Economic and Social Commission for Western Asia

UNITED NATIONS

الاسكوا

ESCWA

# Developing the Capacity of ESCWA Member Countries to Address the Water and Energy Nexus for Achieving Sustainable Development Goals

## Regional Policy Toolkit

Economic and Social Commission for Western Asia

# Developing the Capacity of ESCWA Member Countries to Address the Water and Energy Nexus for Achieving Sustainable Development Goals

## Regional Policy Toolkit

UNITED NATIONS
Beirut

E-mail: publications-escwa@un.org;
website: www.unescwa.org

United Nations publication issued by ESCWA.



E/ESCWA/SDPD/2016/Manual

16-00155

# Acknowledgements

Modules 2 to 7 of this policy toolkit were prepared by Mr. Rabi Mohtar, Endowed Professor at Texas A&M Engineering Experiment Station (TEES) at Texas A&M University in the United States of America. The modules were reviewed by the Water Resources Section and the Energy Section in the Sustainable Development Policies Division (SDPD) at the United Nations Economic and Social Commission for Western Asia (ESCWA) in Beirut.

The topics addressed by the seven modules were jointly identified by the members of the ESCWA Energy Committee and the ESCWA Committee on Water Resources.

# Contents

# Knowledge and Awareness-Raising

1 Module

# Contents



## List of figures



## List of tables



## List of boxes

# Abbreviations and explanatory notes

| | |
|---|---|
| **AMCE** | Arab Ministerial Council of Electricity |
| **AMWC** | Arab Ministerial Water Council |
| **BATNA** | best alternative to a negotiated agreement |
| **CAMRE** | Council of Arab Ministers Responsible for the Environment |
| **CLEW** | climate, land, energy and water |
| **ESCWA** | Economic and Social Commission for Western Asia |
| **EU** | European Union |
| **FAO** | Food and Agriculture Organization |
| **GIZ** | Deutsche Gesellschaft fur Internationale Zusammenarbeit |
| **ICIMOD** | International Centre for Integrated Mountain Development |
| **IWRM** | integrated water resources management |
| **MDG** | Millennium Development Goal |
| **RICCAR** | Regional Initiative for the Assessment of the Impact of Climate Change on Water Resources and Socio-Economic Vulnerability in the Arab Region |
| **SDG** | Sustainable Development Goal |
| **SE4All** | Sustainable Energy for All |
| **Sida** | Swedish International Development Cooperation Agency |
| **UNECE** | United Nations Economic Commission for Europe |
| **UNEP** | United Nations Environment Programme |
| **WBCSD** | World Business Council for Sustainable Development |
| **WEF** | water-energy-food |

# Introduction

The 2030 Agenda for Sustainable Development was adopted by the United Nations General Assembly in September 2015.[1] The process was a lengthy, inclusive public consultation with civil society and other stakeholders, within countries and at regional and global levels. In the course of this, the United Nations General Assembly reaffirmed the international community's commitment to the human right to clean drinking water and adequate sanitation, and to sufficient safe, affordable and nutritious food. It also envisioned a world where there is access to affordable, reliable and sustainable energy. This is founded on the Universal Declaration of Human Rights,[2] the cornerstone for modern human rights, and other international human rights treaties, and informed by the Declaration on the Right to Development of the United Nations.[3]

The 2030 Agenda includes 17 Sustainable Development Goals (SDGs) and 169 targets, which are universal, people-centred and seek to realize the human rights of all and to achieve gender quality and the empowerment of all women and girls. They are integrated and indivisible and balance the three dimensions of sustainable development: the economic, social and environmental. The agenda calls for a new approach based on integrated solutions that are sustainable and inclusive.

This desired and bold approach is well supported by the water-energy-food security nexus. This examines the links between the three sectors, looking to improve the holistic management of natural resources and associated ecosystems by applying a human rights-based perspective and taking into account climate change impacts. The nexus highlights the interdependencies between the water, energy and food sectors, and the need to pursue an integrated management framework across the three sectors.

Energy and water are strongly linked (figure 1). Energy is used to extract groundwater, to power desalination plants, to treat, pump and distribute water and at the end of cycle to collect wastewater and operate its treatment plants. Water is essential for fossil fuel extraction, production and processing, for energy production in hydropower plants and in thermal power plants and renewable energy production. Arab countries face immense challenges in both the water and energy sectors with growing populations and mounting environmental pressures such as droughts, desertification, pollution and climate change. This necessitates a new, comprehensive and systematic approach.

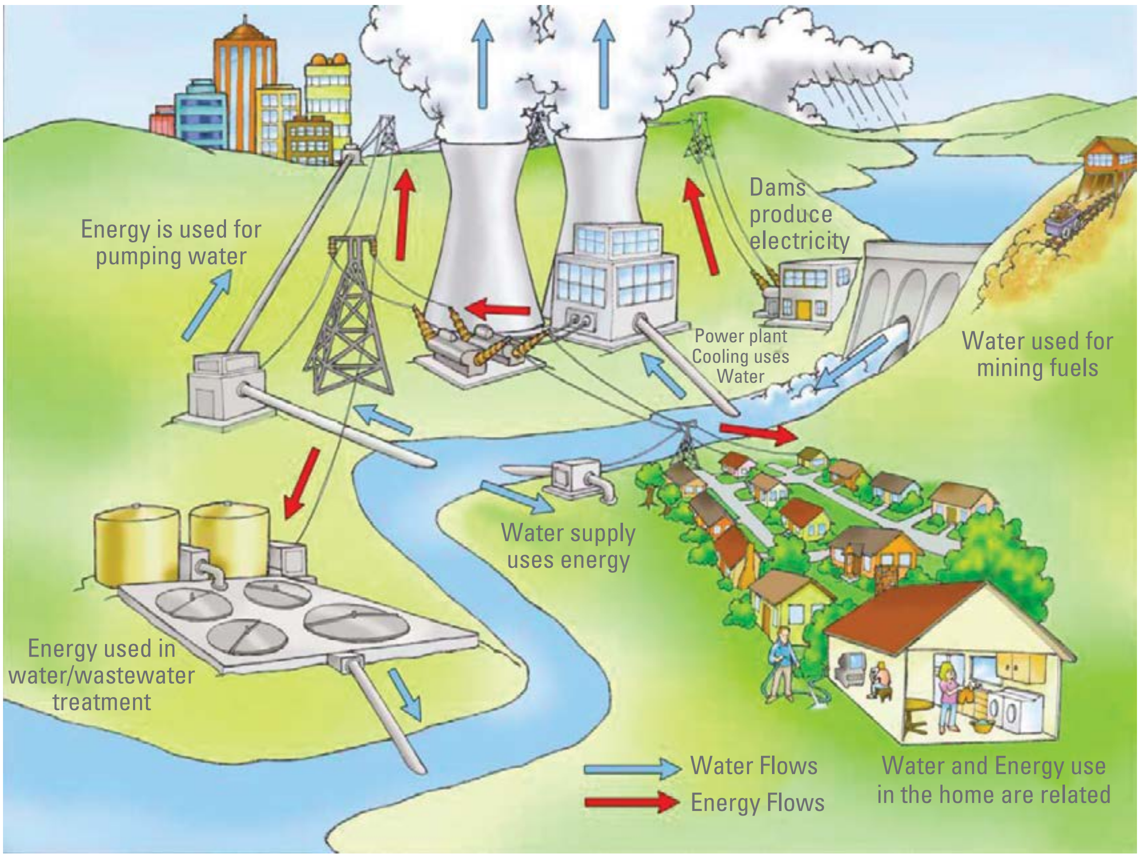
The water-energy-food security nexus framework is particularly suited to the Arab region given the stressors, constraints and strong interdependencies between sectors. It is further necessitated by the cross-sectoral effect of climate change predicted for the region. The understanding of the dynamics of the water and energy sectors it offers is essential for developing effective strategies for the sustainable use of these resources.

# Developing capacity to address the water and energy nexus for achieving the Sustainable Development Goals

The United Nations Economic and Social Commission for Western Asia (ESCWA), as part of efforts to help member countries achieve an integrated approach to the SDGs, is implementing a project to develop their capacity to examine and address the water and energy nexus.

This is being pursued through two parallel and complementary tracks. The first targets high-level officials in ministries for water and energy who will be trained on how to incorporate the nexus in policies and strategies at national and regional levels through a regional policy toolkit. This is comprised of seven modules – of which this is the first – based on priorities identified by an intergovernmental consultative meeting in 2012.[4] The seven priorities were subsequently endorsed by the ESCWA Committee on Water Resources, and the Committee on Energy. They cover the following topics, which are addressed in the toolkit:

**Figure 1.** Examples of water and energy interlinkages




**Source:** United States Department of Energy, 2006.

a. Knowledge and awareness-raising;
b. Increasing policy coherence;
c. Examining the water-energy security nexus;
d. Increasing efficiency;
e. Informing technology choices;
f. Promoting renewable energy;
g. Addressing climate change and natural disasters.

The first of two regional workshops will review policy framework and economic instruments for examining the nexus using the toolkit. Participants will be invited to identify a policy tool or instrument that supports mainstreaming water-energy nexus considerations at national level, and member countries will be asked to prepare proposals for piloting or testing them. Up to three proposals will be accepted by ESCWA, and lessons from these pilots will be presented at a second workshop, which will provide more specificity on institutional mechanisms and incentives for pursuing policy coherence. Accepted proposals will receive technical support and advisory assistance from ESCWA to assist in piloting the tool or instrument at the national level.

The other track will target water and energy service providers with three technical interventions addressed through an operational toolkit made up of the following modules:

a. Resource efficiency. To improve efficiency during the production and consumption of water and energy resources and services;
b. Technology transfer. For water and energy considerations when pursuing the transfer of new technologies regionally;
c. Renewable energy. For assessing costs and benefits related to applying renewable energy technologies in the region.

Each module will be discussed in one of three regional technical training workshops, which will bring together participants doing similar work in different sectors.

# The nexus

Nexus theory is rooted in the need for integrated management of natural resources. It has been developed under various forms, including integrated water resources management (IWRM), sustainable agriculture, green economy principles, sustainable production and consumption frameworks, and sustainable development, to name a few. All are aimed at better managing natural resources by sustaining ecosystems, improving efficiency (creating more with less), improving access and integrating the poorest, and all promote an integrated approach in the face of segmented, fragmented and uncoordinated sectoral decision-making that has led to inefficient and wasteful use.

IWRM early on promoted an integrated attitude based on four principles articulated in the 1992 Dublin Statement on Water and Sustainable Development,[5] and an action agenda aimed at alleviating poverty and disease, protecting against natural disasters, water conservation and reuse, sustainable urban development, agricultural development and rural water supplies, ecosystems protection, resolving water conflicts and building capacity. The Dublin Principles highlight the importance of water as a resource for environmental protection and human development:

a. Freshwater is a finite and vulnerable resource, essential to sustain life, development and the environment;
b. Water development and management should be based on a participatory approach, involving users, planners and policymakers at all levels;
c. Women play a central part in the provision, management and safeguarding of water;
d. Water has an economic value in all its competing uses, and should be recognized as economic goods.

IWRM strategies and plans were, however, water-focused and failed to gain the necessary cross-sectoral support to move an integrated management concept beyond water.

The Millennium Development Goals (MDGs) shifted thinking on integrated natural resources management, calling for a respect of nature and prudent management of all living species and natural resources according to sustainable development precepts. Goal 7 set a 15-year programme of action on environmental sustainability to reverse resource losses, improve access to water supplies and sanitation services, reduce biodiversity loss and improve the lives of slum dwellers, while encouraging States to adopt IWRM plans by 2005. The goal was successful in linking sustainable management to providing water supplies and sanitation.

The global financial crisis and simultaneous food and energy crises of 2007-2008 emphasized the importance of linking managing water, energy and food security, amid increasing concern over growing water scarcity, escalating land degradation, and mounting scientific evidence that human activities are stressing the Earth's natural systems beyond sustainable limits and contributing to climate change.

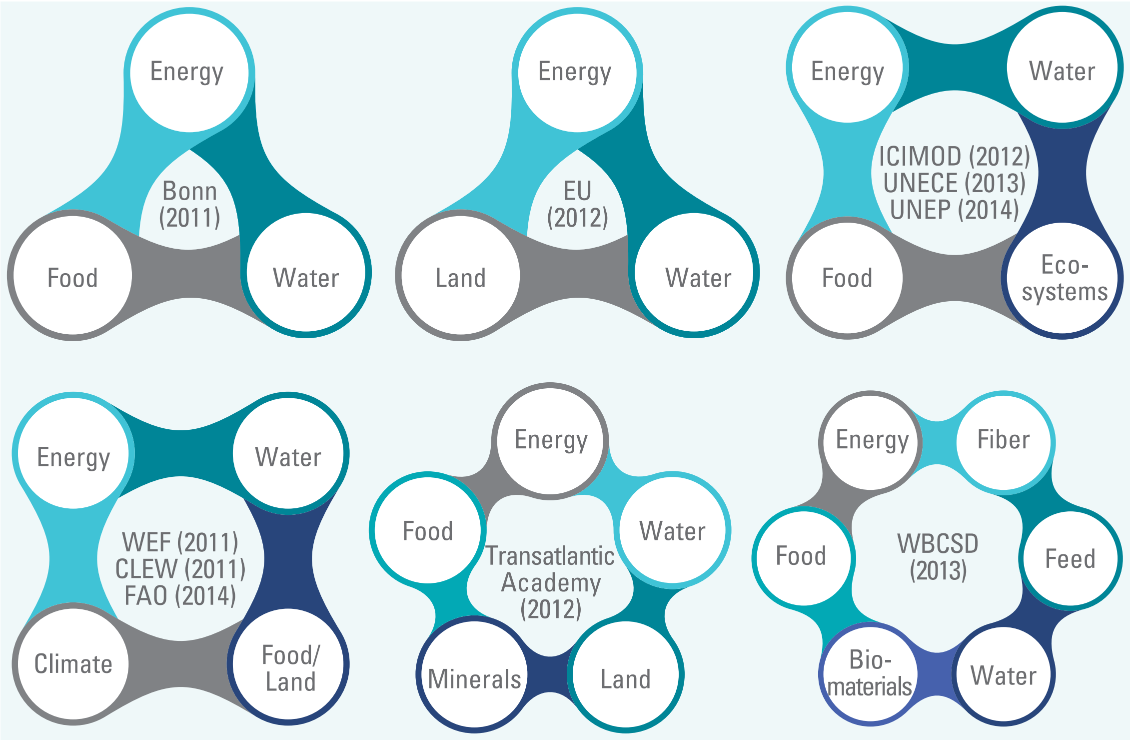
The nexus materialized as a conceptual framework that highlights interdependencies between the water, energy and food sectors, and the need to pursue integrated management across all three. The value of the framework is its focus on the interdependencies from a cross-sectoral perspective, integrating sustainable natural resources management and ensuring adequate access to food, water and sustainable energy for all.

Nexus relationships have addressed bilateral interdependencies, such as energy needed for water supply, or water needed for irrigated agriculture. More recently, they have addressed links between at least three sectors, mainly water-energy-food, emphasizing resource management and services delivery. Multisectoral approaches are best prescribed for these nexus frameworks.

Published work on nexus frameworks varies in the scope, goals and significance of the drivers and pressures. The variations reflect the concerns of the various organizations proposing the frameworks. Some of the major nexus framework variations are presented in figure 2.

A more extensive review of these and other nexus approaches is available in the ESCWA working paper on conceptual frameworks for understanding the water, energy and food security nexus.[6]

**Figure 2.** Selected conceptual frameworks for illustrating the natural resources nexus




**Source:** ESCWA, 2015a.
**Note:** EU stands for European Union; ICIMOD for International Centre for Integrated Mountain Development; UNECE for United Nations Economic Commission for Europe; UNEP for United Nations Environment Programme; WEF for World Economic Forum; CLEW for climate, land, energy and water; FAO for Food and Agriculture Organization; and WBCSD for World Business Council for Sustainable Development.

# A water-energy-food security nexus for the Arab region

Arab States have varying natural resource endowments, between and within countries, and between rural and urban communities. This affects their ability to achieve water, energy and food security for citizens, foreign workers, migrants and refugees who often constitute vulnerable communities.

The relationship between water, energy and food in the region is affected by high population growth, increasing urbanization and socioeconomic disparities. Unsustainable production and consumption patterns, including related shifts in lifestyles and diets in some countries, contrast with growing pockets of poverty in others, further stressing natural resources and the ability of governments to satisfy increasing demands. The problems are compounded by water scarcity, soil and land degradation, growing pollution streams and climate change, which is increasing pressure on these already scarce natural resources and degraded ecosystems. The situation is complicated by the ongoing conflicts and security concerns in the region. Managing natural resources under occupation is another complexity that weighs heavily on achieving sustainable development.

Shams 1 parablic trough in Abu Dhabi © Masdar Official https://www.flickr.com

The Arab region stands to benefit greatly from considering the links between water, energy and food security as they endeavour to progress towards the SDGs. A nexus framework recognizes these complex relationships and can be applied at various scales of analysis, given the varying natural resources and production and consumption patterns.

Constructing an analytical framework for examining the water-energy-food security nexus requires a common vision based on tenets acceptable to all Arab countries. This can be achieved by advocating a people-centred approach, grounded in the SDGs.

Placing food security and universal access to water, sanitation and energy for all within the SDGs requires States to work on policies and plans for food security and universal access to water, sanitation and energy, not only for today, but for generations to come. Such an approach places the nexus in a dynamic context that takes into account the quantity, quality and accessibility of resources.

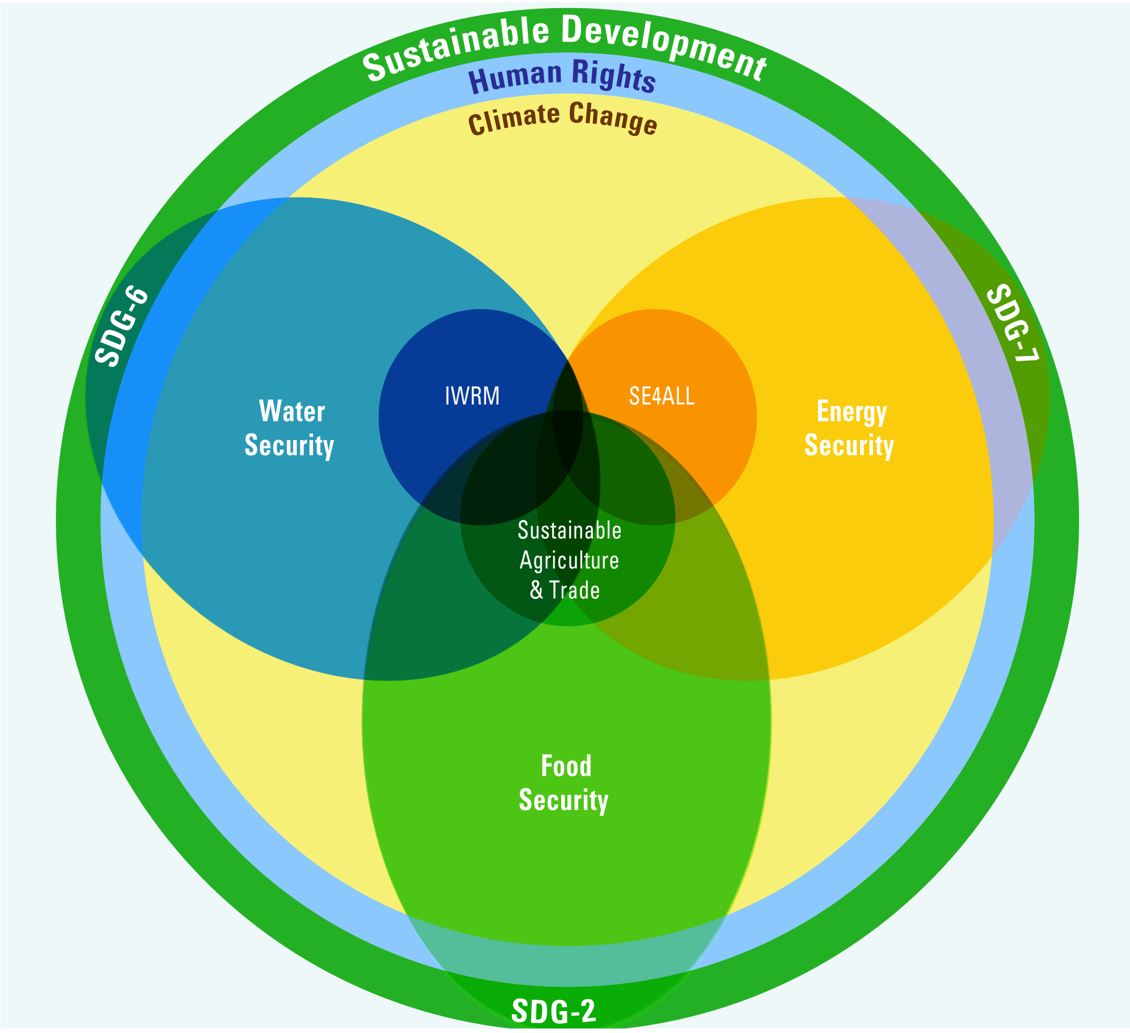
This people-centred approach to development, guided by human rights principles, and the adverse effects of climate change on the ability to enjoy them, can provide the basis for a nexus framework, where the three main components of the nexus are seen as equally important. Such an approach permits a common set of principles on which to base water, energy and food security policy across institutions and sectors, in harmony with United Nations development efforts and human rights standards.[7]

A human rights-based approach to development incorporates principles, capacities and obligations that consider human rights as universal, indivisible, interdependent and nondiscriminatory. The right to adequate food must be upheld alongside the right to safe drinking water and sanitation, and access to sustainable energy for all. The water-energy-food security nexus would theoretically seek to ensure access to energy, water and food in concert, a challenge when political costs and trade-offs must be considered in practical terms. However, as a visionary aim, a human-rights approach to the nexus should consider these rights as inalienable rights, made a priority during policy formulation.

