,208	6,545
Transport services	700	*817*	*811*	*812*	*813*	*818*	*1,025*	*996*	*999*	*1,007*	1,031	1,241	1,181	1,186	1,199	1,251	1,468	1,368	1,373	1,395	1,483
Energy	375	430	458	447	453	434	518	623	580	553	545	596	813	724	759	687	665	1,006	883	923	942
Water	7	8	8	8	8	8	9	8	10	9	10	10	9	11	10	12	11	9	13	10	14

Oman	2015	2020					2030					2040					2050				
		BAU	ESC	WSC	FSC	NSC	BAU	ESC	WSC	FSC	NSC	BAU	ESC	WSC	FSC	NSC	BAU	ESC	WSC	FSC	NSC
Agriculture	58	75	69	69	69	73	114	94	94	94	110	163	121	121	122	155	222	151	150	152	209
Industry	156	184	186	186	186	184	239	247	246	247	238	292	310	307	309	291	345	374	370	374	342
Commercial services	537	*615*	*619*	*619*	*620*	*633*	*751*	*755*	*769*	*770*	820	862	902	900	902	1,003	950	1,017	1,013	1,016	1,180
Transport services	168	*200*	*200*	*200*	*201*	*207*	*264*	*269*	*269*	*269*	294	331	341	340	341	394	398	417	415	416	507
Energy	359	420	420	420	419	425	544	547	532	530	524	665	622	633	631	611	782	707	724	722	685
Water	44	54	54	56	54	58	73	76	81	76	91	95	100	111	100	133	118	127	146	127	183

Qatar	2015	2020					2030					2040					2050				
		BAU	ESC	WSC	FSC	NSC	BAU	ESC	WSC	FSC	NSC	BAU	ESC	WSC	FSC	NSC	BAU	ESC	WSC	FSC	NSC
Agriculture	32	36	36	36	43	35	43	42	42	66	41	49	47	47	89	46	54	51	51	113	50
Industry	400	431	433	433	433	430	487	494	493	493	483	519	531	530	530	510	539	557	555	554	522
Commercial services	270	*306*	*304*	*304*	*304*	*315*	*385*	*379*	*379*	*377*	413	455	445	444	441	506	523	507	506	501	599
Transport services	116	*129*	*129*	*129*	*128*	*133*	*156*	*155*	*155*	*154*	167	178	175	175	174	197	197	193	193	191	224
Energy	400	423	423	423	423	422	460	463	460	459	457	471	470	469	469	465	466	465	465	464	460
Water	50	54	55	55	55	56	62	63	65	63	66	66	68	72	68	73	69	72	77	72	79

Saudi Arabia	2015	2020					2030					2040					2050				
		BAU	ESC	WSC	FSC	NSC	BAU	ESC	WSC	FSC	NSC	BAU	ESC	WSC	FSC	NSC	BAU	ESC	WSC	FSC	NSC
Agriculture	512	597	546	545	545	548	793	631	629	628	639	1,026	720	717	716	738	1,302	813	807	806	842
Industry	968	1,037	1,055	1,055	1,055	1,066	1,170	1,226	1,224	1,225	1,254	1,293	1,399	1,395	1,398	1,440	1,404	1,573	1,566	1,570	1,619
Commercial services	6,582	*7,477*	*7,395*	*7,389*	*7,389*	*7,572*	*9,472*	*9,225*	*9,206*	*9,206*	9,802	11,755	11,303	11,265	11,263	12,429	14,351	13,651	13,584	13,577	15,506
Transport services	598	*679*	*673*	*672*	*672*	*694*	*860*	*841*	*839*	*839*	911	1,068	1,035	1,030	1,029	1,173	1,307	1,256	1,249	1,246	1,488
Energy	2,223	2,430	2,388	2,407	2,413	2,359	2,882	2,741	2,806	2,829	2,620	3,314	3,038	3,167	3,218	2,787	3,706	3,258	3,476	3,564	2,819
Water	352	398	398	403	397	401	502	499	519	499	512	624	618	656	616	642	768	754	818	752	797

Tunisia	2015	2020					2030					2040					2050				
		BAU	ESC	WSC	FSC	NSC	BAU	ESC	WSC	FSC	NSC	BAU	ESC	WSC	FSC	NSC	BAU	ESC	WSC	FSC	NSC
Agriculture	792	892	869	869	865	893	1,098	1,023	1,023	1,013	1,040	1,310	1,168	1,169	1,150	1,171	1,528	1,304	1,305	1,274	1,289
Industry	1,192	1,367	1,388	1,388	1,381	1,564	1,741	1,808	1,808	1,784	2,020	2,145	2,271	2,271	2,228	2,523	2,578	2,776	2,777	2,737	3,071
Commercial services	959	*1,082*	*1,071*	*1,072*	*1,073*	*1,150*	*1,334*	*1,301*	*1,301*	*1,306*	1,423	1,594	1,532	1,533	1,541	1,707	1,862	1,765	1,766	1,780	2,002
Transport services	194	*219*	*216*	*216*	*217*	*251*	*269*	*259*	*259*	*264*	317	320	302	302	310	387	372	343	343	355	462
Energy	203	234	223	223	227	251	298	262	263	272	287	366	295	298	312	317	438	321	327	349	341
Water	9	10	10	9	10	10	12	12	10	11	10	14	13	10	13	11	16	15	9	14	10

UAE	2015	2020					2030					2040					2050				
		BAU	ESC	WSC	FSC	NSC	BAU	ESC	WSC	FSC	NSC	BAU	ESC	WSC	FSC	NSC	BAU	ESC	WSC	FSC	NSC
Agriculture	89	103	103	102	103	103	125	125	124	125	124	147	149	147	148	147	169	171	169	171	170
Industry	1,210	1,344	1,371	1,366	1,369	1,376	1,507	1,587	1,576	1,584	1,594	1,653	1,796	1,777	1,792	1,791	1,774	1,983	1,956	1,979	1,956
Commercial services	2,535	*2,926*	*2,906*	*2,870*	*2,888*	*2,993*	*3,546*	*3,467*	*3,417*	*3,447*	3,777	4,199	4,048	3,981	4,025	4,648	4,831	4,600	4,514	4,575	5,530
Transport services	626	*715*	*712*	*707*	*710*	*734*	*849*	*838*	*832*	*835*	911	987	966	959	963	1,105	1,116	1,086	1,078	1,083	1,300
Energy	1,469	1,651	1,598	1,698	1,650	1,651	1,905	1,990	1,942	1,863	1,866	2,161	1,965	2,179	2,062	2,066	2,403	2,106	2,388	2,226	2,232
Water	171	201	207	215	206	220	252	271	301	270	316	308	345	403	344	437	365	424	519	423	579

Section B: Energy security

Table B1: Primary energy demand (Mtoe)

Table B1	2015	2020					2030					2040					2050				
		BAU	ESC	WSC	FSC	NSC	BAU	ESC	WSC	FSC	NSC	BAU	ESC	WSC	FSC	NSC	BAU	ESC	WSC	FSC	NSC
	Primary energy demand (Mtoe)																				
Egypt	130	165	161	166	164	166	209	195	209	200	194	258	230	258	242	238	306	248	301	282	258
Iran	313	356	354	354	369	374	380	376	373	419	380	386	381	376	458	366	386	378	370	490	335
Israel	47	49	37	49	49	49	54	43	51	52	51	57	49	52	53	53	63	55	57	59	55
Kuwait	77	83	83	88	84	85	96	90	96	94	93	109	95	108	105	95	124	103	122	116	100
Morocco	30	34	34	34	35	34	42	41	41	43	39	49	47	48	52	45	56	51	54	61	48
Oman	40	46	45	45	45	44	58	54	60	59	52	69	61	68	68	57	80	66	79	81	58
Qatar	74	79	78	78	78	78	87	84	84	84	84	91	86	89	89	85	92	85	88	88	84
Saudi Arabia	338	408	401	403	404	408	518	494	500	505	502	640	592	603	614	589	773	691	711	729	669
Tunisia	12	14	13	13	13	14	17	15	16	17	16	21	16	20	20	17	25	16	20	22	18
UAE	127	142	139	140	142	139	162	154	164	160	151	181	166	181	179	161	197	174	195	190	167