Applying such a nexus can exploit regional specificities evident in smaller scales of analysis at the regional, national and subnational levels. Experiences from existing initiatives can help. This allows lessons from IWRM tools, regional efforts to support the Sustainable Energy for All (SE4All)[8] initiative and investments to promote sustainable agricultural practices and reliable trade regimes to be taken on board.

The elaboration of this nexus approach in the Arab region also needs to consider the global environment in which such frameworks will be applied in coming decades; for example, climate change and the way it will affect the ability to achieve water, energy and food security. See figure 3.

**Figure 3.** The water-energy-food security nexus




**Source:** ESCWA, 2015b.

## **Box.** Basic WEF nexus human rights

The following United Nations resolutions support a human-rights approach to the water, energy and food security nexus within the context of ensuring water, energy and food for all.

**The right to food**

- The United Nations General Assembly in the Universal Declaration of Human Rights (1948): "Everyone has the right to a standard of living adequate for the health and well-being of himself and of his family, including food, clothing, housing and medical care and necessary social services, and the right to security in the event of unemployment, sickness, disability, widowhood, old age or other lack of livelihood in circumstances beyond his control".[a]
- United Nations Committee on Economic, Social, and Cultural Rights (1999): "The right to adequate food is realized when every man, woman and child, alone or in community with others, has physical and economic access at all times to adequate food or means for its procurement". [b]
- Human Rights Council (2008): "... reaffirms the right of everyone to have access to safe and nutritious food, consistent with the right to adequate food and the fundamental right of everyone to be free from hunger, so as to be able to fully develop and maintain his or her physical and mental capacities".[c]

**The right to water**

The United Nations Water Conference (Mar del Plata, Argentina, 1977) was the first world conference to declare that "all peoples, whatever their stage of development and social and economic conditions, have the right to have access to drinking water in quantities and of a quality equal to their basic needs".[d] This human right to water and sanitation through United Nations agencies was elaborated in the following:

- United Nations General Assembly resolution 64/292 (July 2010): "Recognizes the right to safe and clean drinking water and sanitation as a human right that is essential for the full enjoyment of life and all human rights".
- United Nations Human Rights Council resolution 15/9 (October 2010): "Affirms that the human right to safe drinking water and sanitation is derived from the right to an adequate standard of living and inextricably related to the right to the highest attainable standard of physical and mental health, as well as the right to life and human dignity".

**The right to development**

The right to development has been enshrined in many United Nations resolutions, and most prominently in the General Assembly's Declaration on the Right to Development (1986).[e] While the declaration focuses on establishing development as an inalienable human right that covers economic, social, cultural and political development, Article 8 asserts: "States should undertake, at the national level, all necessary measures for the realization of the right to development and shall ensure, inter alia, equality of opportunity or all in their access to basic resources, education, health services, food, housing, employment and the fair distribution of income. Effective measures should be undertaken to ensure that women have an active role in the development process. Appropriate economic and social reforms should be carried out with a view to eradicating all social injustices".

While access to basic resources is included in the declaration alongside the right to food and other prerequisites for development, governments have been hesitant to articulate access to energy and electricity services as a necessary condition, despite it being recognized by scholars for decades. This is largely due to concerns over what would be the associated obligation of States to ensure access to energy as a universal human right and the implications the associated increase in energy consumption would pose for national budgets and climate change. There is thus no explicit human right to energy or electricity adopted in a United Nations resolution, although there are significant references to the need for energy to eradicate poverty and the importance of considering access to energy services within a human rights framework.[f]

**Human rights and climate change**

The United Nations Human Rights Council has adopted a resolution on the links between human rights and climate change "emphasizing that the adverse effects of climate change have a range of implications, both direct and indirect, for the effective enjoyment of human rights, including, inter alia, the right to life, the right to adequate food, the right to the enjoyment of highest attainable standard of physical and mental health, the right to adequate housing, the right to self-determination, the right to safe drinking water and sanitation and the right to development, and recalling that in no case may a people be deprived of its own means of subsistence".[g]

**The Arab Charter on Human Rights**

This charter[h] came into force in 2008 after ratification by the seventh member of the League of Arab States (the Arab League). It has been ratified by 13 States in total, including Algeria, Bahrain, Jordan, Kuwait, Lebanon, Libya, the State of Palestine, Qatar, Saudi Arabia, the Sudan, the Syrian Arab Republic, the United Arab Emirates and Yemen. More recently it has been joined by Iraq. The charter refers to the rights to water and food, specifically:

- Article 38: "Every person has the right to an adequate standard of living for himself and his family, which ensures their well-being and a decent life, including food, clothing, housing, services and the right to a healthy environment. The State Parties shall take the necessary measures commensurate with their resources to guarantee these rights".
- Article 39, parts 2e and 2f: "The measures taken by States shall include the following, 'Provision of basic nutrition and safe drinking water for all' and 'Combating environmental pollution and providing proper sanitation systems'".

**Sources:**
[a] United Nations, 1948.
[b] Committee on Economic, Social and Cultural Rights, 1999.
[c] United Nations Human Rights Council, 2008.
[d] International Environmental Law Research Centre, 1977.
[e] United Nations, General Assembly, 1986.
[g] United Nations, Human Rights Council, 2014.
[h] League of Arab States, 2004.

# The nexus within the context of the SDGs

Though the 2030 Agenda did not adopt a nexus approach to achieving the SDGs, it did, however, strongly declare that the "SDGs and targets are integrated and indivisible", and that the "interlinkages and integrated nature of the Sustainable Development Goals are of crucial importance in ensuring that the purpose of the new agenda is realized".[9]

The integrated nature of the SDGs matches well a nexus approach that specifically considers the numerous links between sectors. A systems approach that aims to reduce trade-offs and build synergies by considering interactions and dependencies at all stages, it enhances the efficiency of the entire system rather than increasing productivity of a specific sector often at the expense of others.

An example of this is the climate change goal, SDG 13, which looks to combat climate change and its effects. Climate change is a cross-sectoral stressor and a key driver of water and food systems, with the energy system driving climate change and in return being affected by it. Projections by RICCAR, the regional initiative assessing the impact of climate change on water resources and socioeconomic vulnerability,[10] indicate the Arab region will be affected by a general rise in temperature, more hot summer days and decreasing average monthly rainfall.

At the core of the water-energy-food security nexus, Goals 2, 6 and 7 are easily identified. Goal 2 seeks to end hunger, achieve food security and improved nutrition, and promote sustainable agriculture, and has five associated targets and three means of implementation. Goal 6 aims to ensure availability and sustainable management of water and sanitation for all, and has six associated targets and two implementation means. Goal 7 aims to ensure access to affordable, reliable, sustainable and modern energy for all, with five targets and two implementation means. These are summarized in table 1.[11]

A closer look at the SDGs and their targets reveals several connections. For example, target 6.4, increasing water use efficiency across all sectors, is linked to targets 2.3 and 2.4 that call for better agricultural productivity and resilient agricultural practices, which is connected to target 7.3 related to improvement in energy efficiency. Connections are not limited to these three core goals of the nexus, but spread into others, such as health target 3.9 that calls for the reduction in the number of deaths and illnesses from hazardous chemicals and air, water and soil pollution and contamination, which is closely connected to target 6.1 to achieve universal access to safe drinking water for all.

Examining the SDGs as a system with a nexus lens helps identify these connections, and guide decision makers along the long-term path of sustainable development. Governing bodies must ensure the interdependencies among SDGs and sectors are accounted for in strategy and policy formulation. The water-energy-food nexus approach may also provide a cross-check on how progress in some thematic targets affects others.

The integrated nature of the 2030 Agenda was echoed in the key messages from the Arab Forum for Sustainable Development to the follow-up high-level political forum on sustainable development.[12] They signalled the links among goals relating to environment, natural resources, climate change and economic and social objectives, and called for increased cooperation across the region given the cross-border nature of water, energy, agriculture and food security challenges. The messages also stressed that human rights, including the right to development, and gender equality and women's empowerment, are the foundation of the agenda, and are in harmony with ESCWA's proposed water-energy-food security nexus.

**Table 1.** SDGs, targets and implementation means at the core of the water-energy-food security nexus[13]

| Goal | 2030 Targets | Implementation means |
|---|---|---|
| 2 ZERO HUNGER<br><br>End hunger, achieve food security and improved nutrition and promote sustainable agriculture | **2.1** By 2030, end hunger and ensure access by all people, in particular the poor and people in vulnerable situations, including infants, to safe, nutritious and sufficient food all year round | **2.a** Increase investment, including through enhanced international cooperation, in rural infrastructure, agricultural research and extension services, technology development and plant and livestock gene banks in order to enhance agricultural productive capacity in developing countries, in particular least developed countries<br><br>**2.b** Correct and prevent trade restrictions and distortions in world agricultural markets, including through the parallel elimination of all forms of agricultural export subsidies and all export measures with equivalent effect, in accordance with the mandate of the Doha Development Round<br><br>**2.c** Adopt measures to ensure the proper functioning of food commodity markets and their derivatives and facilitate timely access to market information, including on food reserves, in order to help limit extreme food price volatility |
| | **2.2** By 2030, end all forms of malnutrition, including achieving, by 2025, the internationally agreed targets on stunting and wasting in children under 5 years of age, and address the nutritional needs of adolescent girls, pregnant and lactating women and older persons | |
| | **2.3** By 2030, double the agricultural productivity and incomes of small-scale food producers, in particular women, indigenous peoples, family farmers, pastoralists and fishers, including through secure and equal access to land, other productive resources and inputs, knowledge, financial services, markets and opportunities for value addition and non-farm employment | |
| | **2.4** By 2030, ensure sustainable food production systems and implement resilient agricultural practices that increase productivity and production, that help maintain ecosystems, that strengthen capacity for adaptation to climate change, extreme weather, drought, flooding and other disasters and that progressively improve land and soil quality | |
| | **2.5** By 2020, maintain the genetic diversity of seeds, cultivated plants and farmed and domesticated animals and their related wild species, including through soundly managed and diversified seed and plant banks at the national, regional and international levels, and promote access to and fair and equitable sharing of benefits arising from the utilization of genetic resources and associated traditional knowledge, as internationally agreed | |

| Goal | 2030 Targets | Implementation means |
|---|---|---|
| 6 CLEAN WATER AND SANITATION<br>Ensure availability and sustainable management of water and sanitation for all | 6.1 By 2030, achieve universal and equitable access to safe and affordable drinking water for all | 6.a By 2030, expand international cooperation and capacity-building support to developing countries in water- and sanitation-related activities and programmes, including water harvesting, desalination, water efficiency, wastewater treatment, recycling and reuse technologies<br>6.b Support and strengthen the participation of local communities in improving water and sanitation management |
| | 6.2 By 2030, achieve access to adequate and equitable sanitation and hygiene for all and end open defecation, paying special attention to the needs of women and girls and those in vulnerable situations | |
| | 6.3 By 2030, improve water quality by reducing pollution, eliminating dumping and minimizing release of hazardous chemicals and materials, halving the proportion of untreated wastewater and substantially increasing recycling and safe reuse globally | |
| | 6.4 By 2030, substantially increase water-use efficiency across all sectors and ensure sustainable withdrawals and supply of freshwater to address water scarcity and substantially reduce the number of people suffering from water scarcity | |
| | 6.5 By 2030, implement integrated water resources management at all levels, including through transboundary cooperation as appropriate | |
| | 6.6 By 2020, protect and restore water-related ecosystems, including mountains, forests, wetlands, rivers, aquifers and lakes | |
| 7 AFFORDABLE AND CLEAN ENERGY<br>Ensure access to affordable, reliable, sustainable and modern energy for all | 7.1 By 2030, ensure universal access to affordable, reliable and modern energy services | 7.a By 2030, enhance international cooperation to facilitate access to clean energy research and technology, including renewable energy, energy efficiency and advanced and cleaner fossil-fuel technology, and promote investment in energy infrastructure and clean energy technology<br>7.b By 2030, expand infrastructure and upgrade technology for supplying modern and sustainable energy services for all in developing countries, in particular least developed countries, small island developing States, and land-locked developing countries, in accordance with their respective programmes of support |
| | 7.2 By 2030, increase substantially the share of renewable energy in the global energy mix | |
| | 7.3 By 2030, double the global rate of improvement in energy efficiency | |

# Regional strategies and initiatives for operationalizing the nexus

Arab regional strategies of particular interest to the water-energy-food security nexus are summarized below:

a. *Arab Strategy for Water Security in the Arab Region to Meet the Challenges and Future Needs for Sustainable Development 2010-2030*

In 2011, the Arab Ministerial Water Council (AMWC) of the Arab League, adopted the strategy to unify and guide efforts in managing water resources.[14] Its primary goal is to meet sustainable development challenges through a workplan tackling several aspects of water resources management, such as capacity building, research and development, provision for drinking and irrigation water services, unconventional water resources and integrated management. In May 2014, the AMWC approved an action plan to put the strategy into operation.

Although not specifying a nexus paradigm, the strategy references the importance of the three components of the water-energy-food security nexus within the following goals:

- Increasing energy efficiency within the water sector by 30% within five years;
- Improving energy contracting module in the water sector;
- Introducing renewable energy farms at national level;
- Developing a new market for the private sector in energy management;
- Reducing greenhouse gases.

b. *Strategy for Sustainable Arab Agriculture Development for the Upcoming Two Decades 2005-2025*

The strategy was approved by the Riyadh Arab Summit in 2007 and adopted by the ministers of agriculture in the Arab region with the support of the Arab Organization for Agricultural Development.[15] The main goal is agricultural development through effective resource use, which can achieve food security while maintaining sustainable livelihoods in the agricultural sector.

This was followed in 2009 by endorsement of the Arab Food Security Emergency Programme to increase and stabilize food production. The programme focused on improving water-use efficiency in the agriculture sector, strengthening research and transfer of agricultural technology, increasing investment in the agricultural sector and developing farmers' institutional frameworks.

The impetus for such strategies and programmes is the water-food pillar in the water-energy-food security nexus that seeks to address water scarcity and lack of appropriate agricultural land in the region.

c. *Pan-Arab Strategy for the Development of Renewable Energy Applications 2010-2030*

This strategy[16] was ratified by the third Arab Economic and Social Development summit in Riyadh in January 2013, and presents a roadmap for renewable energy development in the region over a 20-year period.

Yemen, Sana - Mar 6, 2010: Unidentified girls with empty water-pots going in search of drinking water in Sana, Yemen. © Oleg Znamenskiy - Shutterstock_ 249785368

It sets a target of expanding installed power generation capacity in the region to approximately 75 gigawatts by 2030. And it seeks to maximize use of renewable energy, diversify energy sources to improve energy security, make available energy resources and services to support development, improve longevity of regional oil and gas reserves, and reduce the environmental impact of traditional oil and gas use. The intersectoral effects of these targets and actions are only fully exposed through a nexus framework.

*d. Arab Initiative on the Water, Energy and Food Nexus*

Pursuing a regional initiative on the nexus, the Arab League, with the Deutsche Gesellschaft für Internationale Zusammenarbeit (GIZ), organized a dialogue during the 2014 South-South Arab Development Expo.

This led to resolutions by the Arab Ministerial Water Council (AMWC) and the Arab Ministerial Council of Electricity (AMCE) inviting the Arab League, GIZ and ESCWA to solicit funding to implement nexus-related activities and studies in support of the regional initiative, and to organize meetings for Arab experts on nexus-related priorities.

Under this initiative, GIZ initiated a project to prepare policy briefs on the water, energy and food nexus, which were launched in 2016 and covered the following:

- Understanding the water-energy-food nexus;
- Challenges and opportunities;
- Nexus governance and the role of institutions;
- Water-energy-food nexus, resource efficiency and sustainable development;

- Capacity development needs;
- Nexus technology and innovation case studies.

The briefs are intended to foster dialogue and knowledge exchange on the nexus at regional level.

Within the context of this regional initiative, ESCWA is implementing the project entitled "Promoting food and water security through cooperation and capacity development in the Arab region" with regional partners and the financial support of the Swedish International Development Cooperation Agency (Sida). The project supports cross-sectoral dialogue among water and agricultural stakeholders.

*e. Building Capacity on the Food-Water Nexus in the Region*

In December 2014, ESCWA launched a second project on the nexus, funded by the Swedish International Development Cooperation Agency (Sida), and based on the need for better coordination between agriculture and water institutions to develop more appropriate and integrated policies for achieving food security.

It aims to enhance the capacity of stakeholders in: assessing the impact of changing water availability on agricultural production; coordinating the development of food and water security policies; assessing food security; and achieving efficient food production.

Led by ESCWA and implemented in consultation with the Arab League, its ministerial councils and agencies and other organizations serving the region, the four-year project will build on findings and outputs generated under RICCAR, the regional initiative assessing climate change effects on water resources in the Arab region.

Despite the ESCWA projects dealing with binary relations of water-energy or food-water, they do complement each other in addressing the three pillars of the water-energy-food security nexus. The approach is better suited to the institutional set-up of ministries in the region, which are normally mandated with the management of two sectors at the most. These initiatives, however, will help broaden thinking beyond the current silos approach and act as stepping stones for more complex nexus approaches in the future.

# Managing the nexus

An institutional framework for managing the water-energy-food security nexus exists at national scale in most Arab countries, in ministries whose mandate covers two or more components of the nexus. Ministries with a mandate to manage the electricity/energy and water sectors exist in Bahrain, Kuwait, Lebanon, Morocco, Qatar, Saudi Arabia and the Sudan, while Egypt, Jordan and Tunisia have ministries that manage the water and irrigation/agriculture sectors. However, in most cases this framework is a cosmetic approach, lacking the mechanisms for cross-sectoral integrated planning. There is no need to create new institutions or replace existing ones; the challenge is to instil a participatory intersectoral approach to policy formulation and implementation. This requires political commitment and scientific backing; political commitment to ensure proper, substantive and financing backing, and scientific backing to identify and quantify synergies and trade-offs.

For a nexus approach to succeed where other integrated management approaches have faltered, it has to:

a. Adopt a participatory approach;
b. Build understanding of the links between the sectors;
c. Bridge the planning and operational divide between sectors;
d. Facilitate a unified and coherent agenda at least at the level of sustainable development;
e. Exhibit strong commitment to the nexus paradigm at practice level.

## Building bridges

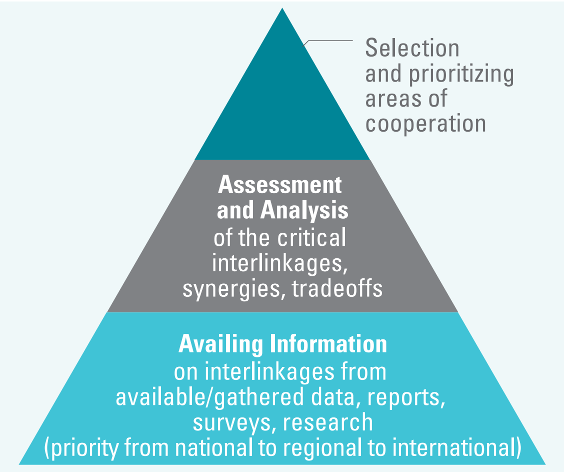
It is necessary to build a relationship between the energy and water communities that facilitates interaction and dialogue. At sector institutional level, this may negate the need for multisectoral ministries or governance units. The process of decision-making and managing is more important than physically or cosmetically grouping people from various sectors. The approach must be participatory at all stages that consider sector perspectives, identifying synergies and managing trade-offs appropriately. These synergies and trade-offs must not be feared but addressed within the agreed nexus framework. This requires transparent resource allocation by developing a shared decision-making process for nexus issues based on a common vision. Figure 4 presents a simplified path for selection of areas of nexus cooperation.

This necessitates a paradigm shift in current resources management, where sector priorities, policies and governance are handled by line ministries in silos. Interaction is kept at a minimum where intersectoral engagement is sporadic and often unwelcome. A nexus approach necessitates intersectoral relationships at levels from decision makers to technical operators, and at all stages of decision-making. The startup point should be an agreement on a common set of values at national level that different sectors can then build on. The human right to water, food and development, and to the SDGs, are common values that can solicit agreement.

The following actions may encourage necessary relationship-building across sectors:

a. Senior officials to set an example, visibly working together to establish a collaborative culture across sectors;
b. Senior officials committing to action, availing themselves, or necessary staff time and resources, as part of planning;
c. Identify counterparts with similar duties in other sectors, and establish working groups. Intersectoral institutional mapping may be needed at least at functions level;
d. Organize regular scheduled meetings to discuss intersectoral issues or present updates. People tend to resist this step, uncomfortable at having to work with those they perhaps avoided in the past, but it is essential for a nexus mentality shift;
e. Implement intersectoral staff exchange programmes, where staff

**Figure 4.** Selection path of nexus cooperation



from different sectors visit each other's institution to learn of opportunities for cooperation;

f. Arrange for intersectoral training programmes of interest to people from the various sectors. This provides an opportunity to interact and improve knowledge of nexus links.

## Building public and policymaker awareness of the nexus

Raising awareness within sectors and government institutions can be achieved through dedicated capacity-building activities, such as workshops, conferences, education and e-learning. One of the most cost-effective methods is through specialized staff sharing experiences with colleagues. Often staff engaged in external learning neglect to disseminate knowledge to colleagues once they return to the office, which could be addressed by sharing materials and training sessions.

In tandem with building consensus within sectors, there is a need to raise awareness among policymakers and the general public to garner support for nexus plans. This could vary depending on the audience and sector. The education sector, for example, should be supported to introduce into the curriculum material that introduces links between sectors while, at university level, system nexus programmes can inform the future professional workforce. This is equally important at vocational level, for an appropriate technical workforce.

With the industrial, commercial and agricultural sectors, targeted programmes with specialized messages are best suited to raising awareness on nexus links. These could be visible pilot projects or outreach programmes relaying the benefits, preferably economic, of the nexus. The public could be sensitized through advertising campaigns; to be effective these must deliver tangible messages that are interesting to the consumer. For example, a campaign encouraging water-saving showers that relays the nexus message that these save water and electricity.

Any awareness activity, however, is unlikely to be effective unless regularly reinforced. It is important to simplify initial messages and work to build knowledge after acceptance has been secured.

## Bridging the information gap

Sound policies, strategies and plans are usually those built on solid scientific study combined with any necessary information. This requires the scientific community to produce timely knowledge that addresses regional and local issues in a manner useful to policymakers. And policymakers must share relevant information with the scientific community. Both must communicate effectively to build a common understanding of priorities, helping the scientific community to better inform decision makers.

Reliable information, therefore, results in useful knowledge and leads to good policymaking. In this sense, water footprinting in the energy sector and energy footprinting in the water sector are critical to better understanding the links between sectors. In general, this knowledge is lacking at regional and national to local levels, and may require a commonly accepted standard on measurement and reporting that both sectors are comfortable with. Information and data must be of good quality, available and accessible, and at an appropriate resolution, which requires a clear data management plan or protocol to increase confidence between nexus parties.

**Figure 5.** Nexus framework must be integrated in all stages of the programming process

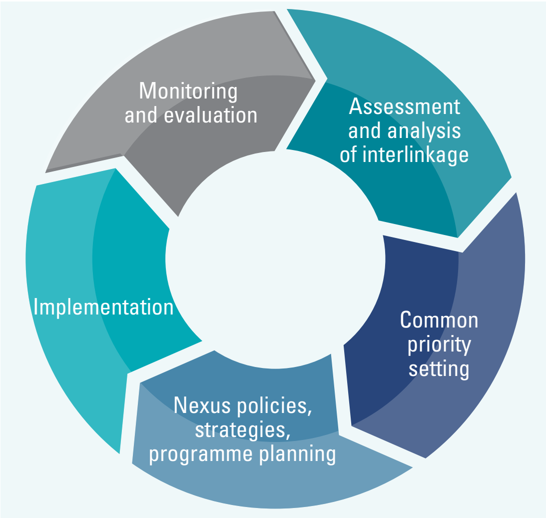



**Figure 6.** Framework for a regional nexus knowledge hub


The nexus framework must be incorporated in all stages of the sectoral programming process. Initially, this is based on analysis of available information leading to common priority setting for the sectors involved. This results in policies, strategies and programme planning and design that is implemented then monitored and evaluated, resulting in more data that may restart the process (figure 5).

## Regional nexus knowledge hub

Information on the nexus, specifically energy use in the water sector and water use in the energy sector, is critically lacking in the region. Efforts are needed to collect information and instill a culture of sharing at national and regional levels. There have been calls for a nexus knowledge hub where data is made available, and successes and lessons are shared within the region. This requires a physical structure and, importantly, an institutional set-up that allows for sustainability, continuity and the resources for collecting information and follow-up. This could act as the platform for a community of practice on the nexus. The basic framework for such a hub is presented in figure 6.

# Dialogue and conflict resolution among stakeholders for resources allocation

Although the benefits of a coherent water-energy nexus are apparent, the political, socioeconomic and security realities faced by ESCWA member countries often complicate the implementation of nexus solutions. Knowing how to negotiate these obstacles with appropriate tactics and strategies can help policymakers overcome zero-sum perspectives and increase the chances of unified nexus policies.

Three areas identified as useful spaces for negotiations include within sectors (intrasectoral), between sectors (intersectoral), and among nexus policies of ESCWA member countries (transboundary nexus relationships).

Negotiation within the water-energy nexus is a matter of balancing the competing inputs and uses of water and energy resources to achieve mutually acceptable and sustainable management policies. A primary way is by developing common standards, particularly around data. It is useful to establish standards prior to entering negotiations, which can help build an environment that generates trust.[17]

Due to the interdependence of water and energy sectors, understanding the trade-offs and synergies that can be made between them is a good place to start looking for consensus. One way to evaluate nexus trade-offs and synergies is by considering private sector involvement. For example, because water is subsidized in many Arab countries, there is little incentive for private-sector investment. The energy sector, however, can attract significant private capital – and spur innovation – due to relatively higher levels of productivity. A potential option might involve leveraging private investment in the energy sector to change the stakes at the bargaining table and make a nexus solution more achievable.[18]

While private sector investment in the energy sector can produce options to negotiate with the water sector, the idea of water as a flexible resource can provide options to negotiate with the energy sector. Water is still perceived as a fixed resource that remains static or decreases in quantity. But the nexus shows that water can be “created” by improving efficiency through

Falaj Al-Katmeen in Nizwa, Dakhiliya, Oman. Five Aflaj Irrigation Systems of Oman were added to the UNESCO list of World Heritage Sites in 2006 © JPRichard - Shutterstock_ 368938112 policies, technologies, and alterations in consumer behaviour.[19] Negotiations are important to the success of the water-energy nexus and should continue to be considered integral to the policymaker toolkit. The following sections outline general guidelines for negotiation, some of which apply to intra- and intersectoral negotiations, others for transboundary nexus relationships.

## Negotiation terms, approaches and analysis

The basic principles of negotiation consists of adversaries, positions, interests and options. Adversaries, or parties, discuss distinct positions with one another to advance and secure their interests in a mutually acceptable manner (defined in table 2). Options, or alternative agreements, allow adversaries to make acceptable trade-offs to achieve their core interests. In reality, an adversary's options are usually limited due to competing constituencies, interest groups or other internal pressures. An effective negotiator must evaluate his or her counterpart's positions and interests from the outset to determine whether options are realistic and achievable.

**Table 2.** Basic negotiation terms

| | |
|---|---|
| **Adversaries or parties** | actors involved in conflict |
| **Position** | implicit or explicit standpoints or objectives towards which all tactics and strategies are directed |
| **Interests** | an actor's true, core objectives |
| **Options** | alternative acceptable agreements that can be used as bargaining |

Source: ESCWA, 2014.

Within the water-energy nexus, the most likely types of conflict are structural and data-based (defined in table 3). While the two are distinct, it is possible they may overlap or even transform from a structural to a data conflict or vice versa. For instance, several countries with major political differences and external stakeholders were involved in a structural conflict over shared international watercourses. Over time, global political changes created the opportunity for cooperation, but instead of reaching a settlement, conflict then centred on different perceptions of data, transitioning from a structural to a data conflict.[20]

**Table 3.** Typical types of conflict in the water-energy nexus

| | |
|---|---|
| **Structural** | conflicts based on systemic rival interests, such as those characterized by alliances with strong external parties, geographic relationships, disparities in power/authority and unequal control of resources |
| **Data** | conflicts based on lack of timely/relevant information, misinformation, differing interpretations and contrasting views on what is relevant, whether intentional or accidental |

Source: ESCWA, 2014.

Although the ideal of negotiation is to achieve either resolution or, if this proves unfeasible, settlement, other possible outcomes include prevention and avoidance (defined in table 4). A common way to prevent conflict is agreement on common values such as human rights to water, food and development or the achievement of the SDGs. Policy incentives (typically economic) are also highly effective at preventing conflict. Further deterrents include awareness -raising, public participation and institution building, each of which should be encouraged in the Arab region.[21]

**Table 4.** Conflict management approaches

| | |
|---|---|
| **Prevention** | active planning to identify potential causes of conflict, and attempting to neutralize or minimize them |
| **Avoidance** | reaction in which parties do not address the core causes of conflict and instead, agree upon incompatible or non-substantive positions; perhaps because no solutions are apparent or for psychological reasons |
| **Settlement** | aims to alter the symptoms as opposed to the root causes of a conflict, significantly increasing the likelihood of the conflict resurfacing; often arbitrated by a third party |
| **Resolution** | mutually acceptable and sustainable agreement that confronts and solves the root causes of the conflict, typically in one of two ways: legal obligations or informal channels |

Source: ESCWA, 2014.

## Preparation, strategy and tactics

Perhaps the most important stage of negotiations – apart from the event itself – is the preparatory work done beforehand to articulate interests, develop a strategy and formulate tactics. Tactics are smaller manoeuvres focused on short-term objectives whereas strategy is the broad, overarching and stable set of goals directed to advance the party’s interest. Typically, preparation for negotiations takes place at three levels: policy, team and individual level. At policy level, such as the resource department of the ministry for instance, authorities are tasked with the groundwork of defining the institution’s core interests and communicating them to a negotiating team. Six recommended steps that policymakers should complete when preparing for negotiations are listed in table 5.

**Table 5.** Preparatory checklist prior to negotiation

| | |
|---|---|
| **1** | Compile and analyze your counterpart’s positions and interests |
| **2** | Review relevant water and energy resources information |
| **3** | Evaluate options and scenarios based on above assessments |
| **4** | Nominate a skilled and reliable head of delegation and other members, including technical and legal advisors when necessary |
| **5** | Convert overall policy and interest into a negotiation strategy |
| **6** | Ensure members of the term know the adversary’s language (often overlooked) |

Source: ESCWA, 2014.

At the team level, one of the best ways to prepare is by ensuring the strategic objectives have been clearly communicated to all members and that they have been adequately trained.[22] For the head of delegation, it is important that he or she understands what is expected of them. A written mandate is recommended to prevent the possibility of blame for mishandling negotiations that sometimes follows an agreement. Below are several additional questions that the head of delegation should address prior to negotiations:[23]

- What are the top, middle and low priority objectives of the adversary?
- How do your party's tactics match with the above?
- How can you get relevant information and how does this data compare with that of your adversary?
- What is the expected timeline; yours and that of your adversary?
- When and how will you mobilize your team to rehearse roles and tactics?
- What kind of information-loop will be designed among team members?
- Does the adversary have experienced negotiators?
- Where is a neutral, agreeable venue for negotiations to take place?

No matter how much preparation goes into negotiations there is always a chance of deadlock. Two steps that can help overcome a deadlock are to address the smaller, less contentious issues, and/or to introduce a neutral third party.[24] Third parties have played a prominent role in negotiations in the Arab region and are recommended for the energy-water nexus.

A delegation should always prepare for the possibility of a deadlock by developing a best alternative to a negotiated agreement (BATNA), or the optimal result expected if negotiations break down.[25] It is helpful because it establishes a defined baseline of what is acceptable. Anything less than that minimum would justify walking away, which is a valuable pressure point in and of itself. The four steps to evaluating a BATNA include: list alternatives; evaluate these alternatives; create the BATNA based on these alternatives; and calculate the reservation value, or the lowest-valued deal acceptable.[26] The general rule in deciding when to walk is as follows: if the value of the deal is lower than the reservation value, reject the offer and choose the BATNA. If the value is higher than your reservation value, accept.

# Key messages

The 2030 Agenda is well supported by the water-energy-food security nexus approach. It examines the links between the sectors to improve the holistic management of natural resources and associated ecosystems based on a human rights approach and climate change impacts. A nexus approach identifies potential trade-offs and synergies among the SDGs and their targets without purely focusing on sectoral progress.

It is participatory, inclusive and not sector focused. It considers the perspective of all sectors and builds on the strengths, strategies and plans of each to enhance efficiency, productivity and integrated management of resources.

A people-centred approach to development, guided by human rights on access to water, food and development, and the adverse effects of climate change on the enjoyment of these rights, can provide the basis for a nexus framework in the Arab region, where all

System pumping water for agriculture, with the control unit powered by solar energy © Franco Nadalin - Shutterstock_282434432

three main components are seen as equally important. Several strategies, action plans and initiatives can play a role in putting such an approach into operation.

The success of a nexus approach hinges on establishing clear dialogue between sectors, backed by political will based on common values such as achieving sustainable development. This can be supported by raising awareness, which gathers support for nexus policies and plans among various audiences and stakeholders. Policies and plans must be based on clear scientific evidence that necessitates greater efforts to use nexus-specific data. The scientific community, provided with the necessary support, must deliver comprehensive research that is politically feasible.

A regional knowledge hub can serve as a nucleus for a community of practice on the nexus. This community can help advance the nexus approach across the region, sharing information and lessons while connecting experts and policymakers.

Synergies and trade-offs are normal with any nexus framework. Trade-offs should not be feared but properly analysed and addressed to avoid conflict. Dialogue is crucial among the various water-energy-food security nexus partners at intrasectoral, intersectoral and transboundary levels. The level of coordination and collaboration between the water and energy sectors in all stages of planning and implementation must be increased, while negotiation skills and team-building must not be overlooked as tools for resource allocation within the framework.

# Endnotes

1. United Nations, General Assembly, 2015.
2. United Nations, General Assembly, 1948.
3. United Nations, General Assembly, 1986.
4. ESCWA, 2012.
5. World Meteorological Organization, 1992.
6. ESCWA, 2015a.
7. HRBA portal, n.d.
8. Sustainable Energy for All initiative, available from http://www.se4all.org/.
9. United Nations, General Assembly, 2015.
10. ESCWA and League of Arab States, 2015.
11. United Nations, General Assembly, 2015.
12. ESC, 2016.
13. United Nations, General Assembly, 2015.
14. League of Arab States, Arab Ministerial Water Council, 2012.
15. League of Arab States and Arab Organization for Agricultural Development, 2007.
16. IRENA, 2014.
17. ESCWA, 2014.
18. Schuster-Wallace and others, 2015.
19. Susskind and Islam, 2012.
20. ESCWA, 2014.
21. Ibid.
22. Ibid.
23. Ibid.
24. Ibid.
25. Harvard Law School, 2014.
26. Ibid.

# Bibliography

Committee on Economic, Social and Cultural Rights (1999). The Right to Adequate Food (At. 11). Contained in Document E/C.12/1999/5 (12 May).

Economic and Social Commission for Western Asia (ESCWA) (2012). *Report on Intergovernmental Consultative Meeting on the Water and Energy Nexus in the ESCWA Region* (E/ESCWA/SDPD/2012/IC.1/2/Report), Beirut, 27-28 June 2012. Available from https://www.unescwa.org/sites/www.unescwa.org/files/publications/files/e_escwa_sdpd_12_ic-1_2_report_e.pdf.

Economic and Social Commission for Western Asia (ESCWA) (2014). A manual for ESCWA Member Countries on *Dispute Resolution of International Water Resources*. Beirut, Lebanon: ESCWA.

Economic and Social Commission for Western Asia (ESCWA) (2015a). Conceptual Frameworks for Understanding the Water, Energy and Food Security Nexus – Working Paper. (E/ESCWA/SDPD/2015/WP.2). Available from http://css.escwa.org.lb/SDPD/3581/WP1A.pdf.

Economic and Social Commission for Western Asia (ESCWA) (2015b). *Water Development Report 6: The Water, Energy and Food Security Nexus in the Arab Region*. (E/ESCWA/SDPD/2015/2). New York: United Nations. Available from https://www.unescwa.org/sites/www.unescwa.org/files/publications/files/e_escwa_sdpd_15_2_e_0.pdf.

Economic and Social Commission for Western Asia (ESCWA) and League of Arab States (2015). Regional Initiative for the Assessment of the Impact of Climate Change on water Resources and Socio-Economic Vulnerability in the Arab Region (RICCAR): Climate Projections and Extreme Climate Indices for the Arab Region (E/ESCWA/SDPD/2015/Booklet.2). Beirut: United Nations. Available from https://www.unescwa.org/sites/www.unescwa.org/files/publications/files/l1500436.pdf.

Economic and Social Council (ESC) (2016). Input from the Arab Forum on Sustainable Development to the high-level political forum on sustainable development. (E/HLPF/2016/3/Add.5). United Nations.

Harvard Law School (2014). BATNA. Available from http://www.pon.harvard.edu/category/daily/batna/. Accessed June 2016.

Human Rights Based Approach (HRBA) portal (n.d.). The Human Rights Based Approach to Development Cooperation: Towards a Common Understanding Among UN Agencies. Available from http://hrbaportal.org/the-human-rights-based-approach-to-development-cooperation-towards-a-common-understanding-among-un-agencies. Accessed June 2016.

International Environmental Law Research Centre (1977). United Nations Water Conference (Resolutions). In *Report of the United Nations Water Conference*, Mar del Plata, 14-25 March. Available from: http://www.ielrc.org/content/e7701.pdf.

International Renewable Energy Agency (IRENA) (2014). *Pan-Arab Renewable Energy Strategy 2030: Roadmap of Actions for Implementation*. Masdar City, United Arab Emirates. Available from http://www.irena.org/DocumentDownloads/Publications/IRENA_Pan-Arab_Strategy_June%202014.pdf.

League of Arab States (2004). Arab Charter on Human Rights (22 May). Available from http://www.lasportal.org/ar/sectors/dep/HumanRightsDep/Documents/%D8%A7%D9%86%D8%AC%D9%84%D9%8A%D8%B2%D9%8A.pdf.

League of Arab States, Arab Ministerial Water Council (2012). *Arab Strategy for Water Security in the Arab Region to Meet the Challenges and Future Needs for Sustainable Development 2010-2030*, adopted by Arab Ministerial Water Council in May 2011. Cairo. English translation by the GIZ/ACCWaM project approved by AMWC in June 2012.