Table B2: Final energy demand (Mtoe)

Table B2	2015	2020					2030					2040					2050				
		BAU	ESC	WSC	FSC	NSC	BAU	ESC	WSC	FSC	NSC	BAU	ESC	WSC	FSC	NSC	BAU	ESC	WSC	FSC	NSC
	Final energy demand (Mtoe)																				
Egypt	61	77	75	78	77	79	99	96	99	95	96	123	118	124	117	122	147	133	146	138	129
Iran	157	179	181	178	186	195	194	200	192	214	208	200	210	196	238	208	203	214	196	258	195
Israel	16	18	15	18	18	18	20	17	19	19	20	22	20	20	20	21	25	23	23	23	22
Kuwait	14	16	16	17	16	17	18	18	19	19	19	21	20	22	21	20	24	23	26	24	22
Morocco	15	17	17	17	17	17	21	21	21	21	20	25	24	25	25	24	29	27	28	29	27
Oman	19	22	22	22	22	21	27	26	29	28	26	32	29	32	32	29	37	32	37	38	31
Qatar	16	17	17	17	17	17	19	18	18	18	19	20	18	19	19	19	21	18	18	18	20
Saudi Arabia	126	152	151	151	151	155	194	190	190	189	196	239	232	231	231	237	290	277	275	275	282
Tunisia	7	8	8	8	8	9	10	9	10	10	11	13	10	13	12	13	15	11	13	13	14
UAE	50	56	56	55	57	55	63	62	64	63	61	70	67	70	70	66	76	71	74	73	69

Table B3: Primary energy mix (Mtoe) by country

Egypt	2015	2020					2030					2040					2050				
		BAU	ESC	WSC	FSC	NSC	BAU	ESC	WSC	FSC	NSC	BAU	ESC	WSC	FSC	NSC	BAU	ESC	WSC	FSC	NSC
	Primary energy mix (Mtoe)																				
Coal	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	2	1	1	1	2
Oil	38	46	45	47	46	46	54	49	54	54	48	65	46	64	63	48	73	37	72	70	39
Gas	83	*107*	*98*	*108*	*106*	*108*	*140*	*113*	*136*	*130*	120	174	115	168	157	143	208	151	196	183	142
Uranium	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Renewable	7	11	17	11	11	11	14	32	18	15	24	17	68	25	21	47	23	58	32	27	76

Iran	2015	2020					2030					2040					2050				
		BAU	ESC	WSC	FSC	NSC	BAU	ESC	WSC	FSC	NSC	BAU	ESC	WSC	FSC	NSC	BAU	ESC	WSC	FSC	NSC
	Primary energy mix (Mtoe)																				
Coal	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
Oil	63	71	71	71	74	75	80	72	78	88	68	85	69	75	92	59	89	64	74	103	47
Gas	220	*255*	*248*	*248*	*258*	*262*	*270*	*260*	*258*	*289*	262	270	259	256	312	245	267	257	248	333	221
Uranium	*1*	*1*	*1*	*1*	*1*	*1*	*1*	*1*	*1*	*1*	2	1	1	1	1	2	1	1	1	1	2
Renewable	29	29	34	34	35	36	29	43	36	40	47	29	52	43	53	60	29	55	46	52	64

Israel	2015	2020					2030					2040					2050				
		BAU	ESC	WSC	FSC	NSC	BAU	ESC	WSC	FSC	NSC	BAU	ESC	WSC	FSC	NSC	BAU	ESC	WSC	FSC	NSC
	Primary energy mix (Mtoe)																				
Coal	17	17	13	17	17	17	19	13	16	17	15	18	12	15	16	11	19	11	14	16	8
Oil	0	0	0	0	0	0	1	0	1	1	1	1	0	1	1	1	1	1	1	1	1
Gas	29	*31*	*22*	*30*	*30*	*30*	*34*	*24*	*31*	*33*	28	37	25	31	34	27	41	25	35	38	25
Uranium	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Renewable	1	1	1	1	1	2	1	6	3	2	7	1	12	6	3	15	2	19	7	4	21

Kuwait	2015	2020					2030					2040					2050				
		BAU	ESC	WSC	FSC	NSC	BAU	ESC	WSC	FSC	NSC	BAU	ESC	WSC	FSC	NSC	BAU	ESC	WSC	FSC	NSC
	Primary energy mix (Mtoe)																				
Coal	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Oil	49	52	51	54	51	52	59	49	54	55	49	67	47	55	57	46	74	43	56	58	45
Gas	28	*31*	*30*	*33*	*31*	*31*	*36*	*34*	*36*	*36*	33	43	38	42	41	32	49	41	49	47	33
Uranium	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Renewable	0	0	2	2	2	3	0	6	6	4	11	0	9	11	7	17	0	19	17	12	22

Morocco	2015	2020					2030					2040					2050				
		BAU	ESC	WSC	FSC	NSC	BAU	ESC	WSC	FSC	NSC	BAU	ESC	WSC	FSC	NSC	BAU	ESC	WSC	FSC	NSC
	Primary energy mix (Mtoe)																				
Coal	16.95	18.89	18.72	18.78	19.44	18.53	20.92	19.58	20.57	23.41	18.15	23.03	18.82	21.46	27.09	17.16	25.09	17.72	21.51	30.50	14.41
Oil	2	2	2	2	2	2	3	2	2	3	2	3	2	2	4	2	3	1	2	4	1
Gas	6	*7*	*7*	*6*	*7*	*6*	*8*	*9*	*8*	*8*	8	9	11	9	9	9	10	13	10	11	10
Uranium	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Renewable	5	7	6	6	6	6	10	10	10	9	11	14	15	15	12	17	17	19	20	15	23

Oman	2015	2020					2030					2040					2050				
		BAU	ESC	WSC	FSC	NSC	BAU	ESC	WSC	FSC	NSC	BAU	ESC	WSC	FSC	NSC	BAU	ESC	WSC	FSC	NSC
	Primary energy mix (Mtoe)																				
Coal	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Oil	1	2	2	2	2	2	3	3	5	5	1	4	5	7	7	1	6	7	9	10	1
Gas	38	*43*	*42*	*43*	*43*	*41*	*53*	*46*	*54*	*53*	45	60	48	58	59	40	65	47	63	65	41
Uranium	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Renewable	0	0	1	0	0	1	2	5	1	1	7	6	9	3	3	16	10	13	6	6	16

Qatar	2015	2020					2030					2040					2050				
		BAU	ESC	WSC	FSC	NSC	BAU	ESC	WSC	FSC	NSC	BAU	ESC	WSC	FSC	NSC	BAU	ESC	WSC	FSC	NSC
	Primary energy mix (Mtoe)																				
Coal	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Oil	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Gas	74	*79*	*78*	*78*	*78*	*78*	*87*	*83*	*83*	*83*	80	91	82	87	89	77	92	80	85	87	72
Uranium	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Renewable	0	0	0	0	0	0	0	2	1	0	4	0	3	2	1	9	0	5	3	1	13

Saudi Arabia	2015	2020					2030					2040					2050				
		BAU	ESC	WSC	FSC	NSC	BAU	ESC	WSC	FSC	NSC	BAU	ESC	WSC	FSC	NSC	BAU	ESC	WSC	FSC	NSC
	Primary energy mix (Mtoe)																				
Coal	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Oil	147	167	160	165	166	163	181	173	175	187	176	179	118	163	215	177	170	118	178	219	134
Gas	191	*241*	*225*	*230*	*238*	*228*	*336*	*272*	*300*	*313*	251	448	326	374	387	265	580	373	462	474	267
Uranium	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Renewable	0	0	16	8	0	16	1	49	25	5	75	13	148	66	12	147	23	201	71	36	267