League of Arab States, Arab Organization for Agricultural Development (2007). *Strategy for Sustainable Arab Agricultural Development for the Upcoming Two Decades (2005-2025)*. Available from http://www.aoad.org/strategy/straenglish.pdf.

Schuster-Wallace, Corinne J., and Robert Sandford (2015). *Water in the World We Want*. United Nations University Institute for Water, Environment and Health and United Nations Office for Sustainable Development. Available from http://inweh.unu.edu/wp-content/uploads/2015/02/Water-in-the-World-We-Want.pdf.

Susskind, Lawrence, and Shafiqul Islam (2012). Water Diplomacy: Creating Value and Building Trust in Transboundary Water Negotiations, *Science and Diplomacy*, Vol. 1, No. 2 (Sep. 2012). Available from http://www.sciencediplomacy.org/files/water_diplomacy_science__diplomacy.pdf.

United Nations, General Assembly (1948). The Universal Declaration of Human Rights (Resolution 217 a (III)) (10 December). Available from http://www.ohchr.org/EN/UDHR/Documents/UDHR_Translations/eng.pdf. Accessed 25 June 2015.

United Nations, General Assembly (1986). Declaration on the Right to Development (A/RES/41/128) (4 December). Available from http://www.un.org/documents/ga/res/41/a41r128.htm. Accessed 3 July 2015.

United Nations, General Assembly (2015). Transforming our world: the 2030 Agenda for Sustainable Development (A/RES/701) (22 September). Available from http://www.un.org/ga/search/view_doc.asp?symbol=A/RES/70/1&Lang=E. Accessed 26 May 2015.

United Nations Human Rights Council (2008). Resolution 7/14: The right to food (27 March). Available from http://ap.ohchr.org/documents/E/HRC/resolutions/A_HRC_RES_7_14.pdf.

United Nations, Human Rights Council (2014). Resolution 26/27: Human rights and climate change (15 July). Available from https://documents-dds-ny.un.org/doc/UNDOC/GEN/G14/083/51/pdf/G1408351.pdf?OpenElement.

United Stated Department of Energy (2006). *Energy Demands on Water Resources: Report to Congress on the Interdependency of Energy and Water.* Washington, D.C. Available from http://www.circleofblue.org/wp-content/uploads/2010/09/121-RptToCongress-EWwEIAcomments-FINAL2.pdf.

World Meteorological Organization (1992). The Dublin Statement on Water and Sustainable Development. Adopted at the International Conference on Water and the Environment, Dublin, 26-31 January. Available from http://www.wmo.int/pages/prog/hwrp/documents/english/icwedece.html. Accessed June 2016.

# Increasing Policy Coherence

2 Module

# Contents



## List of figures



## List of boxes



## List of tables

# Abbreviations and explanatory notes

| | |
|---|---|
| **ASFSD** | Arab Strategic Framework for Sustainable Development |
| **CPUC** | California Public Utilities Commission |
| **ESCWA** | Economic and Social Commission for Western Asia |
| **GCC** | Gulf Cooperation Council |
| **G20** | Group of Twenty |
| **LAS** | League of Arab States |
| **NCoP** | Nexus community of practice |
| **OECD** | Organisation for Economic Co-operation and Development |
| **PCD** | Policy coherence for development |
| **SDCWA** | San Diego County Water Authority |
| **SDG** | Sustainable Development Goal |
| **UNDESA** | United Nations Department of Economic and Social Affairs |
| **UNDP** | United Nations Development Programme |
| **UNECE** | United Nations Economic Commission for Europe |
| **WEF** | Water-energy-food |
| **WSSD** | World Summit on Sustainable Development |

# Background and objectives of this module

The Arab region is moving towards a better understanding of the links between local natural resources and socioeconomic, environmental and political realities. Although there are many factors common to the region, countries can be clustered into three defined ecozones, which share similar climatic conditions, water scarcity levels, energy portfolios, economies and political systems.

Countries in the ESCWA region, and communities within them, are at various stages of social, technological and economic development. Policies and strategies have to be tailored according to the specific circumstances of each environment. At the same time, regional coherence allows for common ground that fosters an open exchange of best practices. This phenomenon reveals globally consistent issues in the water-energy nexus that can also be built upon.

The 17 United Nations Sustainable Development Goals (SDGs) were written based on a global consultative process that faced challenges when seeking to pursue interlinkages between distinct goals, despite progress towards at least 12 goals being directly related to the sustainable use of resources such as land, food, water, energy and materials. The United Nations Environment Programme (UNEP) and International Resource Panel's 2015 report[1] assesses the interlinkages, synergies and trade-offs among natural resource-related SDGs that decision makers should consider when formulating policies for their implementation.

In the face of regional resource, climate and political challenges, the Arab region is focusing on sustainability from a policy and legal standpoint. The Arab Ministerial Water Council adopted a regional water security strategy in 2012 and an action plan in May 2014,[2] and the Arab Ministerial Council for Electricity adopted the Pan Arab Strategy for the Development of Renewable Energy Applications (2010–2030) in 2013.[3] While many countries have adopted internal regulations to move towards better access to resources and a sustainable growth rate for all sectors, greater cooperation and improved governance is needed, particularly for local and transboundary resources. Improved databases, monitoring systems and assessment tools are being developed by many regional organizations and national ministries for improved coherence in the Arab region.

This module presents different models and definitions of policy coherence and country examples. It presents models of policy coherence and their role in development, sustainability and the SDGs. It also provides a vision and a framework appropriate for the ESCWA region that includes resolutions of policy coherence in the water and energy sectors, creation of a community of practice, and a dialogue platform across various sectors. Governance models and accountability measures are discussed. The module concludes with key messages for policymakers on developing a policy coherence plan across the water-energy-food (WEF) nexus.

# Policy coherence for development

## Defining policy coherence for development and its role in sustainability

The concept of policy coherence was introduced by the Organisation for Economic Co-operation and Development (OECD) as a matter of concern when providing assistance to developing countries, not only to ensure that various policies having an impact on countries were not contradictory, but also to build synergies to foster development.

Policy coherence is defined by the OECD as "the systematic promotion of mutually reinforcing policy actions across government departments and agencies creating synergies towards achieving the agreed upon objectives". Within national governments, policy coherence issues arise between different types of public policies, levels of government and stakeholders, and between countries at an international level.

Policy coherence for development (PCD) is a policy tool for integrating economic, social, environmental and governance dimensions of sustainable development at all stages of domestic and international policymaking. According to the OECD, policy coherence for development should entail the following steps:[4]

a. Identify and address interactions among various policies in the economic, social, environmental, legal and political domains to support pathways to inclusive sustainable growth;
b. Establish institutional mechanisms, processes and tools for effective, efficient, sustainable and coherent policies in key sectors and ongoing crisis situations;
c. Develop evidence-based analysis, sound data and reliable indicators to inform decision-making and translate political commitments into practice;
d. Foster multi-stakeholder policy dialogue to identify catalysts and barriers to economic and social transformation.

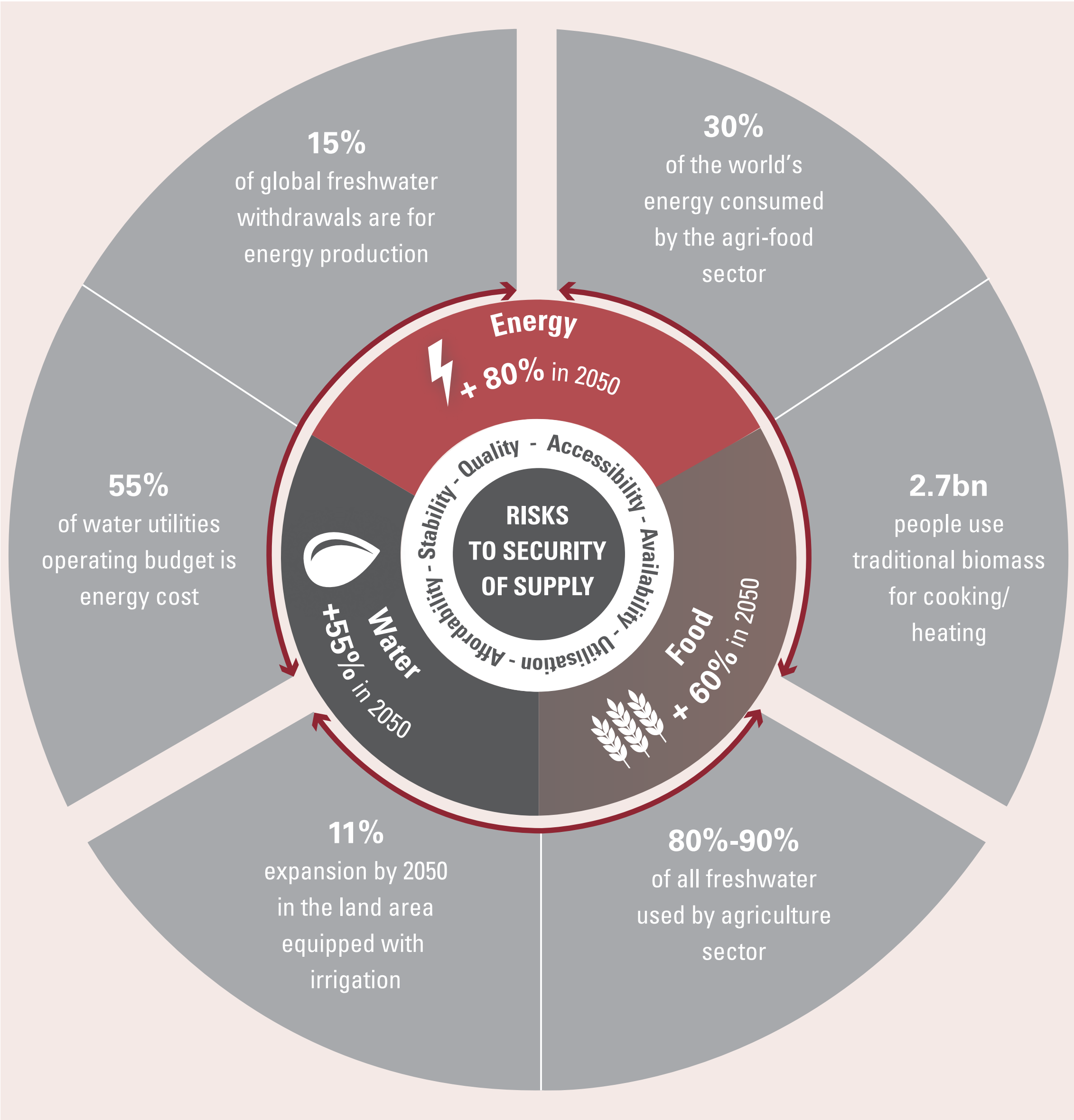
## Resource management and the effects of the lack of policy coherence

Global resources are under major external stress. Unied Nations projections indicate that the world population could pass 10 billion by 2100.[5] Such rapid growth is impacting on water, energy and food securities in regions already experiencing water stress, such as the Middle East, North Africa, Asia and Central America.[6]

Climate change adds further stress on primary resources, with subtropical regions experiencing the highest population growth and stresses on primary resources. Climate change projections are for these regions to receive less rain, which will result in lower soil moisture and consequently impact on food and water security.[7]

Water and energy resource systems are fundamentally interrelated. Secure, reliable access to both resources and their modern services is critical to basic survival, and to ongoing economic development, on all scales and in every region of the world. Water is required to make energy,

**Figure 1.** Resource interconnectedness




**Source:** IRENA, 2015.

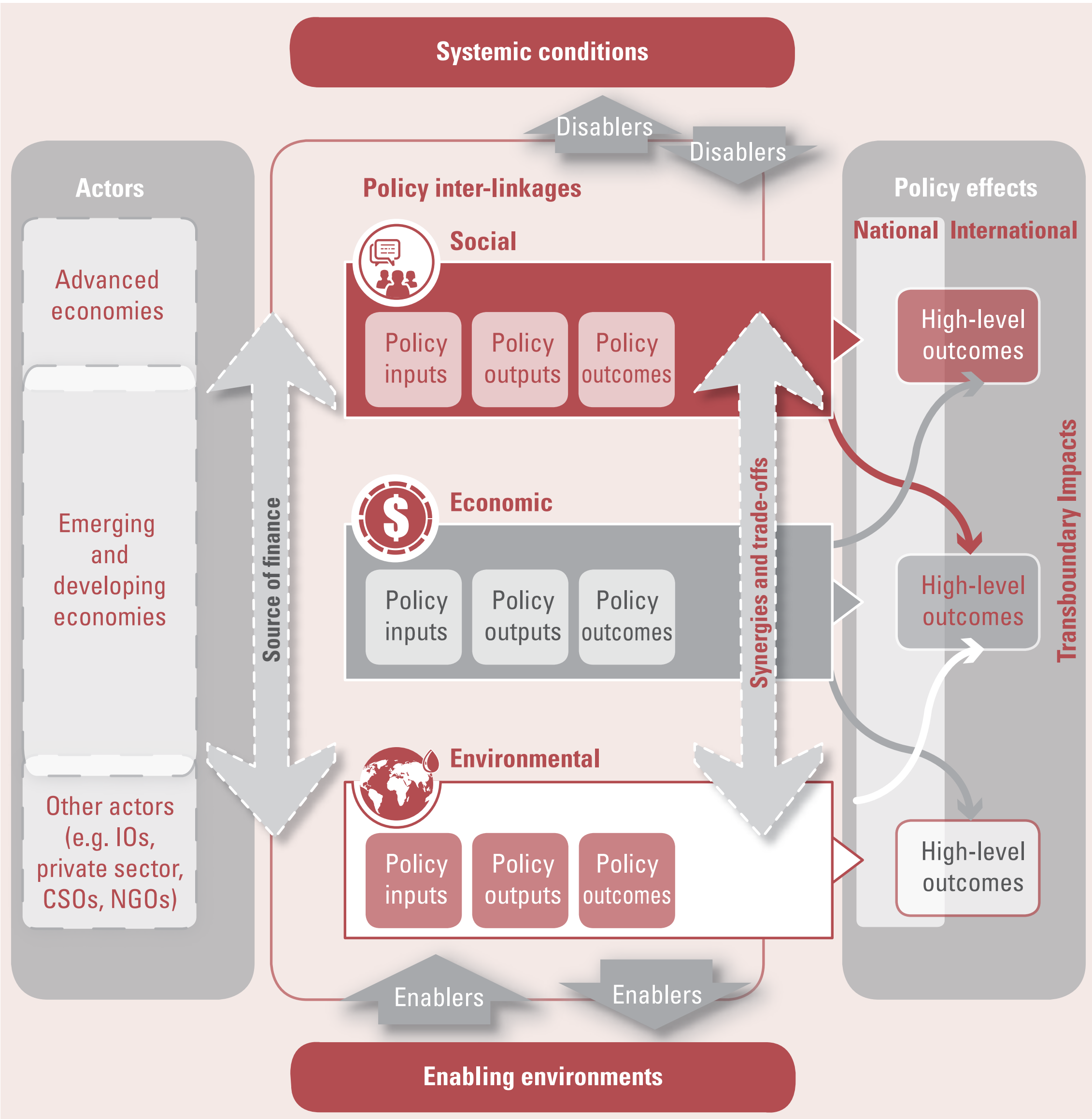
and energy is required to treat and move water, a relationship we call the water-energy nexus. This concept is critical when setting priorities and formulating related policies, from national and regional perspectives. The water-energy nexus is a vital pillar for food production. Food and energy production requires more than 90 per cent of total global water resources.[8] Figure 1 shows the projected increase in resource demand by 2050, and their interconnectedness.

It is evident a lack of policy coherence in managing primary resources, or continuing with "business-as-usual" policies in the Arab region will create serious water and energy security risks and compromise the well-being of future generations. This interdependency of energy, water, food and climate change makes it imperative that policy formulation is coordinated, particularly with mitigation and adaptation, the two main responses to climate change. Conventional policymaking in "silos" needs to give way to an approach that reduces trade-offs and builds synergies across sectors. This new development has created unprecedented opportunities for fundamental policy changes in economic, institutional, technological and social systems.[9] However, weak or lacking real coordination in the Arab region in policies and strategies for water, agriculture, land, energy and climate change must be acknowledged. Climate change policies remain in their infancy stage in the region, fragmented between different entities and sectors.

## Policy coherence under the SDGs

By themselves, the SDGs represent a coherent vision, guiding human well-being, ecosystem health and socioeconomic growth as part of one holistic system. SDG 17 tackles the means of

**Figure 2.** Analytical framework for policy coherence for sustainable development




**Source:** OECD, 2015b.

implementation and global partnerships for sustainable development, target 17.14 specifically referring to “enhance policy coherence for sustainable development”.

While working on the SDGs related to water, energy and food security, it is important to promote synergies within the goal through understanding and managing linkages between resources, and with social and governance systems.

Policies should articulate the co-benefits of the socioeconomic objectives and environmental quality and sustainable resource management targets. In this way, multiple SDGs can be achieved simultaneously. For example, promoting sustainable consumption and production can impact on land, water, energy and other resources.[10] Take SDG 6 (water and sanitation) and SDG 7 (energy). They can be achieved only by linking other focus areas, such as poverty eradication (SDG 1), sustainable agriculture, food security and nutrition (SDG 2), health and population dynamics (SDG 3), education (SDG 4), gender equality and women’s empowerment (SDG 10), economic growth (SDG 8), sustainable consumption and production (SDG 12) and climate (SDG 13). An integrated framework for policy coherence for development that notes linkages between resources, society and politics should be taken into account when developing policies related to the SDGs.[11]

Figure 2 shows an analytical framework for policy coherence for development as proposed by OECD. Close connections and interdependencies between resources and socioeconomic and political circumstances in the Arab region should be considered when formulating policies towards achieving the SDGs and targets. It has been cited that 10 of the SDGs can be achieved only when consumption efficiencies for land, water, materials and other resources are increased.[12]

# Policy coherence framework

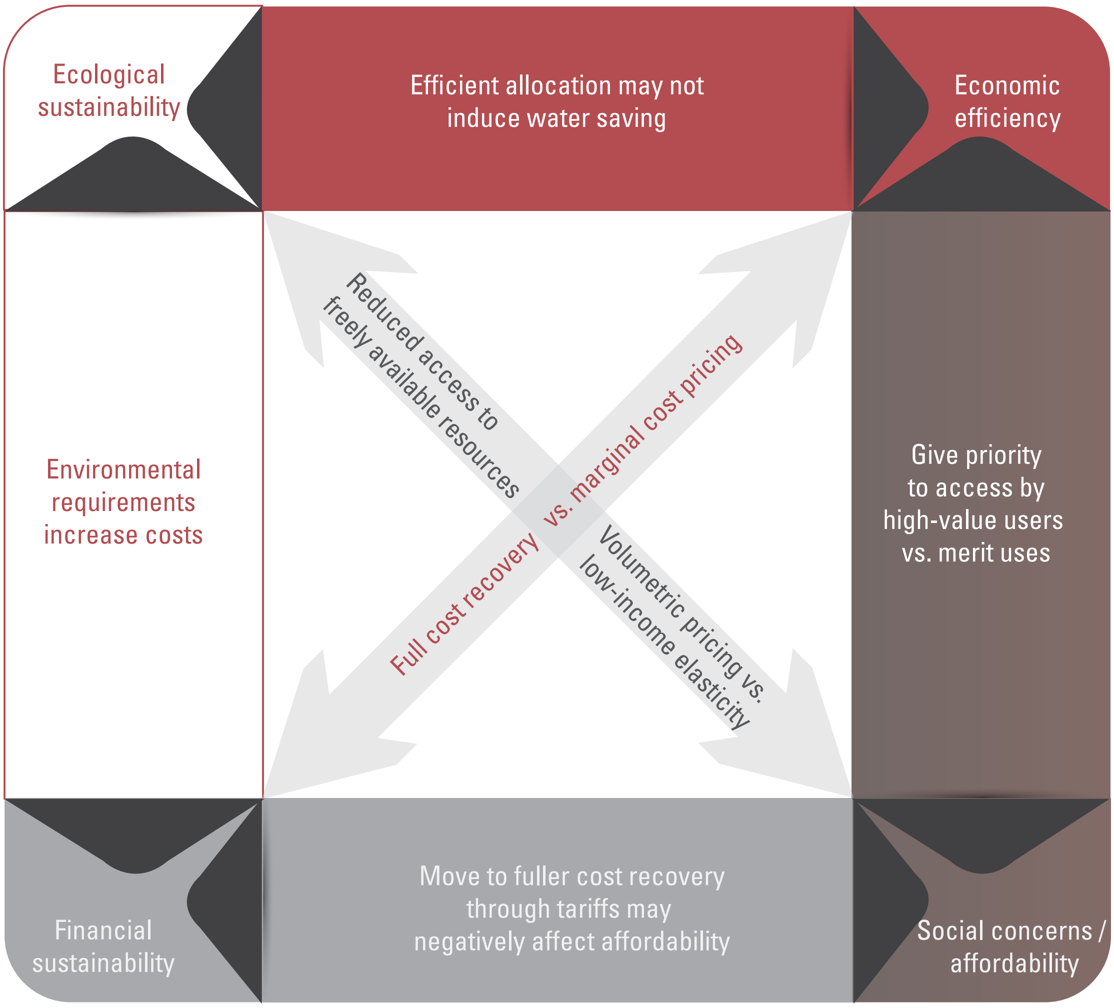
This section presents a framework for policy coherence for Arab region countries. It intends to raise awareness of the importance of interaction and coordination in managing primary resources, and to highlight critical concerns when improving their management. The framework includes the following elements:

a. Balancing competing demands, outcomes and criteria;
b. Resolving policy coherence in the water-energy nexus;
c. Defining scale and level of policy coherence;
d. Developing capacity for more integrated and coherent policymaking;
e. Conducting a dialogue platform among stakeholders;
f. Developing a nexus community of practice;
g. Exploring governance models for the water-energy-food nexus.

## General framework: balancing competing demands, outcomes and criteria

Water and energy governance in Arab countries, like other non-OECD countries, is normally administered by the public sector.  Government-owned and operated, the incentive is lacking

**Figure 3.** Balancing competing demands, outcomes and criteria




**Source:** OECD, 2009.

for more efficient operation and use of water and energy services. These service providers, however, ensure all citizens have access to crucial primary resources. The question is how to strike a balance between access and affordability on the one hand and efficiency on the other, as articulated by OECD in Figure 3.

Water governance in Arab countries is a significant challenge. With regional supplies in chronic deficit and high rates of population growth and urbanization, demand for access to potable drinking water is increasing sharply. Agriculture consumes 85 per cent of the fresh water supply, with only 50 per cent self-sufficiency in food. Desalination alone is not a realistic solution in the long run and costs in poor countries are beyond what most individuals can afford.

As for the energy challenge, fossil fuels remain the dominant form of energy, and increased supply comes at the cost of exports. Energy demand has been growing rapidly with associated grid infrastructure challenges. Despite high rates of electrification across the region, there are more than 40 million people living without electricity, especially in rural areas of Yemen and the Sudan.[13] It is here that off-the-grid renewables, especially solar and wind, could provide millions of people with access to electricity. However, technology adaptation, and creating local capacity, is required to initiate indigenous innovation, operation and maintenance, and manufacturing. Access to renewables will also improve access to water by reducing expensive, energy-intensive desalination.

In addition to the technological issues, access to water and sanitation is a human rights issue enshrined in United Nations resolution 64/292 and there is overwhelming consensus among Member States that access to energy for all is a prerequisite for development and, therefore, a human right. Not all Arab States have signed the human rights conventions, and some have signed with reservations. This must be resolved in order to enhance policy coherence among public management systems used in these States.

While policy coherence could be defined as effective national governance, policy coherence for development is particularly designed to benefit developing countries. It is only relevant if taken into specific scenarios and sectors, and it is here that conflict may arise. For policy coherence, stakeholders must agree on what they consider beneficial in the first place, in the areas of trade, illicit financial flows, migration, technology transfer and global governance, among others.[14]

Creating a science-policy platform creates synergy between stakeholders, allowing them to make decisions based on a common understanding of science and data compared with the current reliance in most developing countries on empirical evidence. In order to create policy coherence for development in the areas of water and energy, policy and decision makers need access to comprehensive tools that:[15]

- Are inclusive of all stakeholders and correspond to the multi-scale nature of the nexus (local, country, regional);
- Define and quantify interlinkages between water and energy resources;
- Enable development of an integrated strategy for resource management.

## Resolving policy coherence between the water and energy nexus in Arab States: way forward

The water and energy sectors must work together to resolve policy coherence issues for the sustainability of both resources. Below are agreed issues that must be resolved and implemented:

- Set measurable, achievable goals for water and energy. The SDGs process can provide the platform and incentives. The United Nations Universal Declaration of Human Rights can and should be consulted, and integrated with these goals;
- Set targets to meet the goals above. Can include access, efficiency of delivery or pricing for these services;
- Quantify the impact of each of these targets on other goals and targets. As such, a matrix of inter-connectedness can be established;
- Establish a structure of governance that allows for interaction across sectors. Can vary from one city or country to another. The choice may be between technical or policy coordination. The composition and nature of the coordinating body must reflect the variability of the ecozones;

An old water wheel in the Syrian city of Hama © Shutterstock.com - Paco Lozano 21579826

- Recognize hotspots, regions or themes that are most vulnerable and require intervention, based on the impact of the matrix;
- Develop an action plan that includes financing, management and governance, to address issues of ownership and incentives to achieve set targets.

## Scales and levels of policy coherence

Policy coherence should focus on enhancing the capacity to exploit synergies across policy areas with cross-border dimensions – trade, investment, agriculture, health, education, environment, migration and development cooperation – to create environments conducive to development.[16]

From a water-energy nexus perspective, coherence is built on a multi-stakeholder approach, across vertical and horizontal scales. The interconnectedness of resources might be evident at the household scale or even at municipality scale but it becomes more complex when going from the local and country level to regional and international contexts.

Examining the multiplicity of stakeholders at a horizontal level, the following groups can be identified:

- Private sector (business). Responds to demand by activating the supply chain and managing critical resource systems. For this sector, it is about optimizing operations and minimizing costs;
- Government. The major actor in shaping the preferences of both society and business through incentives and regulation, and includes ministries, municipalities and legislatures. For the public sector, it is about ownership of governance, establishing

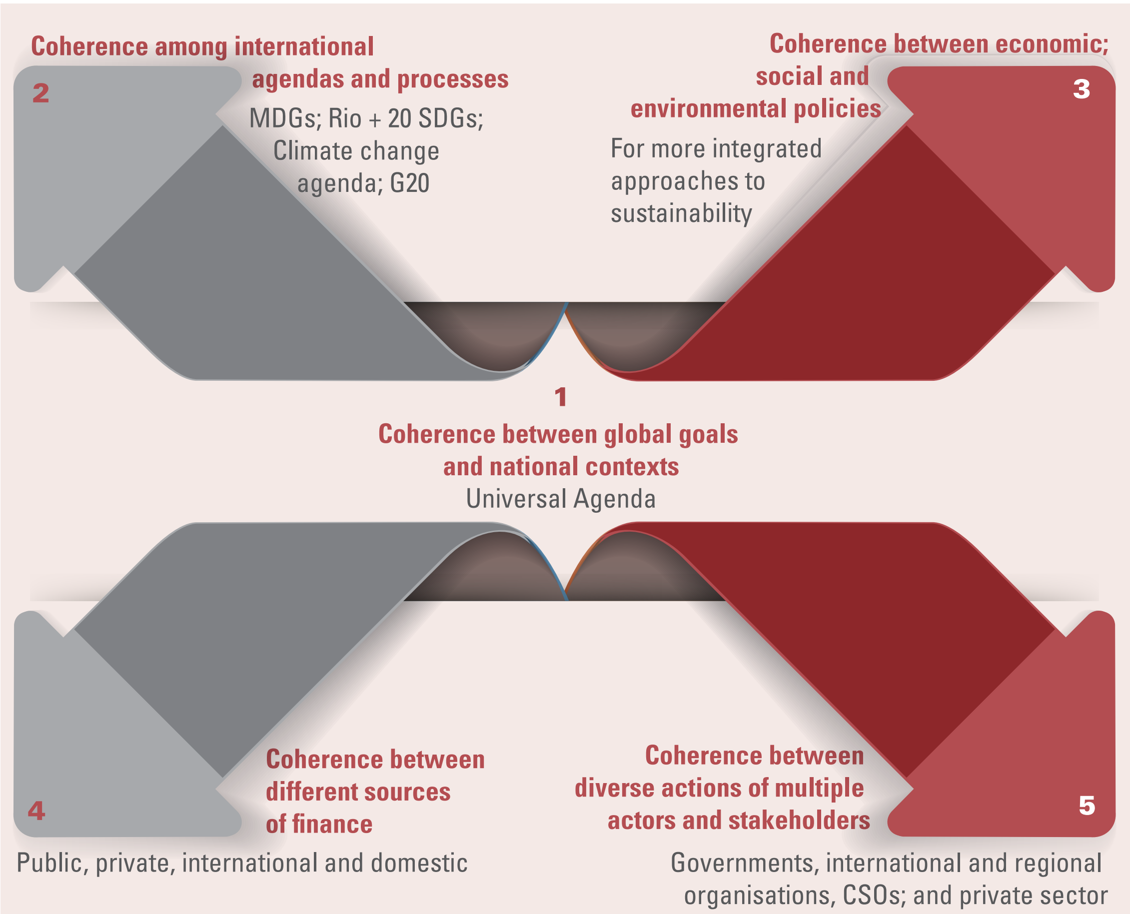
incentives, procedures and policies that promote progress. In the water-energy sector, this will also include utility companies when owned by the public sector;

- Society. The source of demand for resources, which takes shape based on population size, social breakdown, preferences and needs. Also, civil society has an important role as the engine for accountability moving from a passive, critical role into a more proactive, participatory one;
- Others: civil society groups, NGOs, and think tanks. They have an important role in activating discussions. Their main role in the nexus is seeking to improve quality of life.[17 18]

The OECD has defined five levels at which policy coherence for development should be implemented (figure 4):

1. coherence between global goals and national contexts: universal agenda.
2. coherence among international agendas and processes: SDGs, climate change, G20.
3. coherence between economic, social and environmental policies.
4. coherence between different sources of finance: public, private, international and domestic.
5. coherence between diverse actions of multiple actors and stakeholders: governments, international and regional organizations, private sector.

**Figure 4.** Levels of policy coherence




**Source:** Soria, 2014.

Wadi Madbah, with its traditional irrigation canal (aflaj) and date palms, in the desert interior of the Sultanate of Oman © David Steele - Shutterstock_249635827

## Capacity building for more integrated and coherent policymaking

Capacities in Arab countries have been strengthened in the past decade but there are still significant gaps that must be addressed to move more aggressively towards achieving the SDGs in particular and sustainable growth overall.

As reiterated by the United Nations Department for Economic and Social Affairs, the United Nations University asserts that *"Capacity development must be nested within, and form a pillar of, institutional reform at all scales within a country, with an emphasis on transferable skills that can be used for sustainable development across all areas and goals."*[19]

Building national capacities for developing policy coherence towards sustainable growth is an intricate process that should focus on developing dialogue platforms, promoting technological innovation, data generation and dissemination, and finding financial channels to fund initiatives and projects. This dialogue should include the sectors involved. In this case, dialogue should occur between the two ministries of water and energy at multiple levels within these organizations. Dialogue should have a specific target, such as increasing efficiency. Dialogue should be data-driven and transparent, with known and quantifiable metrics. Developing monitoring data and analytics can serve as a catalyst for these discussions and allow for quantitative targets for the dialogue.

It is important for countries to seek appropriate international partnerships and cooperation that can bring change at the institutional and technological levels. Organizations such as ESCWA, the League of Arab States (LAS), the Gulf Cooperation Council (GCC), among others, have undertaken initiatives to build capacity among stakeholders towards the Sustainable Development Goals and a science-policy interface.[20]

Another area where countries in the Arab region, like most developing countries elsewhere, need to build capacity is in raising awareness about resources among decision-makers, businesses, scientists, media, civil society groups and the public at large to create momentum for change in policies and institutions towards sustainable development.[21] Changes need to happen not only in the political arena (governance) but also in values and behavior at all levels.

Reliable and accurate data to support policy coherence is largely absent in the region. Capacity-building efforts should be bolstered to generate, compile and disseminate national and regional data on resources and climate. The use of models or decision-support tools to inform stakeholders and different levels and scales has been instrumental in creating platforms for dialogue and synergies among sectors in past cases and could significantly contribute to building further capacity in the Arab region.

## A platform for dialogue

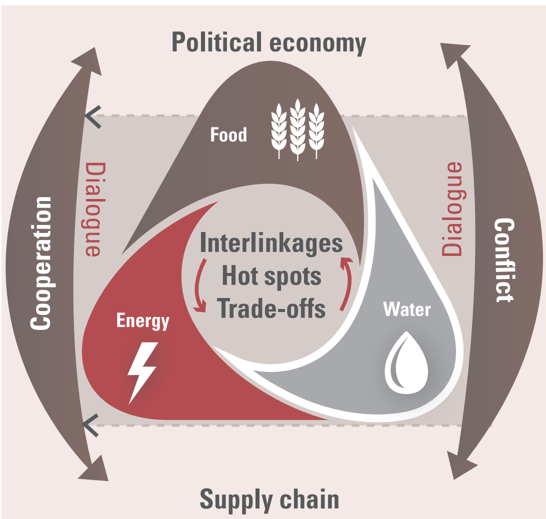
The analytics of the interlinkages between the water-energy-food nexus is a necessary component in the nexus platform. However, such analytics alone are not sufficient.

Analytics can help quantify the interlinkages and identify trade-offs resulting from policies, technology scenarios or actions related to any of the interconnected resource systems. But these quantifications can be useful only if they are used to catalyse dialogue between stakeholders. In OECD countries, stakeholders come from the private and public sectors, but given water and energy resources are mostly managed by the public sector in the ESCWA region, discussions about the supply chain and political economy are usually the domain of the public sector alone. However, trade-offs can exist between efficiency and official management and oversight, and must be based on clear analytics and transparent decision-making. Incentives must be put in place for all parties. Such analytics account for expected trade-offs in resource allocation strategies, to enable dialogue and to identify existing synergistic opportunities. These analytics also account for resources in the supply chain.

The process of the nexus platform outlined above should be demand driven and focused on key players; they are qualified to define the problem, not the framework developers. The stakeholders must willingly participate in the dialogue and be the agents of change. Figure 5 represents how the political economy and supply chain create a dynamic to move from conflict to dialogue.

**Figure 5.** A resources nexus platform outlining the dynamics of three communities: science, private sector/ supply chain and politics and policy

**From science to the politics of the nexus**




**Source:** Mohtar, 2015.

## The role of the community of practice: from concepts to analytics and dialogue

Effective governance, where multiple stakeholders, interests and policies are at stake, requires a community of practice to be established to bridge the gaps. The water-energy-food nexus community of practice can be seen as a platform to enable data, knowledge and best practices to be shared. A jointly owned electronic portal, where regional data can be accessed, along with tools and examples of successful nexus implementation, would enable better coordination and knowledge sharing. This community could have a vital role in monitoring the effectiveness of nexus governance models, although implementing good governance models will likely take years of feedback and iterations to develop into sustainable policies.[22]

A successful implementation of the SDGs will require global efforts and holistic approaches; all SDGs are intrinsically linked and require multidisciplinary approaches for which the nexus can be an ideal platform.

In this sense, creating effective data transfer and sharing mechanisms (data democratization) is essential in such complex policy terrain, where stakeholders share their perceptions of the problem and generate data to prove their hypothesis or version of truth.[23]

In addition, this community can be a place to share data on water, energy, food and land resources for the region, as well as good policies and practices on managing the nexus. Annual meetings and regional workshops can focus on any relevant regional or thematic issues.

The need for the nexus community of practice will become more pertinent in the coming years to promote regional coherence and governance in implementing the SDGs and climate-smart resource management. Tools and data, and good practices, can be managed regionally to save on infrastructure and human capacity investments.

## Governance models

It is increasingly evident that development strategies and national policies can no longer be formulated for individual sectors but must be multisectoral to better manage synergies and trade-offs.

The water-energy-food nexus concept as a tool for sustainable management of resources was introduced less than a decade ago; data on large-scale case studies remains scarce. Diverse sectors are involved in governing the nexus. It is a shared space between agriculture, water, climate, energy, finance, municipalities and other units at a local and global scale. The private sector and civil society have important roles to play. There is an inherent need to develop and implement systematic approaches in which all stakeholders share ownership and are willing to cooperate.

There are several possible models for regulating the nexus:

a. Shared governance, coordinated among various units where all the parties involved have representatives to a single body empowered and entrusted with governing the nexus. This can be successful if all parties involved are assured a voice at the policy table;

b. A high-level governance body, with oversight for all units and with representation from all stakeholders, which has the resources and authority to implement decisions on the nexus. This is more a leadership model, where "charisma" of one unit will create cooperation among the others.

Implementing the nexus approach is expected to save resources, which can be translated into financial savings. The benefits can be even greater through public-private partnerships. However, for such partnerships to emerge, initial financing, or seed funding, is needed. This is crucial in States where resources have been privatized.[24] It should be noted public-private partnerships without proper governmental and legal oversight can have unintended consequences, limiting access to and availability of resources and services among those in most need. In rural regions where financial gains are less attractive for the private sector, a cooperative model might be the best option for implementing nexus policies and governance.

### **Box.** The benefits of good governance policy: a regional comparison

Another area experiencing acute water scarcity is the western United States, where shrinking supplies have also disrupted activities in the energy sector. Yet over the past two decades, initiatives taken by California's Public Utilities Commission (CPUC) have demonstrated the potential of good governance policy to promote cooperation between the water and energy sectors, conserve valuable resources and enhance overall efficiency.

In 2006, for instance, the CPUC enacted a policy mandating investor-owned utilities to evaluate energy savings associated with water efficiency. Under this new policy, energy utilities were required to partner with a single large water service provider to implement pilot programmes that save water and energy. The San Diego County Water Authority (SDCWA) and San Diego Gas & Electric (SDG&E) formed a partnership to develop three pilot water efficiency programmes, one of which became known as the Managed Landscapes Pilot Program.

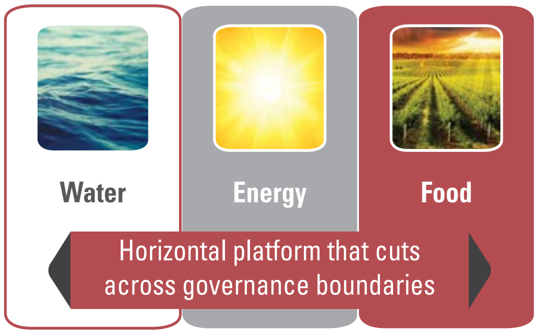
This programme combined smart irrigation control technology and professional irrigation management services to reduce water usage at large commercial landscapes. As part of the agreement, the SDG&E was responsible for selecting a contractor, marketing the programme, assessing savings potential, enrolling customers and installing and monitoring the systems at each site. The SDCWA was responsible for designing the programme and technical guidance for the systems at each of the 13 sites. Overall, the pilot exceeded expectations on water savings: although the contractor was required to achieve only a minimum 20 per cent water savings, savings averaged 35 per cent.

A key finding was the need for a methodology to calculate energy savings from water conservation and efficiency measures. Had such a methodology been established, for example, the SDG&E could have received credit for energy savings, and more money to reinvest. While good governance policy can help spur cooperation and efficiency between the water and energy sectors, sound monitoring and evaluation can ensure the sustainability and scalability of water-energy partnerships.

**Source:** Cooley, Heather and Kristina Donnelly (2013). Water-Energy Synergies. Oakland, California: Pacific Institute.

Choosing the optimum governance structure for a nexus platform has a multiscale effect, and must be considered from local, regional and national perspectives.

**Figure 6.** Environmental governance




**Source:** Mohtar, 2016.

Addressing the bottlenecks in policy coherence requires political will. Implementation plans for the SDGs or climate mitigation and adaptation measures, for example, require an integrated resource management structure. Human and infrastructural investments no longer exist within silos but are part of a comprehensive, nexus governance structure – important where there are few examples to draw from internationally. Water and energy is traditionally managed by separate government entities, often with minimal collaboration. Managing these primary resources requires a governance model that allows for a fresh look at trade-offs and analysis of policy or technology options in a non-biased, cooperative model. An "inter-governance" unit established as a bridge between the managing sectors can help identify nexus solutions and implement the cross-cutting nature of these solutions.[25] A suggested structure is shown in figure 6.