Tunisia	2015	2020					2030					2040					2050				
		BAU	ESC	WSC	FSC	NSC	BAU	ESC	WSC	FSC	NSC	BAU	ESC	WSC	FSC	NSC	BAU	ESC	WSC	FSC	NSC
	Primary energy mix (Mtoe)																				
Coal	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Oil	0	1	1	1	1	1	1	0	1	1	0	1	0	1	1	0	1	0	1	1	0
Gas	11	*13*	*12*	*12*	*12*	*13*	*16*	*12*	*14*	*15*	13	19	13	17	18	12	22	12	16	19	11
Uranium	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Renewable	0	0	1	1	0	1	1	2	1	1	2	1	3	2	1	5	1	4	3	2	7

UAE	2015	2020					2030					2040					2050				
		BAU	ESC	WSC	FSC	NSC	BAU	ESC	WSC	FSC	NSC	BAU	ESC	WSC	FSC	NSC	BAU	ESC	WSC	FSC	NSC
	Primary energy mix (Mtoe)																				
Coal	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Oil	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	2	1	2	2	1
Gas	126	*141*	*137*	*138*	*139*	*136*	*160*	*135*	*153*	*152*	129	179	133	161	167	126	194	126	167	171	117
Uranium	-	-		-	-	-	-	*1.39*	-	-	-	-	1.84	-	-	-	-	2.32	-	-	-
Renewable	0	0	2	2	2	2	0	17	10	7	22	0	32	18	11	34	1	47	26	17	49

Table B4: Electricity demand (Mtoe)

Table B4	2015	2020					2030					2040					2050				
		BAU	ESC	WSC	FSC	NSC	BAU	ESC	WSC	FSC	NSC	BAU	ESC	WSC	FSC	NSC	BAU	ESC	WSC	FSC	NSC
	Electricity demand demand (Mtoe)																				
Egypt	13.7	18.7	18.2	18.2	18.1	18.1	24.1	23.0	23.3	23.0	23.0	30.3	28.4	29.0	28.5	28.5	36.9	33.6	35.0	34.3	35.1
Iran	18.3	20.3	22.3	20.6	20.8	25.0	25.5	29.1	22.3	22.8	30.4	29.7	36.3	34.7	36.3	33.5	33.6	38.6	35.4	37.8	33.1
Israel	4.8	5.5	5.4	5.5	5.5	5.4	6.7	6.4	6.5	6.5	6.3	7.9	7.5	7.6	7.6	7.1	9.1	8.6	8.7	8.7	8.0
Kuwait	4.1	4.7	4.6	4.6	4.6	4.6	5.7	5.6	5.6	5.6	5.6	6.9	6.6	6.6	6.7	6.8	8.1	7.8	7.8	7.8	8.0
Morocco	2.6	2.9	2.9	2.9	3.0	2.9	4.1	3.4	3.4	3.6	3.2	5.0	3.8	3.8	4.2	3.5	5.9	4.1	4.2	4.8	3.6
Oman	1.6	2.0	2.0	2.0	2.0	2.0	2.7	2.6	2.6	2.6	2.7	3.3	3.3	3.3	3.3	3.5	4.1	4.0	4.0	4.0	4.3
Qatar	2.9	3.2	3.1	3.1	3.1	3.0	3.7	3.3	3.3	3.3	3.2	4.1	3.4	3.3	3.3	3.1	4.3	3.4	3.3	3.2	3.0
Saudi Arabia	22.3	25.7	25.4	25.4	25.4	25.5	35.3	30.9	31.0	30.9	31.3	47.3	37.0	37.1	37.1	37.7	62.7	43.8	44.0	43.9	44.9
Tunisia	1.4	1.6	1.6	1.6	1.6	1.7	2.0	1.9	1.9	1.9	2.0	2.4	2.2	2.2	2.2	2.3	2.8	2.6	2.5	2.5	2.6
UAE	6.0	7.0	7.0	7.0	7.0	7.1	8.4	8.2	8.2	8.2	8.5	9.7	9.4	9.5	9.4	10.0	11.0	10.5	10.7	10.5	11.6

Table B5: Energy intensity of the economy (toe/US$ 2010)

Table B5	2015	2020					2030					2040					2050				
		BAU	ESC	WSC	FSC	NSC	BAU	ESC	WSC	FSC	NSC	BAU	ESC	WSC	FSC	NSC	BAU	ESC	WSC	FSC	NSC
	Energy intensity of the economy (toe/US$ 2010)																				
Egypt	510	508	499	509	507	520	500	459	496	475	460	491	438	493	461	416	479	386	472	440	356
Iran	646	623	616	617	643	654	638	617	615	691	630	640	605	627	765	560	634	589	609	807	501
Israel	178	165	122	161	162	164	149	117	139	141	139	131	112	118	121	116	128	110	117	121	102
Kuwait	603	598	585	629	604	615	586	537	582	576	566	574	497	563	550	461	564	469	565	559	413
Morocco	285	283	280	281	286	282	282	272	276	291	263	280	265	270	294	248	276	245	263	298	226
Oman	530	522	508	509	509	504	519	472	514	525	453	514	441	492	497	394	510	410	512	530	338
Qatar	389	383	378	378	378	380	371	358	357	353	352	358	338	350	352	329	345	317	335	340	306
Saudi Arabia	511	564	553	555	557	565	604	569	574	584	558	640	580	600	617	547	671	595	618	634	527
Tunisia	256	258	243	245	246	261	260	222	249	253	228	263	201	258	256	197	264	179	224	239	174
UAE	299	297	291	292	296	289	293	276	295	288	266	289	262	288	286	238	284	248	282	276	218

Table B6: Energy efficiency in each country

Table B6	2015	2020					2030					2040					2050				
		BAU	ESC	WSC	FSC	NSC	BAU	ESC	WSC	FSC	NSC	BAU	ESC	WSC	FSC	NSC	BAU	ESC	WSC	FSC	NSC
	Energy efficiency																				
Egypt	47%	47%	47%	47%	47%	48%	47%	49%	47%	48%	49%	48%	51%	48%	48%	51%	48%	54%	49%	49%	50%
Iran	50%	50%	51%	50%	50%	52%	51%	53%	51%	51%	55%	52%	55%	52%	52%	57%	53%	57%	53%	53%	58%
Israel	35%	36%	39%	36%	36%	37%	37%	40%	38%	37%	39%	38%	41%	39%	39%	40%	39%	41%	40%	39%	40%
Kuwait	19%	19%	19%	19%	19%	19%	19%	20%	20%	20%	20%	19%	21%	20%	20%	21%	19%	23%	21%	21%	22%
Morocco	50%	50%	50%	50%	49%	50%	51%	51%	51%	48%	52%	51%	52%	51%	48%	54%	53%	54%	52%	47%	56%
Oman	48%	48%	48%	48%	48%	49%	47%	48%	48%	48%	50%	47%	48%	47%	47%	51%	46%	48%	47%	47%	52%
Qatar	22%	22%	22%	22%	22%	22%	22%	21%	21%	21%	23%	23%	21%	21%	21%	23%	23%	21%	21%	21%	23%
Saudi Arabia	37%	37%	38%	38%	37%	38%	37%	38%	38%	38%	39%	37%	39%	38%	38%	40%	37%	40%	39%	38%	42%
Tunisia	62%	61%	62%	62%	61%	64%	60%	63%	62%	61%	69%	60%	64%	62%	61%	74%	59%	66%	63%	61%	80%
UAE	40%	40%	40%	39%	40%	40%	39%	40%	39%	39%	40%	39%	41%	39%	39%	41%	39%	41%	38%	39%	41%

Table B7: Energy diversity index in each country

Table B7	2015	2020					2030					2040					2050				
		BAU	ESC	WSC	FSC	NSC	BAU	ESC	WSC	FSC	NSC	BAU	ESC	WSC	FSC	NSC	BAU	ESC	WSC	FSC	NSC
	Energy diversity index																				
Egypt	50%	51%	46%	42%	51%	51%	52%	43%	41%	50%	46%	52%	38%	40%	48%	51%	53%	45%	40%	49%	41%
Iran	62%	64%	62%	62%	62%	62%	64%	63%	61%	61%	60%	63%	62%	59%	52%	57%	62%	61%	58%	60%	57%
Israel	50%	51%	44%	51%	51%	44%	51%	38%	48%	51%	37%	53%	34%	45%	39%	40%	53%	33%	45%	50%	34%
Kuwait	54%	53%	50%	51%	51%	50%	53%	45%	46%	48%	42%	53%	42%	42%	20%	21%	55%	37%	39%	42%	36%
Morocco	39%	38%	38%	38%	39%	38%	35%	34%	35%	37%	34%	34%	32%	34%	48%	54%	33%	33%	34%	35%	36%
Oman	93%	90%	89%	90%	90%	89%	83%	75%	82%	82%	74%	75%	63%	74%	47%	51%	68%	55%	66%	66%	57%
Qatar	100%	100%	100%	100%	100%	100%	100%	96%	98%	99%	91%	100%	92%	96%	21%	23%	100%	89%	94%	97%	75%
Saudi Arabia	61%	62%	57%	59%	62%	56%	65%	52%	58%	63%	46%	68%	49%	56%	38%	40%	75%	49%	59%	62%	42%
Tunisia	88%	87%	85%	85%	87%	85%	85%	74%	77%	83%	74%	83%	67%	71%	61%	74%	80%	61%	67%	78%	51%
UAE	98%	98%	96%	96%	96%	96%	98%	79%	87%	90%	74%	98%	68%	80%	39%	41%	97%	59%	76%	82%	58%

Table B8: Energy import dependency (%) in each country

Table B8	2015	2020					2030					2040					2050				
		BAU	ESC	WSC	FSC	NSC	BAU	ESC	WSC	FSC	NSC	BAU	ESC	WSC	FSC	NSC	BAU	ESC	WSC	FSC	NSC
	Energy import dependency (%)																				
Egypt	10.69	10.90	10.93	10.99	11.00	11.22	11.20	11.23	11.38	11.45	12.06	11.52	11.56	11.82	11.93	12.95	11.87	11.86	12.27	12.45	11.21
Iran	4.24	4.07	4.05	4.06	4.07	4.00	3.74	3.69	3.72	3.73	3.67	3.46	3.41	3.45	3.45	3.41	3.22	3.17	3.23	3.22	3.16
Israel	57.44	55.05	56.02	55.08	55.13	55.20	55.26	56.15	55.32	55.49	55.73	55.69	56.29	55.79	56.08	56.84	55.77	56.46	55.92	56.32	56.04
Kuwait	3.67	3.68	3.83	3.71	3.70	3.80	3.71	4.14	3.80	3.75	4.04	3.74	4.46	3.88	3.81	4.27	3.76	3.80	3.90	3.83	3.53
Morocco	67.17	67.37	67.44	67.41	67.23	67.71	67.16	67.32	67.24	66.80	68.07	66.92	67.13	67.67	67.69	68.27	66.65	67.50	68.03	68.56	66.97
Oman	4.24	4.23	4.25	4.24	4.25	4.26	4.20	4.26	4.23	4.24	4.32	4.17	4.27	4.22	4.23	4.37	4.15	4.28	4.20	4.22	4.34
Qatar	0.36	0.37	0.36	0.36	0.36	0.37	0.38	0.37	0.37	0.37	0.39	0.40	0.37	0.37	0.37	0.40	0.41	0.38	0.38	0.37	0.42
Saudi Arabia	2.13	2.01	1.98	1.99	1.99	1.97	1.83	1.77	1.79	1.79	1.70	1.63	1.54	1.57	1.59	1.41	1.43	1.29	1.35	1.38	1.10
Tunisia	50.41	49.81	49.75	49.73	49.66	50.48	48.66	48.46	48.40	48.27	49.94	47.59	47.13	47.05	46.89	49.18	46.57	45.72	45.65	45.27	47.08
UAE	14.32	14.44	13.90	14.31	14.25	13.51	14.66	13.14	14.38	14.18	12.06	14.87	12.31	14.44	14.07	10.38	15.07	11.39	14.47	13.94	10.98

Table B9: Value of energy imports (% of total merchandise exports)

Table B9	2015	2020					2030					2040					2050				
		BAU	ESC	WSC	FSC	NSC	BAU	ESC	WSC	FSC	NSC	BAU	ESC	WSC	FSC	NSC	BAU	ESC	WSC	FSC	NSC
	Value of energy imports (% of total merchandise exports)																				
Egypt	21.19	23.73	20.89	20.13	20.72	19.24	22.20	20.51	19.46	20.54	16.81	20.84	20.14	18.74	20.35	14.63	19.59	18.76	18.09	20.15	13.39
Iran	5.44	5.51	5.40	5.41	5.63	5.45	5.09	4.79	4.83	5.37	4.58	4.66	4.23	4.31	5.07	3.81	4.31	3.76	3.88	4.76	3.09
Israel	17.65	16.18	12.81	15.84	15.86	15.73	14.15	11.79	13.35	13.43	13.24	12.20	10.88	11.14	11.24	11.25	11.44	10.07	10.11	10.22	10.41
Kuwait	1.44	1.45	1.44	1.36	1.43	1.30	1.46	1.49	1.30	1.42	1.25	1.47	1.52	1.22	1.41	1.19	1.47	1.55	1.14	1.40	1.12
Morocco	40.22	37.71	37.19	37.26	37.24	37.18	35.62	33.89	34.06	33.98	33.91	33.65	31.03	31.28	31.22	30.97	31.82	27.81	28.83	28.84	28.34
Oman	4.45	4.50	4.40	4.40	4.41	4.28	4.65	4.39	4.38	4.39	4.12	4.79	4.32	4.31	4.32	3.88	4.91	4.19	4.18	4.19	3.57
Qatar	0.21	0.22	0.21	0.21	0.21	0.21	0.23	0.21	0.21	0.21	0.22	0.24	0.21	0.21	0.21	0.23	0.26	0.21	0.21	0.21	0.24
Saudi Arabia	2.15	2.13	2.05	2.07	2.08	1.98	2.13	1.92	1.97	1.99	1.71	2.05	1.73	1.81	1.85	1.39	1.90	1.48	1.60	1.67	1.03
Tunisia	17.94	17.31	16.52	16.58	16.63	14.06	16.17	14.17	14.32	14.46	11.85	15.15	12.07	12.29	12.50	9.80	14.25	10.18	10.44	10.56	7.90
UAE	2.46	2.49	2.39	2.44	2.43	2.32	2.55	2.26	2.44	2.41	2.08	2.62	2.12	2.43	2.38	1.83	2.68	1.97	2.42	2.34	1.56

Table B10: Share of energy expenditure (%) in each country

Table B10	2015	2020					2030					2040					2050				
		BAU	ESC	WSC	FSC	NSC	BAU	ESC	WSC	FSC	NSC	BAU	ESC	WSC	FSC	NSC	BAU	ESC	WSC	FSC	NSC
	Share of energy expenditure (%)																				
Egypt	5.87	5.67	5.83	5.49	5.49	5.03	5.22	5.47	4.84	4.82	3.76	4.72	5.13	4.14	4.17	2.65	4.17	4.49	3.50	3.54	4.52
Iran	9.75	9.93	9.81	9.89	10.22	10.28	11.04	10.65	10.97	12.02	10.65	11.86	11.18	11.77	13.78	10.58	12.35	11.51	12.42	15.50	10.27
Israel	3.60	3.14	1.03	3.08	3.10	3.03	2.17	1.02	2.07	2.09	2.00	1.21	1.01	1.13	1.14	1.15	1.02	0.99	0.94	0.94	0.99
Kuwait	17.58	17.09	20.69	24.10	19.28	33.85	16.17	18.02	20.56	17.57	28.60	15.31	15.54	17.21	15.99	23.62	14.50	13.23	14.04	14.52	16.51
Morocco	7.44	7.64	8.56	8.16	8.11	7.91	8.00	10.62	9.49	9.43	8.75	8.27	12.49	10.69	10.60	9.35	8.46	13.74	11.76	11.75	8.36
Oman	15.32	14.96	15.23	15.18	15.06	15.63	14.64	13.94	14.03	13.94	13.27	14.27	12.58	12.80	12.72	11.02	13.88	11.16	11.49	11.43	8.87
Qatar	6.24	6.08	5.94	5.93	5.90	5.80	5.76	5.41	5.38	5.32	5.07	5.47	4.92	4.87	4.79	4.45	5.20	4.46	4.40	4.31	3.91
Saudi Arabia	15.72	16.73	16.22	16.38	16.40	15.78	18.81	17.17	17.57	17.66	15.71	20.71	17.52	18.21	18.40	14.91	23.42	17.38	18.37	18.70	13.52
Tunisia	5.59	5.74	5.50	5.51	5.67	5.37	6.01	5.31	5.34	5.63	4.88	6.25	5.02	5.08	5.49	4.24	6.47	4.63	4.75	5.19	3.49
UAE	3.16	3.31	2.36	4.83	3.65	3.58	3.58	2.30	4.94	3.51	3.35	3.83	2.23	5.00	3.37	3.12	4.07	2.16	5.04	3.23	2.90