An integrative and cross-cutting platform of nexus decision-making enables stakeholders from different managing units empowered by a country's political system to make policy and technology choices. This platform should have access to data, tools and long-term national plans for water and energy, and develop future scenarios to quantify interlinkages and trade-offs. The platform should be able to holistically assess these impacts for more informed decisions. Nexus tools are abundant, and the choice is dependent on the problem and its scale. The water-energy nexus module provides a visual representation of this process. Policies that affect wide-ranging sectors, such as water, energy and food, which include construction, conservation, trade and foreign affairs, can be assessed objectively.[26] Such governance requires deliberate decision-making on sensitive resources management. It is the only way to move forward in a constrained ESCWA region, given the primary resources and finances available, and the political and climate changes in the world at large.

# Policy coherence and the nexus

The integrated nature of the SDGs is crucial to achieving the goals and targets of the new agenda. Considering the ambitious goals of zero hunger (SDG 2, food security), clean water and sanitation for all (SDG 6, water security) as well as affordable and clean energy (SDG 7, energy security), it is important to understand how they are interlinked in pursuance of the specified targets for each SDG.

The nexus approach highlights the need for an integrated landscape or socioecological perspective, and also a broad conceptual framework linking water to the larger sustainable development agenda. According to a report by the United Nations Department of Economic and Social Affairs (UNDESA), the proposed SDG targets and indicators would suggest that a nexus perspective has not been adopted and that they fail to recognize inherent trade-offs and synergies. Addressing all challenges simultaneously is probably not possible without drastic changes in human behaviour, supported by reform in policies and institutions at global, national and local level.[27]

Some in academic circles would argue that population growth, health and nutrition, among others, should be added to the nexus factors. But with consensus seemingly out of reach, the simpler the modelling and framework, the better; it is about resource management and allocation.

## Implementation: funding and incentives

Binding common objectives across institutions and sectors through appropriate indicators can send clear messages to donors and investors on multi-objective investments – messages that should make them question their own silos. Compromises with sectors and silos will lead to better outcomes.

In most cases, investment comes from the private sector, but strategic public investment can help attract other sources of financing – for infrastructure, irrigations systems, education and women's empowerment, for example. Public policies in the water and energy space in the ESCWA member countries must be established to help private sector investment generate

Kuraymat, Egypt. Taken on November 4, 2011 © Green Prophet - Flickr.com positive long-term benefits – employment, for example – and to reduce reliance on external technology. Policy coherence and coordination in the water and energy sectors will ensure public-private support for these nexus activities, support that is mutually reinforcing and requires ownership by both sectors.

Transparent tax systems have to be considered a major funding source for sustainable development policies. Also, governments should give incentives to sectors that seek to shift to greener technologies and improve efficiency; implementing policies, for example, that provide incentives for green buildings and green transportation.

Creating the right policy environment at a national level can also attract foreign investment. No government alone has the necessary technological, scientific, financial and human resources to move towards sustainable growth.

## Localizing variability in the Arab region: ecozones, economic models and governance structures (political systems)

Despite the variability in socioeconomic, financial, governance, and climatic conditions in the Arab region, there are sufficient similarities for a common nexus policy coherence to be established. However, maintaining regional policy coherence on major issues, such as combating climate change and population and demographic issues, while monitoring localized issues that do vary, remains a significant challenge. Addressing this problem via regional efforts has the greatest impact, although local capacities to effectively manage the nexus at the ground level must also be built.

## Water-energy nexus approach as a tool for enhancing policy coherence

A better understanding of the interdependence of water, energy, food and climate policy in the Arab region would provide an informed framework for determining trade-offs and synergies that meet demand for resources without compromising sustainability. Water, energy and food security are inextricably linked in the region, perhaps more so than in any other in the world. Generally, the region is known to be energy rich, water scarce and food deficient, one of the world's most economically and environmentally vulnerable to climate change.[28] The scarcity of resources, their inherent interconnectedness and increasing demand for them and global shifts, make it necessary to implement policies that have a more holistic approach.

The nexus approach is a tool that focuses on policy coherence. The nexus is most useful in identifying hotspots where a specific policy, technology or consumption pattern can be assessed and evaluated. It generates a platform of dialogue between multiple levels and sectors charged with policy and management, utilizing evidence-based models that demonstrate interlinkages, hotspots and trade-offs between resources.

The League of Arab States recognized the importance of the nexus approach in the 2013 Arab Strategic Framework for Sustainable Development (ASFSD). The framework aims to address the key challenges faced by Arab region countries in achieving sustainable development during the period 2015–2025.[29]

Lebanon hill lakes at Laklouk, Akoura. © Joelle Comair - https://water.fanack.com

# Institutional support for policy coherence

## Partnerships and incentives

As a general rule, partnerships are usually voluntary, self-enforced and non-negotiated agreements between governments, international organizations, NGOs, industry partners and civil society. Given this, flexible, decentralized, market-oriented approaches to environmental issues have proved more effective than top-down, State-centric decision-making.[30] As synergies and winning platforms are negotiated in the partnership, corporate social responsibility is encouraged and civil society involvement moves from the merely critical to being more proactive.

Success of a partnership not only relies on fair representation of stakeholders, but also on the extent of participation. Partnerships should entail new initiatives, providing added value, clear objectives and specific targets and deadlines.[31] Three main groups have different roles and “powers” over these types of partnerships: governments (coercive power); private sector/markets (persuasive power); and civic movements (moral power or pressure).[32]

Implementing policies derived from a partnership for sustainable development requires, in most cases, investment in structural change, policy development and execution, and capacity building, among others. Several shareholders must be identified, including those from the public and private sectors, and foreign donors.

Dialogue and cooperation within sectors and among different scales can be promoted if there are incentives for action. For example:

a. Efficiency gains and cost reductions, translating into better resource availability and less competition;

b. Cost recovery;
c. Good citizenship working towards the betterment of society;
d. Financial gains directly benefiting a sector’s operations.
e. Incentives for compliance to policies and laws also play a critical role in the sustainability of resources.

Such incentives must apply to multiple implementing agencies or sectors of the nexus solution, from high-level ministries to the private sector and end-users of resources. In some cases, streamlining and allocating domestic taxes will be essential for government financing of the Sustainable Development Goals.

## Policy coordination mechanisms

In policy networks, there are multiple governance sites and power is diffused among stakeholders, making the issue of accountability a particularly difficult challenge. Coordinating mechanisms should establish monitoring mechanisms to address this problem. Top-down coordination and accountability is not effective in partnerships; horizontal accountability mechanisms are more suitable, and NGOs, media, donors and civil society play a key role in establishing good coordination and accountability mechanisms. Civic movements need to move from being mere critic to play a more proactive, supportive role, monitoring progress and indicators. Likewise, governments need to ensure policies are in place and are inclusive and responsive.[33]

In a review of Arab preparedness for meeting the SDGs, ESCWA and UNEP report that voice and accountability are associated with higher levels of development. When economic growth is perceived as a substitute for development, the correlation becomes weak in the Arab region as all Arab countries fall below the global average in terms of voice and accountability, regardless of their per capita GDP level.[footnote 34] Development efforts should thus concentrate on enhancing voice and accountability as a means to increase the engagement of civil society and draw upon the knowledge generated by the scientific community to inform policy-making processes.[34]

It is imperative that policy coordination frameworks use science to drive a dialogue based on transparency and inclusiveness. These elements, highlighted in the framework section above, are expanded upon in the following sections.

### Monitoring, analysis, accountability and reporting

Developing sustainable growth policies involves an unspecified number of areas and sectors, and as such, the outcome of potentially disparate policies are hard to monitor. The effects of such policies can also emerge at different times.

The OECD is exploring the feasibility of a monitoring matrix for policy coherence for development. This involves identifying indicators to illustrate country efforts to implement policies conducive to policy coherence. This monitoring matrix can potentially feed into a “scorecard” for countries to self-assess their enabling environments for development.

Such indicators can facilitate monitoring and the assessment of transition towards greener growth. The OECD Green Growth Strategy delivered a set of about 25 green growth indicators (GGIs) to: analyse the sources of green growth; support policy integration and coherence; measure progress; and identify opportunities and risks. Indicators were selected based on their policy relevance, analytical soundness and measurability, and were organized around

Cooling towers of nuclear power plant of Doel near Antwerp, Belgium © TasfotoNL - Shutterstock_320813735

four interrelated dimensions of green growth, with so-called "headline" indicators developed to facilitate communication with policymakers, the media and citizens:

1. The environmental and resource productivity of the economy (carbon productivity; material productivity; multifactor productivity).
2. The natural asset base (natural resource index; land use and land cover changes).
3. The environmental dimension of quality of life (air pollution).
4. Policy responses and economic opportunities.

The list of indicators is not final; as knowledge advances and new data become available, the OECD will continue to advance the methodologies and measurement of green growth indicators.[35] The overlap with policy coherence means these indicators can inform the type of indicators used by ESCWA member States. Monitoring and quantifying progress are essential if critical nexus targets for governance, financing and communication are to be reached for better coordinated primary resources management and allocation.

Multi-stakeholder partnerships are complex and it is hard to track progress of commitments made. Accountability tracking and monitoring systems will help document commitments, measure their efficacy and progress, provide transparency and hold stakeholders to account for their promises. A coordinating mechanism should raise public awareness, build commitment to action, and track progress and implementation.

Documenting progress and commitments is key to promoting effective participation. The multilateral commitments to sustainable development should include concrete action, specific targets and deadlines. Clear reporting guidelines should be put in place. This requires water and energy system data be monitored for better informed policies and decisions.

Transparency in policymaking partnerships could be measured using three indicators:

1. Website for sharing public information.
2. Clear reporting system to track progress.
3. Monitoring mechanism to define standards of goal attainment.

In one example of how the lack of mandatory reporting mechanisms affects partnerships, Backstrand reports that of 311 registered partnerships after the 2002 World Summit for Sustainable Development, 59 (20 per cent) had submitted updates on their activities; and only 1 per cent reported they met their stated goal.[36] Reporting in general provides incentives for better transparency and improvement, especially if on strategic national targets for water and energy resources.

## Science-policy interface in the Arab region

In the Arab region, political unrest, conflict, the refugee crisis, unemployment and poverty, combined with environmental degradation and unsustainable use of resources, make it difficult to implement policies for sustainable development.

The water-energy-food nexus framework was originally promoted by the business community, including the World Economic Forum, in collaboration with experts in the academic and research fields to raise awareness of the need to coordinate these resources across various stakeholders. Scientific knowledge is a key ingredient in policymaking; it can provide justifications for certain realities and project future scenarios that evaluate the effects of a certain policy or "portfolio". The application of science is particularly important to the water-energy nexus, where precise measurements and data are prerequisites for determining appropriate policies.

The science-policy interface in the Arab region, as in most developing countries, is not well developed. Policymakers do not always inform scientists about their need for scientific data. In general, scientific advancement has not been given the prominence it requires to support development in the Arab region. A water-energy policy coherence plan was outlined in section 2, including a plan for: balancing competing demands and resolving policy coherence issues; levels of policy coherence; integrated capacity building; dialogue among water and energy stakeholders; and establishing a community of practice and governance models to manage water and energy resources.

The table below illustrates the disparity in scientific advancement between Arab countries and the rest of the world.

**Table.** Investment and outcomes of scientific research in the Arab region

| | Arab countries | World average |
|---|---|---|
| % of GDP spent on research and development | 0.2% | 1.7% |
| Full-time researchers per million inhabitants | 373 | 1,080 |
| Scientific and technical articles published in 2011 | 7,800 (1.3% of world total) | 600,000 (world total) |
| Articles published per million inhabitants | 22 | 117 |

**Source:** ESCWA and UNEP, 2015.

Despite considerable advancement over the past decade, there is a big data gap in official national statistics throughout the region. To strengthen the science-policy interface, it is crucial that a mechanism to measure and calculate statistics in each country be created, along with a regional network for transparent data transfer.

Creating successful policies for sustainable development involves an array of stakeholders at different scales and levels. For dialogue platforms to be successful and proactive, sound data and reliable indicators must be available for decision makers to help translate political commitments into practice. Indicators may include sustainable consumption and access targets for water and energy SDGs that do not infringe on other resources.

The bodies responsible for collecting statistical data on the state of natural resources need to be strengthened (or created in some cases). Generating high-quality, reliable data is a priority to support governments in understanding the challenges they face. Comprehensive support to improve the quality of data collection and the creation of decision support systems tailored to regional scenarios will build more reliable information for national and international policy planning.

Multiple evidence-based tools are available for decision makers to help identify trade-offs among the water-energy-food nexus components to support an integrated allocation of resources.[37] These are discussed in *Examining the Water-Energy Security Nexus* module (Module 3).

Countries in the Arab region will need to focus their efforts on linking the scientific community to policymakers, specifically to establish monitoring mechanisms, devise metrics, enhance infrastructure and standardize data. For instance, regular meetings of the nexus community of practice around specific SDGs would allow policymakers to outline their efforts and challenges, and the science community to share data and tools that may help to implement these SDGs.

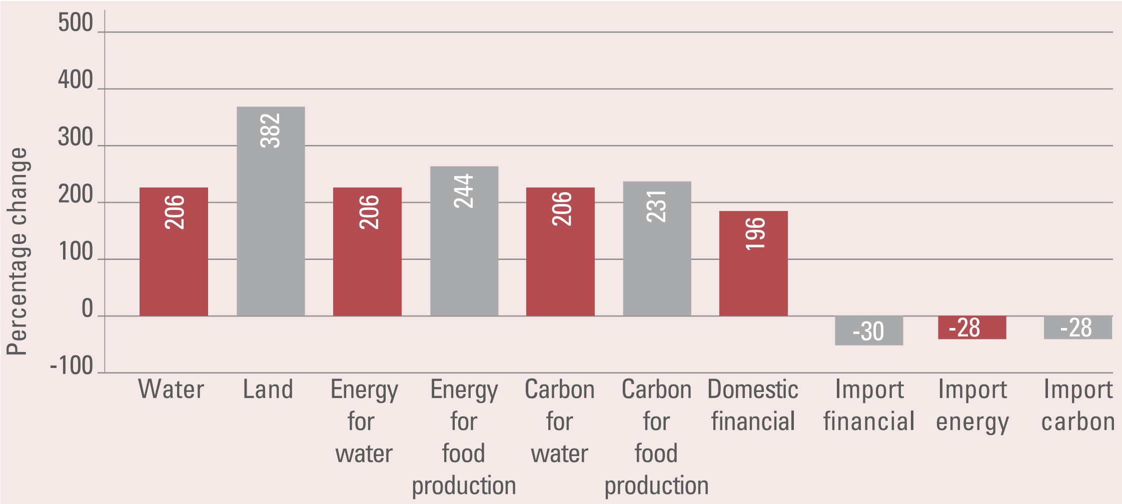
## Identifying and resolving incoherent policies

Isolating and evaluating specific policies in place at local, national and international levels can be challenging. But successfully addressing these challenges is crucial in moving towards policy coherence as a country and as a region. Specific examples, targeting a specific objective, will need to be drawn, then the impact of these policies measured and quantified looking at current conditions.

The use of models and decision-support tools is an excellent illustration of how to best target incoherent policies. One of the objectives of Qatar's national food security programme, by way of example, was to increase local production of eight agricultural products by 25 per cent. Based on 2010 production levels for these eight products in Qatar, a group of scientists created a scenario representing an additional 25 per cent increment for each (i.e. if self-sufficiency in tomato production was 10 per cent for 2010, it would be 35 per cent in the scenario), using the WEF Nexus tool 2.0.

The results of the assessment of this policy are shown in figure 7. Under available water and energy technologies and efficiencies, and existing crop yields and trade portfolio, to achieve 25 per cent more local production would require 206 per cent more water, 382 per cent more land, more than 200 per cent more energy and emissions, and a 196 per cent increase in financial resources. To adopt such a scenario (which may be instigated by national security

**Figure 7.** Percentage change in resource needs for a 25 per cent increase in the self-sufficiency of eight agricultural products in Qatar




**Source:** Mohtar and Daher, 2014.

concerns) would depend on the ability to secure the indicated water, energy, land and financial resources, all of which might require a radical change in production techniques, given local resource constraints.[38]

# Key messages and recommendations

This module has touched on serious issues in the water-energy nexus, and how successful implementation can be managed. Accordingly, six key conclusions are drawn:

1. A policy coherence platform must be developed regionally for an effective use of resources. While the investment in financial and human capital to mobilize this framework may be done regionally, to achieve real progress, concerted effort is required at local level. Elements include:

   a. A balance between competing demands, outcomes and criteria;
   b. Resolution of policy coherence in the water and energy nexus in Arab region countries;
   c. Scales and levels of policy coherence;
   d. Capacity building for better integrated, coherent policymaking;
   e. Dialogue platform among stakeholders;
   f. Role of the community of practice: from concepts to analytics and dialogue;
   g. Governance models for the water-energy-food nexus.

2. Countries and communities are at differing stages of social, technological and economic development. Policies and strategies must be tailored to local circumstances, but remain regionally and globally consistent and coherent.
3. Establishing a nexus community of practice in the region is important for advancing strategic partnerships to achieve water and energy securities at local, national, regional and international levels. The nexus approach is a practical tool enabling policy coherence at different levels.

4. Build capacity to include science, analytics, conflict resolution and dialogue skills to move the nexus agenda forward.
5. Improve nexus governance to enhance decision-making across sectors, financing and incentives for nexus approaches.
6. Transparency and accountability in the nexus cannot be overlooked. Monitoring and accountability measures must be taken and the decision-making process must be kept open, inclusive and transparent.

# Endnotes

1. UNEP, 2015.
2. United Nations, 2015.
3. The Arab Strategy for the Development of Renewable Energy Applications (2010–2030) was adopted as a framework for the joint Arab action in renewable energy field, in accordance with the recommendations of the 3rd Arab Economic and Social Development Summit held in Riyadh (21–22 January 2013).
4. OECD, 2015a.
5. UNDESA, 2015b.
6. DESA, 2015a.
7. Mohtar and Daher, 2016.
8. Ibid.
9. Gyawali, 2015.
10. UNEP, 2015.
11. Knoll, 2014.
12. UNEP, 2015.
13. Arab Union of Electricity, 2015.
14. Knoll, 2014.
15. Mohtar and Daher, 2016.
16. OECD, 2015.
17. Mohtar and Daher, 2016.
18. Mohtar and Lawford, 2016.
19. UNDESA, 2015a.
20. ESCWA and UNEP, 2015.
21. UNEP, 2015.
22. Mohtar and Lawford, 2016.
23. Gyawali, 2015.
24. Mohtar, 2016.
25. Ibid.
26. Ibid.
27. UNDESA, 2015.
28. AFED, 2015.
29. ESCWA and UNEP, 2015.
30. Backstrand, 2006.
31. Gyawali, 2015.
32. Ibid.
33. Ibid.
34. ESCWA and UNEP, 2015.
35. OECD, 2014.
36. Backstrand, 2006.
37. Mohtar and Daher, 2016.
38. Mohtar and Daher, 2014.

# Bibliography


Arab Forum for Economic Development (AFED) (2015). Sustainable Consumption for Better Resource Management in Arab Countries. 2015 Annual Report of the Arab Forum for Environment & Development (AFED). Available from http://www.afedonline.org/Report2015/English/p8-63%20report%20today.pdf

Arab Union of Electricity (2015). *Statistical Bulletin 2015*, issue 24. Available from http://www.auptde.org/Article_Files/inside%202016.pdf.

Backstrand, Karin. (2006). Multi-stakeholder Partnerships for Sustainable Development: Rethinking Legitimacy, Accountability and Effectiveness. *European Environment* vol. 16, pp. 290-306.

Cooley, Heather and Kristina Donnelly (2013). *Water-Energy Synergies. Coordinating Efficiency Programs in California*. Oakland, California: Pacific Institute. Available from http://www2.pacinst.org/wp-content/uploads/2013/09/pacinst-water-energy-synergies-full-report.pdf

Economic and Social Commission for Western Asia (ESCWA) and United Nations Environment Programme (UNEP) (2015). Arab Sustainable Development Report, First Edition. E/ESCWA/SDPD/2015/3. Available from https://www.unescwa.org/publications/arab-sustainable-development-report-2015.