Section C: Water security

Table C1: Total renewable water resources (bn m3/yr)

Table C1	Total renewable water resources (bn m3/yr)	2015	2020	2030	2040	2050
		Renewable water availability (m3/person/yr)				
Egypt	58	622	566	487	425	380
Iran	137	1,728	1,639	1,542	1,491	1,464
Israel	1.8	213	195	170	151	135
Kuwait	0.0	5	5	4	4	4
Morocco	29.0	834	782	710	663	635
Oman	1.4	345	306	281	267	252
Qatar	0.1	24	21	18	16	15
Saudi Arabia	2.3	73	66	58	54	51
Tunisia	4.6	409	388	359	344	332
UAE	0.2	16	15	14	12	11

Table C2: Water demand (bn m3/yr)

Table C2	2015	2020					2030					2040					2050				
		BAU	ESC	WSC	FSC	NSC	BAU	ESC	WSC	FSC	NSC	BAU	ESC	WSC	FSC	NSC	BAU	ESC	WSC	FSC	NSC
	Water demand (bn m3/yr)																				
Egypt	61.4	81.1	81.4	80.7	80.8	81.0	111.7	94.6	92.7	99.8	94.9	149.2	115.5	114.3	126.3	112.4	192.4	137.3	134.2	154.6	131.3
Iran	80.9	90.3	88.8	87.2	88.8	88.0	103.9	94.4	84.9	93.5	95.7	113.3	97.0	81.1	96.2	86.9	124.7	97.3	78.4	95.6	79.0
Israel	2.0	2.3	2.4	2.3	2.3	2.4	2.8	2.9	2.9	2.9	2.7	3.4	3.4	3.5	3.4	3.2	3.8	4.0	4.1	4.0	3.7
Kuwait	1.2	1.4	1.4	1.4	1.3	1.4	1.6	1.6	1.4	1.5	1.5	1.7	1.7	1.6	1.7	1.6	1.9	1.9	1.8	1.9	1.7
Morocco	17.1	19.4	19.1	18.8	19.5	18.9	22.9	22.1	21.0	23.3	21.0	26.1	24.6	22.3	27.2	22.7	29.0	26.9	22.9	28.7	23.3
Oman	0.8	1.0	1.0	1.0	1.0	1.0	1.3	1.3	1.3	1.3	1.2	1.6	1.7	1.5	1.7	1.5	2.2	2.0	1.8	2.0	1.9
Qatar	0.30	0.43	0.39	0.37	0.42	0.40	0.52	0.47	0.47	0.49	0.47	0.61	0.56	0.55	0.61	0.54	0.66	0.62	0.60	0.68	0.59
Saudi Arabia	20.1	22.3	21.8	21.9	22.2	21.9	25.7	24.9	24.9	25.6	25.0	28.5	27.3	27.2	28.1	27.4	30.5	29.6	29.1	30.2	28.9
Tunisia	1.8	2.1	2.0	1.9	2.0	2.0	2.5	2.4	2.1	2.3	2.1	3.0	2.8	2.5	2.8	2.4	3.4	3.2	3.1	3.5	3.1
UAE	1.6	1.8	1.8	1.8	1.8	1.8	2.2	2.1	2.1	2.2	2.2	3.0	2.5	2.5	2.5	2.4	3.6	2.9	2.8	3.0	2.7

Table C3: Water demand per person (m3)

Table C3	2015	2020					2030					2040					2050				
		BAU	ESC	WSC	FSC	NSC	BAU	ESC	WSC	FSC	NSC	BAU	ESC	WSC	FSC	NSC	BAU	ESC	WSC	FSC	NSC
	Water demand per person (m3)																				
Egypt	653	788	791	784	785	787	933	790	774	833	792	1,088	843	834	922	820	1,254	895	875	1,008	856
Iran	1,021	1,079.7	1,062.3	1,042.7	1,061.8	1,052.6	1,169	1,062	956	1,052	1,077	1,232.7	1,055.8	882.9	1,046.7	945.3	1,333	1,040	838	1,022	844
Israel	243	250.2	258.8	255.8	254.9	259.0	270	274	276	274	261	284.1	287.9	296.3	291.7	267.8	292	301	314	307	281
Kuwait	314.7	321.7	318.7	324.9	308.7	324.0	324.7	321.7	295.1	311.2	306.0	328.7	325.8	301.3	319.6	303.8	331.0	330.1	311.2	332.0	307.3
Morocco	492	523.9	515.4	506.5	526.9	509.1	560	540	513	569	514	597.2	563.5	511.1	621.9	518.4	636	590	502	628	510
Oman	209	213.6	215.7	210.4	216.3	210.6	264	263	252	263	248	305.8	316.2	292.9	319.1	294.6	397	361	333	365	336
Qatar	124	153.3	138.2	131.8	149.2	141.8	160	147	146	150	145	171.7	158.7	156.8	172.1	151.7	175	163	159	180	156
Saudi Arabia	640	643.5	628.0	630.0	640.6	631.3	651	630	631	647	634	666.7	639.0	635.2	657.4	639.7	677	656	645	670	642
Tunisia	163	173.1	171.5	161.9	168.2	168.0	195	190	162	181	164	219.6	210.1	187.5	207.3	182.3	244	229	221	252	221
UAE	169	185.2	184.7	181.3	184.6	183.2	196	194	193	195	195	245.2	201.2	204.5	202.5	197.7	275	223	211	227	208

Table C4: Relative water stress (%)

Table C4	2015	2020					2030					2040					2050				
		BAU	ESC	WSC	FSC	NSC	BAU	ESC	WSC	FSC	NSC	BAU	ESC	WSC	FSC	NSC	BAU	ESC	WSC	FSC	NSC
	Relative water stress (%)																				
Egypt	10	14	14	14	14	14	19	16	16	17	16	25	20	19	21	19	32.6	23.3	22.2	26.2	21.3
Iran	59	66	65	63	65	64	76	69	62	68	69	83	71	59	70	63	91	71	57	70	57
Israel	59	64	66	64	65	65	76	77	73	76	69	87	87	80	87	73	95	96	85	97	77
Kuwait	98	110	109	105	105	100	122	121	95	115	86	132	130	90	124	85	137	136	83	132	81
Morocco	59	67	65	59	67	59	78	74	55	79	54	89	81	87	92	84	98	87	81	97	75
Oman	50	56	56	53	55	53	68	67	61	66	58	80	77	67	76	65	92	88	71	82	69
Qatar	83	112	101	88	108	89	119	107	90	110	90	137	107	96	118	81	126	118	98	109	87
Saudi Arabia	60	65	64	71	74	72	71	71	73	79	76	74	74	71	80	76	75	77	67	79	73
Tunisia	39	44	44	41	43	43	54	52	43	50	44	63	60	51	59	49	72	67	59	74	59
UAE	47	54	53	48	50	49	61	60	55	58	58	81	65	61	65	63	93	74	64	77	70

Table C5: Water intensity of the economy (liters/$US 2010)

Table C5	2015	2020					2030					2040					2050				
		BAU	ESC	WSC	FSC	NSC	BAU	ESC	WSC	FSC	NSC	BAU	ESC	WSC	FSC	NSC	BAU	ESC	WSC	FSC	NSC
	Water intensity of the economy (litres/$US 2010)																				
Egypt	241	250	253	247	250	254	267	222	220	237	225	284	219	218	241	196	301	214	211	241	181
Iran	147	158	154	152	155	154	174	155	140	154	159	188	154	135	161	133	205	152	129	158	118
Israel	8	8	8	8	8	8	8	8	8	8	7	8	8	8	8	7	8	8	8	8	7
Kuwait	10	10	10	10	10	10	10	9	9	9	9	9	9	8	9	8	9	8	8	9	7
Morocco	163	160	157	155	161	158	155	148	140	156	140	149	139	126	154	125	144	130	112	140	109
Oman	11	11	11	11	11	11	12	11	11	12	11	12	12	11	12	11	14	13	12	13	11
Qatar	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	3	2
Saudi Arabia	31	31	30	30	31	30	30	29	29	30	28	29	27	27	28	25	26	25	25	26	23
Tunisia	39	39	38	36	38	38	38	37	32	36	31	37	36	32	36	28	36	35	34	39	29
UAE	4	4	4	4	4	4	4	4	4	4	4	5	4	4	4	4	5	4	4	4	4

Section D: Food security

Table D1: Food accessibility index

Table D1	2015	2020					2030					2040					2050				
		BAU	ESC	WSC	FSC	NSC	BAU	ESC	WSC	FSC	NSC	BAU	ESC	WSC	FSC	NSC	BAU	ESC	WSC	FSC	NSC
	Food accessibility index																				
Egypt	0.33	0.32	0.34	0.34	0.34	0.34	0.28	0.36	0.36	0.36	0.37	0.25	0.38	0.37	0.38	0.38	0.22	0.39	0.39	0.40	0.41
Iran	0.53	0.68	0.70	0.70	0.70	0.48	0.61	0.69	0.68	0.71	0.53	0.56	0.69	0.68	0.71	0.58	0.50	0.71	0.70	0.75	0.66
Israel	1.14	1.14	1.11	1.13	1.13	1.18	1.14	1.10	1.10	1.11	1.26	1.13	1.09	1.08	1.10	1.35	1.14	1.08	1.06	1.09	1.47
Kuwait	6.44	6.30	6.40	6.50	6.36	6.28	6.04	6.08	6.11	6.08	6.06	5.83	5.82	5.78	5.83	7.12	6.07	6.53	6.40	6.57	8.39
Morocco	0.43	0.44	0.44	0.44	0.44	0.44	0.47	0.46	0.46	0.46	0.47	0.50	0.48	0.48	0.48	0.50	0.54	0.50	0.50	0.49	0.70
Oman	3.50	3.44	3.56	3.56	3.55	3.34	3.29	3.62	3.62	3.62	3.46	3.14	3.68	3.67	3.65	4.02	2.98	3.73	3.72	3.68	4.20
Qatar	3.74	3.80	3.81	3.81	3.51	3.99	3.92	3.94	3.95	3.21	4.41	4.02	4.05	4.07	2.96	4.81	4.11	4.15	4.17	2.74	5.19
Saudi Arabia	0.74	0.76	0.76	0.76	0.76	0.77	0.79	0.79	0.80	0.79	0.83	0.81	0.83	0.83	0.83	0.89	0.84	0.87	0.88	0.87	0.97
Tunisia	0.37	0.37	0.37	0.37	0.38	0.42	0.37	0.37	0.37	0.38	0.44	0.36	0.37	0.37	0.38	0.47	0.35	0.36	0.36	0.35	0.50
UAE	1.73	1.71	1.70	1.70	1.70	1.76	1.66	1.63	1.64	1.63	1.79	1.62	1.57	1.57	1.56	1.80	1.58	1.52	1.53	1.51	1.81

Table D2: Food import dependency (%)

Table D2	2015	2020					2030					2040					2050				
		BAU	ESC	WSC	FSC	NSC	BAU	ESC	WSC	FSC	NSC	BAU	ESC	WSC	FSC	NSC	BAU	ESC	WSC	FSC	NSC
	Food import dependency (%)																				
Egypt	11.5	10.8	11.8	12.3	11.1	12.3	9.7	10.7	11.8	10.2	12.0	8.9	10.4	11.5	9.4	12.1	8.2	10.3	11.5	8.6	11.9
Iran	5.1	4.9	5.7	5.7	5.6	6.2	4.9	5.4	5.7	5.4	6.0	4.9	5.1	5.5	5.1	5.7	4.9	4.7	5.3	4.7	5.3
Israel	35.8	37.1	37.3	37.0	37.5	37.7	39.7	40.1	39.4	40.6	41.5	42.5	43.1	41.9	43.9	45.7	45.4	46.2	44.6	47.3	50.4
Kuwait	67.7	65.8	65.7	65.7	65.8	67.2	62.0	62.0	62.0	62.2	65.7	58.8	58.7	58.7	58.9	64.4	55.8	55.7	55.8	56.0	63.1
Morocco	14.1	13.7	13.8	13.8	13.7	14.0	14.4	14.9	14.9	14.7	15.6	15.1	16.1	16.1	15.7	17.2	15.9	16.3	17.4	16.2	19.1
Oman	38.2	35.9	39.0	39.0	38.9	37.8	35.1	39.2	39.0	38.9	36.7	38.9	39.5	39.2	38.8	35.6	38.5	40.0	39.6	39.0	35.0
Qatar	45.3	45.5	45.5	45.5	43.3	45.8	45.7	45.8	45.9	40.3	46.6	45.9	46.2	46.3	37.8	47.4	46.2	46.5	46.7	35.7	48.2
Saudi Arabia	47.2	42.0	43.8	45.2	41.9	42.4	34.8	39.5	42.2	36.1	37.3	31.5	37.3	40.4	33.1	34.9	34.7	36.1	39.6	31.4	33.8
Tunisia	30.4	32.8	31.4	31.4	31.4	31.8	36.0	33.1	33.2	33.2	34.3	38.5	35.1	35.1	35.1	37.1	40.0	37.2	37.3	31.7	40.1
UAE	99.6	99.3	93.6	96.0	93.4	95.2	96.2	84.9	94.6	89.0	90.1	96.1	85.4	93.2	84.6	85.1	95.4	83.1	89.8	80.4	82.0

Table D3: Value of food imports (% of total merchandise exports)

Table D3	2015	2020					2030					2040					2050				
		BAU	ESC	WSC	FSC	NSC	BAU	ESC	WSC	FSC	NSC	BAU	ESC	WSC	FSC	NSC	BAU	ESC	WSC	FSC	NSC
	Value of food imports (% of total merchandise exports)																				
Egypt	46.8	52.0	46.0	45.0	45.2	44.4	48.5	46.4	44.3	44.2	42.1	45.6	46.7	43.3	43.1	39.9	43.0	48.4	42.4	41.9	36.2
Iran	10.1	9.9	9.9	9.8	9.5	11.5	9.8	9.5	9.5	8.7	10.5	9.8	9.2	9.2	7.9	9.7	10.2	8.8	8.9	7.0	8.8
Israel	10.1	10.1	10.6	10.1	10.1	9.8	10.1	10.3	10.0	10.1	9.4	10.0	10.1	9.9	10.0	9.0	9.9	9.9	9.7	9.9	8.5
Kuwait	6.6	6.7	6.6	6.4	6.6	5.8	6.8	7.0	7.0	7.0	6.3	6.9	7.4	7.5	7.3	6.7	7.0	7.7	7.9	7.5	7.0
Morocco	19.1	17.1	16.9	16.9	16.7	17.2	15.4	14.5	14.7	14.1	15.5	13.9	12.6	12.8	11.9	13.9	12.5	11.1	11.1	9.9	12.5
Oman	3.5	3.7	3.7	3.7	3.7	3.7	4.0	4.1	4.1	4.1	4.2	4.3	4.6	4.6	4.6	4.8	5.4	5.1	5.1	5.1	5.4
Qatar	2.0	2.1	2.1	2.1	2.1	2.1	2.3	2.2	2.2	2.2	2.2	2.6	2.4	2.4	2.4	2.4	2.8	2.6	2.6	2.6	2.6
Saudi Arabia	8.1	8.3	8.2	8.2	8.2	8.1	8.6	8.3	8.3	8.3	8.3	8.8	8.5	8.4	8.4	8.4	9.0	8.7	8.5	8.5	8.7
Tunisia	19.1	18.5	18.6	18.6	18.5	15.2	17.3	17.5	17.6	17.4	14.7	16.4	16.6	16.7	16.4	14.2	15.5	15.8	15.9	14.1	13.7
UAE	3.6	3.7	3.7	3.6	3.7	3.7	3.8	3.9	3.8	3.8	3.9	4.0	4.1	4.0	4.0	4.0	4.3	4.3	4.2	4.2	4.2