European Union Coherence Program (2007). *Policy Coherence for Development: A Practical Guide*. Brussels. Available from http://www.globaleverantwortung.at/images/doku/coherence-guide-concord.pdf.

Gyawali, Dipak. (2015). *Nexus Governance: Harnessing Contending Forces at Work, Nexus Dialogue Synthesis Papers*. Gland, Switzerland: IUCN.

Knoll, Anna. (2014). Bringing Policy Coherence for Development into the post-2015 agenda – Challenges and Prospects. Discussion paper No. 163. European Center for Development Policy Management.

Mohtar, Rabi H, and Bassel Daher (2014). A *Platform for Trade-off Analysis and Resource Allocation: The Water-Energy-Food Nexus Tool and its Application to Qatar's Food Security*. Produced as part of the Valuing Vital Resources in the Gulf series. London: Chatham House. Available from https://www.chathamhouse.org/sites/files/chathamhouse/field/fielddocument/20141216WaterEnergyFoodNexusQatarMohtarDaher.pdf.

Mohtar Rabi H and Bassel Daher (2016). Water-Energy-Food Nexus Framework for Facilitating Multi-stakeholder Dialogue. In *Water International*, DOI: 10.1080/02508060.2016.1149759.

Mohtar, Rabi H (2015). Ven Te Chow Memorial Lecture: Localizing Water and Food Security. In *Water International*, vol. 40, No. 4 (9), pp. 559–567.

Mohtar Rabi H (2016). The Water-Energy-Food Nexus: Who Owns it? Policy brief presented at the OCP Policy Center. Rabat, April.

Mohtar Rabi H and Richard Lawford (2016). Present and Future of the Water-Energy-Food Nexus and the Role of the Community of Practice. *Journal of Environmental Studies and Sciences*, DOI 10.1007/s13412-016-0378-5.

Organization for Economic Cooperation and Development (OECD) (2009). *Sustainable*

*Management of Water Resources in Agriculture*. OECD. Paris. Available at www.oecd.org/tad/env.

Organization for Economic Cooperation and Development (OECD) (2014). *Better Policies for Development 2014: Policy Coherence and Illicit Financial Flows*. Paris. Available from http://www.oecd.org/pcd/Better-Policies-for-Development-2014.pdf.

Organization for Economic Cooperation and Development (OECD) (2015a). *Policy Coherence for Inclusive and Sustainable Development*. Element 8, paper 1. Paris. Available from http://www.oecd.org/dac/POST-2015%20PCD.pdf.

Organization for Economic Cooperation and Development (OECD) (2015b). *Policy Coherence for Sustainable Development in the SDG Framework: Shaping Targets and Monitoring Progress*. Paris. Available from http://www.oecd.org/development/pcd/Note%20on%20Shaping%20Targets.pdf.

Soria, E. (2014). *Policy Coherence for Sustainable Development in the Post-2015 Framework*. EU PCD focal points meeting presentation. Brussels, October 21, 2014.

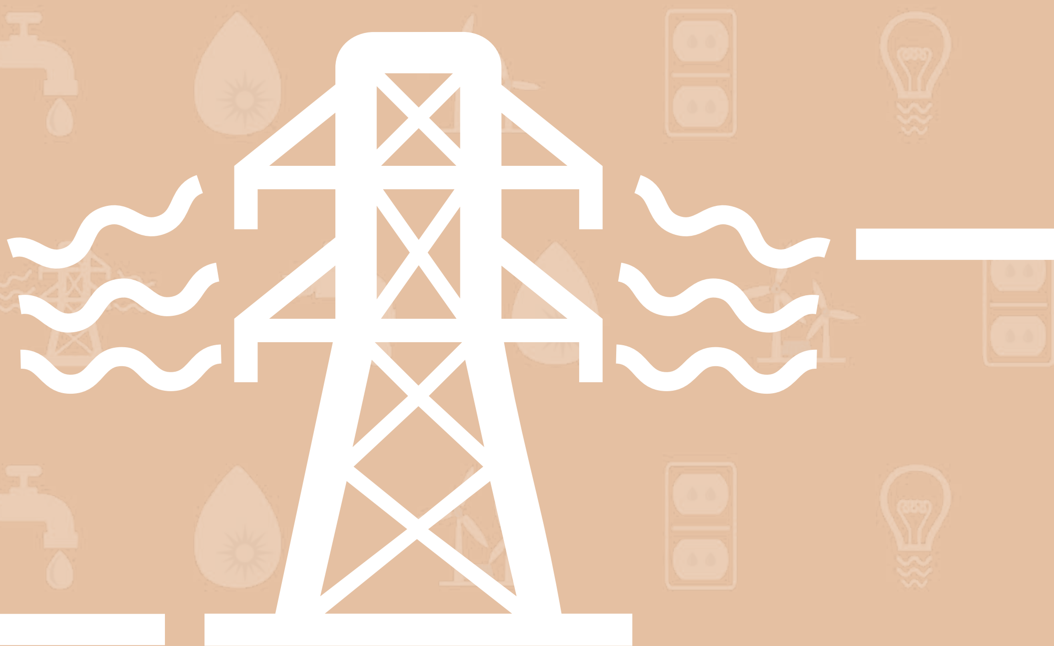
United Nations (2015). *The United Nations World Water Development Report 2015: Water for a Sustainable World* (WWDR 2015). New York. Available from http://www.unesco.org/new/en/natural-sciences/environment/water/wwap/wwdr/2015-water-for-a-sustainable-world/.

United Nations Department of Economic and Social Affairs (UNDESA) (2015a). *The Critical Role of Water in Achieving the Sustainable Development Goals: Synthesis of Knowledge and Recommendations for Effective Framing, Monitoring, and Capacity Development*. New York. Available from https://sustainabledevelopment.un.org/content/documents/6185Role%20of%20Water%20in%20SD%20Draft%20Version%20February%202015.pdf.

United Nations Department of Economic and Social (UNDESA) (2015b). *World Population Prospects: Key findings and advance tables*. New York. Available from https://esa.un.org/unpd/wpp/Publications/Files/Key_Findings_WPP_2015.pdf.

United Nations Environment Programme (UNEP) (2015). Policy Coherence of the Sustainable Development Goals: A Natural Resource Perspective. New York. Available from http://www.unep.org/resourcepanel/Portals/50244/publications/Policy_Coherenceofthe_Sustainable_DevelopmentGoals.pdf.

World Bank (2013). Middle East and North Africa Integration of Electricity Networks in the Arab World: Regional Market Structure and Design. Report No. ACS7124. Washington, D.C. Available from http://wwwwds.worldbank.org/external/default/WDSContentServer/WDSP/IB/2014/07/10/000442464_20140710112306/Rendered/PDF/ACS71240ESW0WH0I0and0II000Final0PDF.pdf



# Examining the Water-Energy Security Nexus

3 Module

# Contents



## List of figures



## List of boxes

# Abbreviations and explanatory notes

| | |
|---|---|
| **AFED** | Arab Forum for Environment and Development |
| **CLEWs** | climate, land-use, energy and water strategies |
| **DSS** | decision support tools/systems |
| **EDF** | Électricité de France |
| **ESCWA** | United Nations Economic and Social Commission for Western Asia |
| **ETSAP** | Energy Technology Systems Analysis Program |
| **FAO** | Food and Agriculture Organization |
| **GDP** | gross domestic product |
| **IEA** | International Energy Agency |
| **IRENA** | International Renewable Energy Agency |
| **GCC** | Gulf Cooperation Council |
| **GHG** | greenhouse gas |
| **GIS** | geographic information system |
| **LEAP** | long range energy alternatives planning system |
| **LEDS** | low-emission development strategies |
| **MENA** | Middle East and North Africa region |
| **MuSIASEM** | multi-scale integrated analysis of societal and ecosystem metabolism |
| **PPCP** | public-private community partnership |
| **PPSP** | public-private social partnership |
| **PPP** | public-private partnership |
| **PV** | photovoltaic |
| **SDG** | Sustainable Development Goal |
| **SE4All** | Sustainable Energy for All |
| **SEI** | Stockholm Environment Institute |
| **TIMES** | The Integrated MARKAL-EFOM 1 System |
| **UNDP** | United Nations Development Programme |
| **UNEP** | United Nations Environment Programme |
| **UNFCCC** | United Nations Framework Convention on Climate Change |
| **WEAP** | water evaluation and planning system |
| **WEF** | water-energy-food |
| **WWC** | World Water Council |
| **WWF** | World Wildlife Fund |
| **WWDR** | World Water Development Report |

# Background and objectives of this module

Water scarcity and limited access to modern energy services, as well as poor infrastructure and technology choices, limit the potential for human well-being and sustainable economic growth at local and national levels. Exploring linked systems of water use and energy and food production can realize this potential.[1] At a time when limited natural resources are under stress from population growth, urbanization, climate change, conflict and economic and political forces, it is important to define and quantify the connectedness of water, energy and food.

This module lays out the concepts of the water-energy-food nexus, focusing on the ESCWA region, presenting a framework to guide users on the data and models needed for a nexus study. It explains obstacles and solutions to nexus integration, its role in implementing the Sustainable Development Goals (SDGs) by 2030, and presents models to help decision makers by quantifying how a policy affects different sectors involved in water and energy security. The document identifies ways water can be viewed as a major policy guide for the energy sector, and vice versa, and concludes with key messages for future progress.

# Introducing the water-energy security nexus

## The water-energy security framework

Global population growth, urbanization, changing social values and behaviours, climate variability and economic growth are putting enormous pressure on natural resources, affecting the availability of water, food and energy. Other factors, such as land degradation and the increasing environmental impact of energy production, are seriously compromising the efforts of local and international communities to improve human well-being.

Food and energy production requires more than 90 per cent of global water resources. It is estimated this water demand for energy will increase by 85 per cent over the next two decades,[2] promoting further intersectoral competition. At a time of political, social and climatic uncertainty, water will be the limiting factor for economic development and future energy and food security.[3] Environmental pressures, climatic changes and growing economies and populations all emphasize the intricate connections between resources and external pressures.

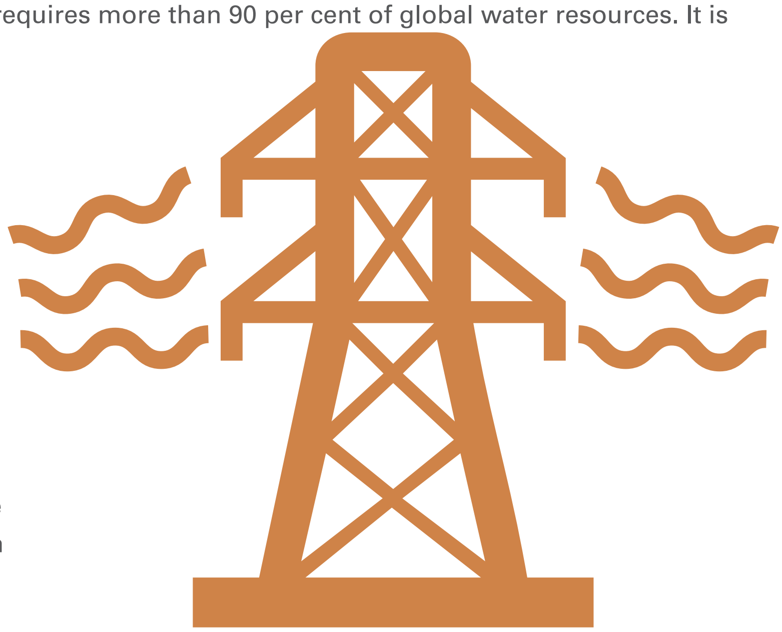
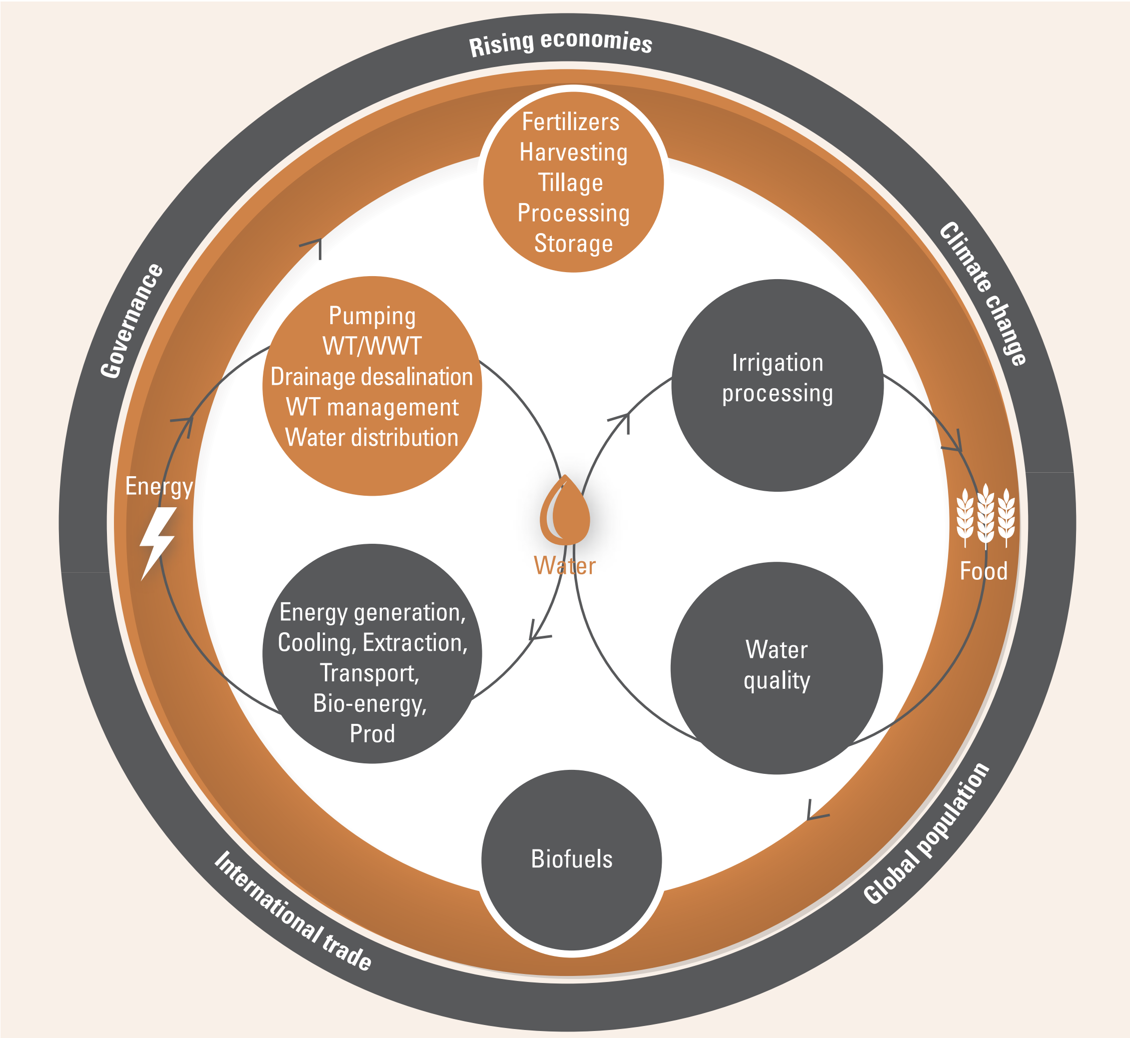


**Figure 1.** Schematic showing the water-energy-food nexus with effecting parameters




**Source:** Daher and Mohtar, 2015.

The World Economic Forum in its *Global Risks Report 2016* identified water security as the highest risk the world will face in the near future;[4] over the past decade, the highest risks to human security have shifted from geopolitical to resource scarcity and economic insecurity.[5]

Water, energy and food are intimately linked. For example, producing water uses energy through electricity for pumping, drainage, desalination, water treatment and distribution to farms and cities. In general, about 55 per cent of a country's water utilities operating budget is energy cost.[6] Energy, in turn, is the second highest water consumer, after agriculture and food production, with water needed to generate power and extract and refine resources, and for cooling, transport and biofuel production. Energy production can also affect water quality by contaminating water sources. The dependency of one system on the other is largely defined by the technology used in activities that demand energy and water.[7] Figure 1 shows a conceptual framework of the nexus between resources and the external pressures affecting it.

The interactions between water, energy and food are complex and vary drastically depending on local and regional conditions. A water-energy-food nexus approach to manage and govern these resources must:

1. Include all stakeholders and create dialogue. It must be holistic and promote a community of practice that is participatory, with clear targets;
2. Be quantitative and provide clear indicators for decision makers in the policymaking process. Moving from analytics to quantification is the building block for moving science to policy. This also helps stakeholders recognize synergies and trade-offs among sectors that will assist in reaching local, national and regional water-energy security targets;

**Figure 2.** Seven-question guideline for modelling nexus issues


**Source:** Daher and others, 2016.

3. Be evidence-based, using local and regional data, and create synergies to generate and share data;
4. Build on current structures and scenarios rather than relying on a substitution approach.

According to the United Nations, water development and management programmes, if planned properly, can serve multiple functions, from contributing to energy and food production to helping communities adapt to climate change. A nexus approach to sectoral management, through enhanced dialogue, collaboration and coordination, is needed to ensure that co-benefits and trade-offs are considered and that appropriate safeguards are put in place.[8]

To guide selection of nexus modelling, Daher proposed the following questions, which are also illustrated in figure 2:[9]

a. What is the nexus question being asked that drives the study?
b. Who are the major players and stakeholders impacted in the study?
c. What is the study's scale?
d. How is the nexus system being defined?
e. What specific aspects do we want to assess?
f. What data is needed?
g. How do we communicate outcomes of the study, and when do we involve the decision maker?

# Obstacles and solutions to nexus integration

## Lack of coherence: silo thinking

Economic models that lack regulation and coherence in resource use and allocation risk irreversibly depleting and degrading resources. Silo, or fragmented approaches, arise from competition between urban and rural municipal governments and inadequate management coordination among line departments and ministries. How to best allocate water to meet the needs of the energy sector is a complex matter that requires synergies and trade-offs across all sectors. We have seen the negative impact of fragmented thinking in resource management when trade-offs are poorly executed, such as in Texas in 2011 when water shortages in the energy sector almost caused a statewide blackout.[10]

Countries in the Arab region have an opportunity to learn from mistakes and adopt nexus policies that move them towards national water and energy targets.

## Data gaps

Lack of coordination is often due to poor or non-existent data on the demand for and availability and regulation of primary resources. The absence of information on climate conditions, soil characteristics and land use, and of wind and solar maps, can make nexus implementation inefficient. For example, it is difficult to predict the environmental impact of constructing dams, tube wells or storm drains due to sediment capture, aquifer recharge and wastewater reuse without reliable information.[11]

Decision makers need feedback on legal and policy formulation, environmental changes and socioeconomic impacts within communities. Without a good means to exchange data, inefficiencies will carry across sectors, making it difficult for governments to adequately respond to growing demands and environmental stresses.

## Technological barriers

Technologies and infrastructure for water and energy sectors in most Arab countries are inefficient. When sectors come together to analyse and quantify scenarios and consider the links between resources, it becomes evident which areas require infrastructures, investments, technologies and policies to be reoriented. Promoting innovation in technology and governance systems that integrates global, national and local levels will help countries move towards achieving the Sustainable Development Goals and sustainable growth.[12]

An example of such innovation is in the production of solar energy in the desert areas of the Gulf region. Dust storms affect the performance of photovoltaic systems, and the effects of climate change have increased the frequency and intensity of such storms. Deposits of sand on the surface of solar panels can, over a short period, decrease their capacity to produce energy by up to 60 per cent.[13] Research and innovation efforts in the Gulf region – by the Qatar Environment and Energy Research Institute, for instance – has focused on developing materials and systems that are self-cleaning and able to remove dust without using water or scratching the panels, and are, therefore, capable of eliminating uncertainties surrounding water supply and cost.[14] This is an example of a renewable energy source being successfully implemented and adapted, but some renewables need operating experience in regional climate conditions before performance can be optimized.