Table D4: Share of food expenditure (%)

Table D4	2015	2020					2030					2040					2050				
		BAU	ESC	WSC	FSC	NSC	BAU	ESC	WSC	FSC	NSC	BAU	ESC	WSC	FSC	NSC	BAU	ESC	WSC	FSC	NSC
	Share of food expenditure (%)																				
Egypt	27.0	27.4	26.5	26.8	27.0	26.3	30.2	25.9	26.2	27.0	25.0	33.0	25.4	26.4	27.0	23.7	35.8	24.9	26.2	27.0	21.5
Iran	22.3	16.3	15.8	15.9	16.0	22.4	18.2	16.1	16.3	16.3	20.8	20.2	16.5	16.6	16.7	19.3	22.2	17.0	17.0	17.1	18.3
Israel	10.3	10.3	10.6	10.4	10.4	9.8	10.2	10.6	10.6	10.5	9.1	10.2	10.7	10.8	10.7	8.3	10.1	10.8	11.0	10.7	7.5
Kuwait	2.2	2.2	2.1	2.0	2.2	1.7	2.3	2.2	2.1	2.2	1.6	2.3	2.3	2.2	2.3	1.6	2.4	2.4	2.3	2.3	1.6
Morocco	33.5	34.1	33.8	34.0	34.2	33.9	33.2	32.6	33.0	33.2	32.3	32.3	31.5	32.1	32.8	31.3	31.5	30.5	31.3	32.3	30.1
Oman	2.0	2.1	1.9	1.9	1.9	1.9	2.3	1.8	1.8	1.8	1.9	2.5	1.8	1.8	1.8	1.9	2.8	1.7	1.7	1.8	1.9
Qatar	7.4	7.2	7.2	7.2	7.7	7.0	6.9	6.9	6.9	8.2	6.3	6.5	6.6	6.6	8.6	5.7	6.2	6.3	6.3	9.0	5.2
Saudi Arabia	7.7	7.5	7.3	7.3	7.3	7.2	7.2	6.8	6.7	6.7	6.5	6.9	6.3	6.2	6.2	5.8	6.5	5.8	5.8	5.8	5.2
Tunisia	25.2	25.3	25.1	25.1	24.9	24.6	25.4	24.8	24.8	24.5	23.5	25.6	24.6	24.6	24.0	22.4	25.8	24.4	24.4	25.6	21.4
UAE	3.6	3.8	3.9	3.8	3.8	3.7	4.3	4.4	4.2	4.3	4.1	4.7	4.8	4.7	4.9	4.5	5.0	5.3	5.1	5.3	4.8

Section E: EWF Security composite indices

Table E1: Change in economic, social and securities results in BAU scenario

Table E1	Percentage of change over the period 2015-2030					Percentage of change over the period 2030-2050				
	Change in economic, social and securities results in BAU scenario									
	Economics	Social	Energy security	Water security	Food security	Economics	Social	Energy security	Water security	Food security
Israel	39%	38%	6%	-18%	-2%	35%	34%	4.1%	-3.1%	-2.3%
Kuwait	29%	35%	4%	-24%	0%	34%	42%	3.9%	0.3%	2.2%
Oman	49%	50%	8%	-20%	-1%	40%	42%	12.0%	-4.0%	-4.0%
Qatar	23%	26%	2%	-24%	1%	13%	42%	3.0%	-0.5%	0.9%
Saudi Arabia	30%	40%	-13%	-8%	6%	34%	46%	-21.6%	-0.1%	0.8%
UAE	30%	34%	-1%	-22%	0%	25%	30%	-0.3%	-0.5%	-1.7%
Iran	23%	21%	-1%	-22%	7%	2%	3%	-0.1%	-14.0%	-5.8%
Egypt	64%	70%	0%	-17%	-11%	53%	59%	4.6%	-25.1%	-3.3%
Morocco	41%	40%	6%	-23%	6%	36%	33%	7.5%	-6.1%	0.7%
Tunisia	41%	42%	0%	-15%	-2%	41%	43%	0.8%	-2.3%	-0.9%

Table E2: Change in economic, social and securities results in ESC scenario

Table E2	ESC compared with BAU -2030					ESC compared with BAU -2050				
	Change in economic, social and securities results in ESC scenario									
	Economics	Social	Energy security	Water security	Food security	Economics	Social	Energy security	Water security	Food security
Israel	0.9%	-0.5%	11.4%	10.2%	-1.2%	0.6%	1.7%	11.1%	-0.8%	3.9%
Kuwait	2.4%	-2.0%	7.1%	13.3%	0.2%	0.0%	-3.9%	21.9%	0.8%	7.5%
Oman	2.2%	0.1%	10.1%	13.8%	0.7%	2.6%	-0.8%	19.0%	2.6%	8.1%
Qatar	0.3%	0.1%	3.1%	13.9%	0.1%	0.7%	-0.2%	8.1%	6.8%	4.2%
Saudi Arabia	1.4%	-3.3%	14.6%	2.6%	-1.2%	0.8%	-6.7%	45.4%	-1.3%	11.0%
UAE	0.6%	1.2%	13.3%	19.5%	5.1%	1.5%	-2.7%	26.1%	12.5%	15.4%
Iran	2.5%	0.2%	3.9%	15.4%	3.3%	5.3%	-0.2%	7.1%	22.1%	12.7%
Egypt	1.7%	-6.3%	9.7%	15.8%	17.2%	0.4%	-11.7%	11.7%	33.5%	19.7%
Morocco	0.9%	-1.5%	-0.6%	18.6%	1.8%	2.3%	-2.6%	-1.6%	11.4%	4.9%
Tunisia	-1.3%	-1.9%	16.1%	9.8%	2.8%	-2.6%	-4.0%	35.0%	2.5%	15.0%

Table E3: Change in economic, social and securities results in WSC

Table E3	WSC compared with BAU -2030					WSC compared with BAU -2050				
	Change in economic, social and securities results in WSC scenario									
	Economics	Social	Energy security	Water security	Food security	Economics	Social	Energy security	Water security	Food security
Israel	0.4%	-0.4%	3%	13%	-1%	-1.4%	2.0%	5.2%	5.9%	-1.0%
Kuwait	1%	-2%	-1%	35%	0%	-1.6%	-3.8%	12.5%	47.4%	0.9%
Oman	4%	0.3%	3%	17%	1%	-1.3%	0.1%	6.1%	12.7%	4.1%
Qatar	0%	0.0%	2%	26%	0%	-1.3%	-0.1%	4.0%	22.1%	0.1%
Saudi Arabia	2%	-3%	9%	1%	-2%	-0.1%	-5.9%	31.0%	4.8%	-0.7%
UAE	1%	0.1%	4%	23%	1%	-0.4%	-0.3%	9.6%	18.5%	2.8%
Iran	2%	0.3%	3%	22%	3%	-0.1%	-0.3%	4.1%	34.8%	8.9%
Egypt	1%	-5%	9%	17%	20%	-0.2%	-9.3%	9.5%	35.4%	25.8%
Morocco	1%	-1%	0%	34%	1%	1.3%	-2.6%	-1.6%	20.4%	6.1%
Tunisia	-1%	-2%	10%	16%	3%	-2.7%	-3.9%	21.9%	7.0%	3.9%

Table E4: Change in economic, social and securities results in FSC scenario

Table E4	FSC compared with BAU -2030					FSC compared with BAU -2050				
	Change in economic, social and securities results in FSC scenario									
	Economics	Social	Energy security	Water security	Food security	Economics	Social	Energy security	Water security	Food security
Israel	0.3%	-0.5%	1%	10%	-1%	-1.5%	1.8%	2.3%	-1.1%	-2.1%
Kuwait	0%	-1%	2%	18%	0%	-5.0%	-2.0%	9.8%	4.8%	1.6%
Oman	1%	0%	2%	14%	1%	-2.6%	-0.3%	5.2%	6.0%	4.1%
Qatar	1%	1%	2%	12%	-3%	-2.2%	2.5%	2.1%	13.1%	-4.5%
Saudi Arabia	1%	-3%	5%	-2%	0%	-0.2%	-5.8%	26.0%	-2.4%	2.9%
UAE	1%	-1%	4%	21%	3%	-0.8%	-1.9%	9.8%	10.4%	7.3%
Iran	2%	1%	-3%	16%	4%	-0.4%	2.5%	-13.1%	21.5%	11.2%
Egypt	1%	-2%	5%	11%	19%	0.3%	-1.9%	4.3%	23.0%	27.8%
Morocco	1%	-1%	-3%	12%	1%	1.2%	-0.5%	-6.5%	1.7%	6.6%
Tunisia	-1%	-2%	6%	11%	4%	-3.8%	-4.2%	15.9%	-1.6%	7.5%

Table E5: Change in economic, social and securities results in NSC scenario

Table E5	NSC compared with BAU -2030					NSC compared with BAU -2050				
	Change in economic, social and securities results in NSC scenario									
	Economics	**Social**	**Energy security**	**Water security**	**Food security**	**Economics**	**Social**	**Energy security**	**Water security**	**Food security**
Israel	1%	1%	8%	15%	2%	9.5%	6.7%	10.4%	10.9%	4.1%
Kuwait	1%	3%	-9%	42%	0%	9.8%	5.2%	19.7%	49.3%	7.5%
Oman	3%	5%	15%	19%	1%	10.1%	10.3%	29.1%	14.1%	7.5%
Qatar	2%	2%	8%	26%	3%	3.8%	4.6%	19.5%	30.4%	5.0%
Saudi Arabia	5%	0%	22%	0%	0%	10.0%	1.0%	68.1%	1.6%	2.8%
UAE	3%	5%	15%	21%	4%	10.8%	10.4%	27.9%	14.7%	9.0%
Iran	1%	3%	6%	14%	-5%	9.7%	2.2%	18.0%	37.0%	7.1%
Egypt	1%	-2%	13%	15%	28%	13.5%	-2.4%	18.0%	45.0%	50.8%
Morocco	1%	0%	3%	35%	1%	5.3%	1.1%	6.3%	25.5%	6.8%
Tunisia	4%	7%	24%	16%	9%	10.9%	5.6%	48.3%	7.9%	11.1%

Table E6: Composite EWF security index

Table E6	2015	2030					2050				
		BAU	ESC	WSC	FSC	NSC	BAU	ESC	WSC	FSC	NSC
	Composite E-W-F security index										
Israel	61	59	64	62	61	64	59	61	61	59	64
Kuwait	54	53	56	57	55	55	52	56	59	55	62
Oman	60	59	63	63	62	62	58	63	62	61	67
Qatar	56	53	56	57	54	55	53	55	56	54	61
Saudi Arabia	54	52	54	53	52	53	49	54	53	52	58
UAE	56	53	59	57	57	57	51	59	56	56	60
Iran	61	56	60	61	59	59	54	61	62	57	65
Egypt	47	42	47	47	46	47	41	49	49	47	54
Morocco	50	48	50	52	49	50	50	51	52	49	54
Tunisia	54	51	57	56	55	57	51	58	56	54	62

Table E7: GDP ($US bn, 2010) for country grouping

Table E7	2015	2030					2050				
		BAU	ESC	WSC	FSC	NSC	BAU	ESC	WSC	FSC	NSC
	GDP ($US bn, 2010) for country grouping										
High income	1,739	2287	2312	2314	2303	2356	2981	3010	2961	2945	3266
Low income	846	1228	1251	1243	1243	1244	1544	1581	1541	1542	1710
Energy rich	1,961	2515	2553	2553	2542	2590	3096	3154	3082	3065	3393
Energy poor	671	999	1010	1004	1004	1010	1428	1436	1420	1422	1583
Water availability(more than m3/person/yr)	846	1162	1186	1177	1177	1176	1450	1489	1450	1452	1606
Water availability(less than m3/person/yr)	1,786	2353	2378	2379	2369	2425	3075	3101	3052	3035	3370

Table E8: Total employment (Mn person) for country grouping

Table E8	2015	2030					2050				
		BAU	ESC	WSC	FSC	NSC	BAU	ESC	WSC	FSC	NSC
	Total employment (Mn person) for country grouping										
High income	25,238	34710	34225	34206	34169	35410	48055	46207	46704	46634	50391
Low income	64,031	94130	90811	91346	93530	94258	130339	120557	122339	129151	129658
Energy rich	42,424	54794	54381	54378	54630	56315	67056	65029	65485	66145	69489
Energy poor	46,845	74045	70655	71173	73069	73353	111337	101735	103558	109640	110561
Water availability(more than m3/person/yr)	60,682	89378	86148	86681	88880	89160	123545	114034	115812	122643	122483
Water availability(less than m3/person/yr)	28,587	39462	38888	38871	38819	40508	54848	52731	53231	53142	57567

Table E9: Composite Energy security index for country grouping

Table E9	2015	2030					2050				
		BAU	ESC	WSC	FSC	NSC	BAU	ESC	WSC	FSC	NSC
	Composite Energy security index for country grouping										
High income	53	54	60	56	56	57	52	64	59	58	67
Low income	45	48	51	50	48	51	47	53	51	47	57
Energy rich	50	51	56	53	52	54	50	60	55	53	64
Energy poor	40	43	47	45	44	45	43	48	46	44	51
Water availability(more than m3/person/yr)	50	52	54	54	52	53	52	55	54	50	58
Water availability(less than m3/person/yr)	53	55	61	57	57	58	54	66	60	59	70

Table E10: Composite water security index for country grouping

Table E10	2015	2030					2050				
		BAU	ESC	WSC	FSC	NSC	BAU	ESC	WSC	FSC	NSC
	Composite water security index for country grouping										
High income	53	41	43	45	43	42	34	35	37	34	43
Low income	59	44	48	51	47	45	38	41	44	39	48
Energy rich	55	42	45	47	45	43	37	38	41	37	44
Energy poor	56	42	45	48	45	44	39	41	45	39	45
Water availability(more than m3/person/yr)	58	42	46	49	45	43	38	41	43	38	51
Water availability(less than m3/person/yr)	48	37	39	41	39	37	31	32	34	31	40

Table E11: Composite Food security index for country grouping scenario

Table E11	2015	2030					2050				
		BAU	ESC	WSC	FSC	NSC	BAU	ESC	WSC	FSC	NSC
	Composite Food security index for country grouping										
High income	65	68	68	68	68	65	63	66	66	66	69
Low income	43	42	44	44	44	42	43	46	46	47	48
Energy rich	64	68	69	68	68	68	63	67	67	67	69
Energy poor	43	42	43	43	43	42	43	44	45	45	48
Water availability(more than m3/person/yr)	43	42	45	45	45	42	43	47	47	48	49
Water availability(less than m3/person/yr)	48	50	50	50	50	51	48	49	49	49	51

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