## Lack of negotiation and communication tools and skills

Securing access to water and modern energy services within an institutional framework requires all sectors to find a common platform to agree on national priorities. Given the challenges in the Arab region, water and energy security goals are influenced by how the current state of affairs is perceived, and the way countries and communities wish to frame their development priorities. It is important, therefore, to plan the water-energy nexus in a human rights framework, establishing common principles for negotiations, and common goals among parties and sectors.[15]

The institutions governing resources often do not communicate, and frequently operate in crisis mode. Also, the interface between science and policymaking is not always clear and decision makers do not have the tools to analyse and quantify possible trade-offs, a process that helps facilitate dialogue. A water-energy nexus approach is an important tool in advancing such platforms and integrating scientific data and policy considerations.[16] The nexus also equips citizens, community groups, organizations and policymakers to help create synergies to achieve institutional change and accountability.

## War and conflict

The impacts of water scarcity and energy insecurity are exacerbated by regional conflicts. In the Syrian Arab Republic, for example, access to water decreased by 70 per cent in 2013. Damaged infrastructure has forced residents in conflict areas to spend significant amounts on water – of questionable quality – from private tankers and alternative sources.[17]

To define energy and water securities as having reliable access to resources would be too narrow a definition. The relationship between water-energy and national security cannot be ignored. Indeed, some have argued that almost half of the interstate war conducted since 1973 have been linked to oil.[18] The control of energy and its transport to market thus present threats

Sunset over oil field in the Red sand "Arabian desert" near Dubai, United Arab Emirates © Fedor Selivanov - Shutterstock_ 350313140

to global security, and for the Middle East in particular. Geopolitical tensions that led to the First Gulf War also resulted in most of Kuwait's desalination capacity being destroyed, constraining local access to fresh water, while water rights to the Euphrates River have historically been an underlying source of conflict between the Syrian Arab Republic, Iraq and Turkey.[19]

Only by thinking systematically about the relationship between oil and water conflicts will countries be able to develop informed foreign policies and cooperation, and implement technologies that support efficient production and consumption of resources.

## Production and consumption behaviours

Businesses need to use resources more efficiently, and citizens need to adopt sustainable habits. The consumption of domestic water in some Arab countries ranks among the highest in the world, while inefficient irrigation practices resulting in water losses of up to 50 per cent in agriculture run in parallel with a lack of reuse and recycling in industry.[20] The same can be said of the energy sector. The Gulf region is one of the world's major energy demand centres, with a per capita consumption in Qatar of 20 times the world average.[21] In addition to most Gulf Cooperation Council (GCC) countries, Algeria and Libya have per capita energy consumption rates higher than the world average. Although the remaining Arab countries have lower rates, there is still potential for improvement. Through integrated nexus approaches, policymakers could make substantial energy savings with policies and technologies that move the region towards more sustainable consumption and production patterns.

Energy consumption is growing at an annual rate of 3-4 per cent, twice the world average. Electricity generation is growing at a rate of 6-8 per cent, three times the world average. Subsidized electricity rates and growing urbanization and populations contribute to this.[22] There has been reluctance in most countries of the Arab region to seriously tackle energy subsidies, though some, such as Morocco and Egypt, have taken the initiative and scaled them down, due to either a crisis or strategic national development objectives. In the GCC, there have been attempts to gradually increase electricity and gas costs but in some cases progress has been reversed (Kuwait) or has not yet materialized (Qatar). According to a study published by the Masdar Institute, the United Arab Emirates has reduced energy subsidies by about 30 per cent since 2013; direct energy subsidies were estimated at US$12.6 billion in 2015, or nearly 3 per cent of gross domestic product (GDP).[23]

In Saudi Arabia, up to 9 per cent of annual electrical energy consumption is attributed to groundwater pumping and desalination, but subsidies on water and energy have been cut as part of its 2030 vision.[24] Other Gulf countries are devoting 5-12 per cent of electricity consumption to desalination.[25]

## Governance models, implementation and financing of the nexus

Governance solutions must be country-specific and can be identified only through collaborative partnerships. By creating synergy and together exploring possible gains, stakeholders can identify barriers to development and select the best options.[26]

There are several possible models for regulating the nexus:

a. Distributed (or decentralized). Shared governance coordinated among units where all parties involved have representatives on a single body empowered and entrusted with governing the nexus;

b. Centralized. High-level independent governance body, with oversight of all units, representation from all stakeholders and the resources and authority to implement decisions.

The operation of these models in the Arab region countries could be through:

a. Private-public partnerships (PPP). Implementing the nexus approach is expected to save resources, which can be translated into financial savings. A private enterprise provides a public service or project and assumes financial, technical and operational risks. However, such a partnership requires initial financing (seed funding). This is also important in States where resources have been privatized;

   Another public-private model is the community partnership (PPCP) and the social partnership (PPSP), where governments and private enterprises work with organizations for social welfare in a non-profit model.

   Oversight or regulating bodies are needed to ensure the success of PPPs, and to see that services and pricing stay in line with country requirements.

b. Cooperative or community model. Particularly suitable in remote and rural communities, these community associations, or cooperatives, mostly own small-scale projects for off-grid production of renewable energy and/or water distribution.

In Tunisia, for example, water-user associations have developed a pricing system that has encouraged more efficient use of water (UNDP, water governance). Studies have shown this approach is an excellent source of jobs and income, encouraging women's participation, reducing rural migration and promoting access to education and services.[27]

# Regional perspective of the water-energy security nexus

## The nexus stakeholders: ownership of the nexus

The nexus dialogue relies upon a multi-stakeholder approach. The public sector should pursue sustainable food, water and energy policies that support, not infringe on one another. The private sector should seek to optimize operations and minimize costs (or maximize productivity), whether supplying water, energy or technology. And civil society should seek to improve quality of life by safeguarding health and reducing risk.[28]

## Water-energy security nexus in the Arab region

In the Arab region, nexus implementation is shaped by local and site-specific attributes, which are biophysical and governance-related. Climate change is another important factor when considering water scarcity in the region.

The following ecozones have been classified according to their similar climatic conditions, and socioeconomic and social structures:

a. The Gulf: Bahrain, Kuwait, Oman, Qatar, Saudi Arabia, the United Arab Emirates and Yemen;
b. Eastern Mediterranean: Iraq, Jordan, Lebanon, the State of Palestine and the Syrian Arab Republic;
c. North Africa: Algeria, Djibouti, Egypt, Eritrea, Libya, Mauritania, Morocco, Tunisia and the Sudan.

With 392 million people, the region has 5 per cent of the world's population[29] and exhibits a wide range of socioeconomic conditions; GDP per capita ranges from US$100-US$100,000.[30] More than 50 per cent of food calories are imported, and with only 1 per cent of global water resources. The region is home to 55 and 27 per cent of the world's proven oil and natural gas reserves respectively,[31] and a huge untapped solar energy potential. It is highly vulnerable to climate change, which has placed further strain on limited water supplies and is predicted to continue to do so. For the past decades, the region has experienced conflicts that have further complicated efforts to achieve water and energy security. Amid these difficulties there are also rural and urban stakeholders with different needs, opportunities and challenges that must also be addressed in the water-energy nexus.

All these factors influence the water and food distribution process and challenge the fundamental human right to access to food, water and energy.

## Water governance models

As populations grow and concentrate in urban areas, stresses on water supplies increase. In regions already experiencing water scarcity, such as the Middle East, North Africa, Asia and Central America, water-related challenges are a major hindrance to sustainable development and improving human conditions. Of the 22 Arab countries, 18 already fall below the water scarcity level of 1,000 cubic metres ($m^3$) per capita per year,[32] affecting almost 75 per cent of the region's people. Just under half live below the extreme scarcity level of 500 $m^3$.[33]

Many countries in the Arab region depend heavily on conventional water sources to supply the increasing demand; up to 80-90 per cent of water is used in arid and semi-arid river basins where supplies are scarce, according to the World Water Council.[34] Egypt, Iraq and the Sudan depend primarily on surface water, while Jordan, Morocco and Lebanon rely more heavily on groundwater. But these sources are being rapidly depleted, and the use of non-conventional sources (desalination, treatment, harvesting) is increasing across the region, with treated wastewater and desalinated water making up a rising share of water budgets in the GCC countries.[35]


Kuraymat Hybrid solar Plant Egypt © Green Prophet - https://www.flickr.com

Some countries, such as Bahrain, Djibouti, Egypt, Jordan, Lebanon, Libya, the State of Palestine, Saudi Arabia, the Syrian Arab Republic, Tunisia and Yemen, have incorporated integrated water resources management (IWRM) in national policies, but most are in need of policy reform. Even when changed, water policies often fail to consider social and economic goals, and do not focus on human rights and reaching vulnerable communities. Solutions will differ for each country or ecozone, but common reforms in governance and management practices using a multisectoral approach will help Arab countries meet water governance and management challenges.[36]

### Energy governance models

Arab countries are struggling to achieve energy security. Many are seeking to reorient their energy mix towards renewable energy sources to meet growing demand but fossil fuels will continue to dominate the regional energy portfolio in the foreseeable future. With lack of good policies and subsidies, and poor energy governance, and despite the rich endowment of fossil, solar, wind, hydro and other renewable energy sources, the region is among the world's most energy insecure regions, with more than 40 million (mainly rural) people in the Arab region living without electricity.[37]

While regional cooperation and grid integration for water and energy can help stabilize and secure electricity in the region, there is room for decentralizing energy sources for rural areas, where off-the-grid technologies can be more economically feasible. One example of grid integration that did not succeed is DESERTEC, a programme designed to trade excess solar power with Europe.

### Capacity building and knowledge and institutional gaps

Policymakers in Arab region countries should consolidate their capacity-building efforts by implementing a water-energy-food nexus approach. The following is a useful protocol for the ESCWA region:

a. Assemble a multi-stakeholder working group from the water, energy and food sectors across the public and private sectors to help manage all resources;
b. Develop institutional and individual capacity-building programmes across sectors. Priority must be given to creating competence in dialogue and conflict resolution, data management and analysis, and an understanding of the water-energy-food nexus at a technical and policy level;
c. Determine the right tools and data sets for scale-specific conditions (local, national, regional) and goals;
d. Apply outcomes from holistic nexus tools and comprehensive data sets to manage water, energy and food resources. Use this data to bring stakeholders into negotiations and find trade-offs;
e. Create training programmes across sectors to build capacity on analytics and negotiations for implementing nexus solutions at different levels.

## Decision support systems: nexus analytical tools

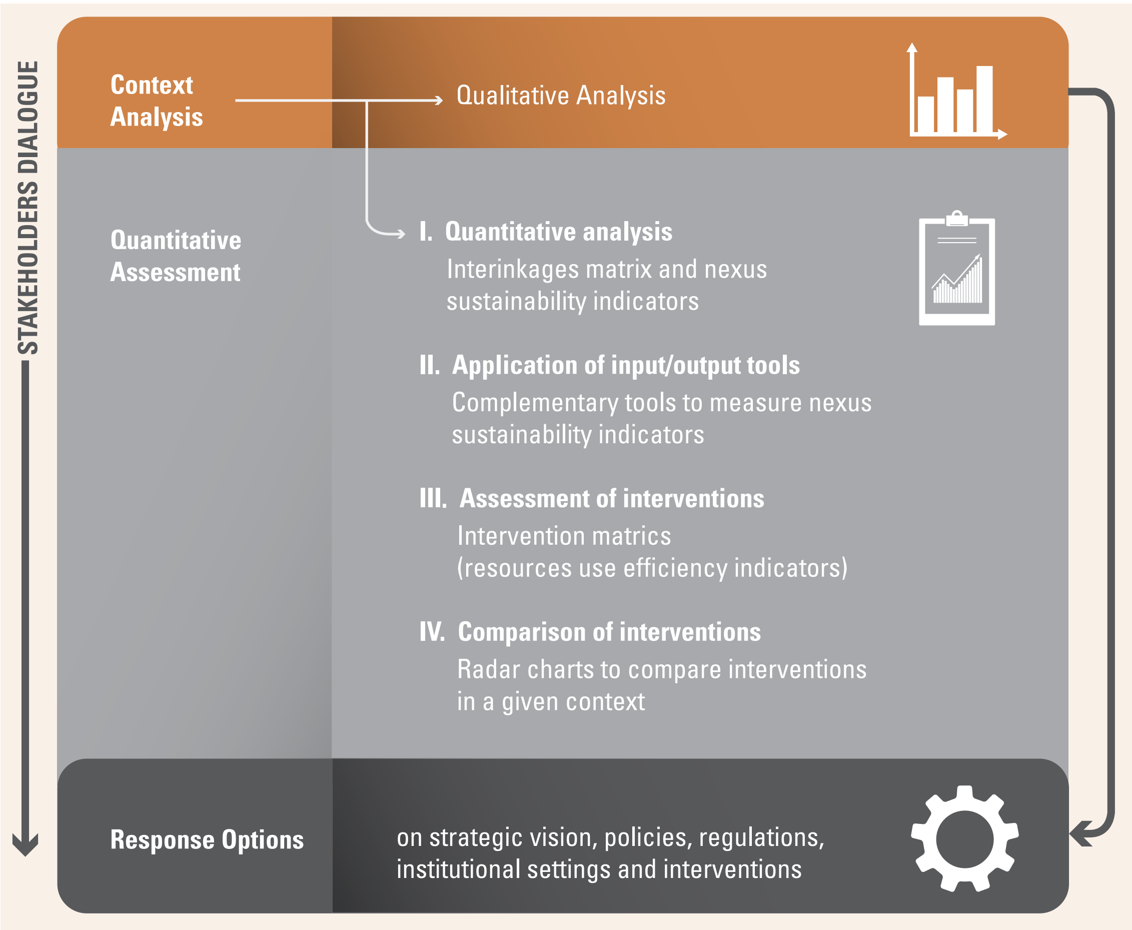
### Review of existing tools: uses and data requirements

Planning and decision-making that consider the impact of water and energy strategies on other sectors require substantial qualitative and quantitative insight. Adopting a nexus approach to sector management involves analysing cross-sectoral interactions, and using different decision support tools and methodologies, depending on the purpose of the analysis, access to data and availability of technical capacity.[38] Outcomes inform policymaking by quantifying the extent to which a policy affects sectors.

Analytical tools can be either qualitative or quantitative. Qualitative tools are useful in preliminary analysis of the water-energy nexus where stakeholders are looking at a scenario in resource management; geographical area, stakeholders involved and regions/communities potentially affected, for example. Quantitative tools build on the data generated by a qualitative analysis and generate indicators that assess the impact on sustainability, resource management and efficiency, resource gaps and the needs of a specific scenario (figure 3).

A comprehensive nexus tool accepts inputs from the three sectors and provides information on basic resource requirements (e.g. total land needed), complemented with "quality" data (e.g. types of land) and other particulars related to scale, distribution/equity or governance, among others. In some cases, the outputs of one analysis could be inputs to a more comprehensive one.[39]

**Figure 3.** Components of nexus assessment




**Source:** Food and Agriculture Organization (FAO), 2014.

Decision support tools are available to provide guidance on science-based policies. Tools should be chosen based on local conditions and can provide projected solutions or a suite of solutions for a more integrated resource management approach when comparing business-as-usual scenarios with a nexus approach. The tools are also valuable in promoting cross-sectoral communication and trade-offs, and it is critical to create these competencies at an individual as well as institutional level.

Several nexus tools with different analytical approaches are available, depending on the inputs required, the outputs provided and the analytical characteristics. In many cases, basic tools with limited scope have proved useful in bridging the gap between a silo approach and a more comprehensive nexus assessment.

It is critical to define the stakeholders – private, public or from the science sector – and understand at what scale each is represented. Such knowledge will dictate the scope of the modelling platform to be used. Modelling should be kept simple: water-energy-food systems are complex, so adding unnecessary externalities will over-complicate the analytics. Processes modelling or trade-off analyses must be considered, and the choices made will vary, depending on who the platform is for. Defining links between variables will stem from existing disciplinary data that identifies the interconnectedness of resources. The resolution, aggregation, disaggregation, quality and access to data must also be considered.[40]

It is beneficial if a tool meets the following criteria:

a. addresses at least two of the three elements of the nexus;
b. allows policy analysis at national and local levels;
c. has open access for end-users.

The eight tools most relevant in the nexus implementation are the WEF Nexus Tool 2.0, WEAP/LEAP, LEAP, MARKAL/TIMES, the Global Calculator tool, CLEWs, MuSIASEM and FAO tool.[41]

## WEF nexus tool 2.0

The nexus modelling tool allows the user to create scenarios with varying food self-sufficiencies, water sources, energy sources and countries of import. The output includes a summary of water and local energy requirements, local carbon emissions, land requirements, financial requirements, energy consumption through imports and carbon emissions through food imports.

The user is able to visualize the resources consumed in proposed scenarios, and determine the importance of each system (water, local energy, local carbon, land, financial, and energy and carbon through import). Based on the input, the tool calculates the sustainability index, a calculated indicator that identifies whether a proposed scenario is suitable in the area of study. Two major components constitute a sustainability index: resource requirements for a scenario (water, land, energy, finances and carbon) and importance factors for each of the systems defined by stakeholders.[42]

## The LEAP/WEAP tools

Created by the Stockholm Environment Institute (SEI), the WEAP (water evaluation and planning) tool is an integrated watershed hydrology and water planning model that incorporates supply, demand, water quality and ecological considerations to better allocate limited water resources into different sectors. It is based on a geographic information system (GIS) and creates physical simulation of water demands and supplies. The WEAP model calculates multiple dimensions of water, including water demand and supply, run-off, infiltration, crop requirements, flows, storage, pollution generation, treatment, discharge and in-stream water quality under varying hydrologic and policy scenarios. In its evaluation of water development and management options, it accounts for multiple and competing uses of water systems.

The LEAP (long range energy alternative planning) tool creates a platform for integrated energy planning and greenhouse gas (GHG) mitigation assessment. It can assess the cost-benefit of energy and emissions. It has been used by countries assessing their national communications to the United Nations Framework Convention on Climate Change (UNFCCC), and for developing low emission development strategies (LEDS).[43]

Individually, both LEAP and WEAP were developed to address aspects of water and energy planning. For example, LEAP could model hydropower, but does not consider water scarcity as a possible constraint. WEAP, meanwhile, could calculate the potential for hydropower to change under different water supply and demand scenarios but is unable to explore how hydropower fits within a larger energy system. SEI has integrated WEAP and LEAP to address these limitations. They remain separate tools, but have an interface that allows them to exchange parameters and results, such as hydropower generated or cooling water requirements, and together they can represent evolving conditions for water and energy systems. Using the two together can help planners see how individual water or energy management choices ripple through both water and energy systems and understand trade-offs that might not be apparent when looking at either system in isolation. Planners can then evaluate outcomes against their policy goals and priorities; for example, to supply enough water for all, or reduce GHG emissions. If one approach leads to unacceptable results, they can explore alternative policies and measures.[44]

## The MARKAL/TIMES tool

TIMES (the Integrated MARKAL-EFOM 1 System) is an economic model generator for local, national or multi-regional energy systems. It is usually applied to the analysis of the entire energy sector, but may also be applied to detailed study of single sectors, such as the electricity and district heat sector.

The user provides estimates of the existing stock of energy-related equipment in all sectors, and the characteristics of available future technologies, plus present and future sources of primary energy supply and their potential. Using these as inputs, the TIMES model aims to supply energy services at minimum global cost, or more accurately, at minimum loss of surplus, by simultaneously making equipment, investment, operating, primary energy supply and energy trade decisions by region. The scope extends beyond energy-oriented issues, to the representation of environmental emissions – and perhaps materials – related to the energy system.

MARKAL was developed in a cooperative multinational project over two decades by the Energy Technology Systems Analysis Programme (ETSAP) of the International Energy Agency.

## The global calculator tool

The Global Calculator focuses on climate change and the effects of human activity. It is a model of the world's energy, land and food systems that allows users to explore options for reducing global emissions by 2050, and to see the climatic consequences of these choices by 2100. It is a free web-based interactive system and incorporates an Excel spreadsheet with an online interface (tool.globalcalculator.org).

The Global Calculator projects the world's energy supply and demand by modelling physical units such as land, cars and power plants. This decision-support system is best suited to long-term global strategic questions, such as highlighting the role for electric vehicles or wind power. It is not for country-level analysis. User-driven, it does not automatically take account of potential feedback effects between supply and demand sectors and levers, and it does not include macroeconomic impacts.[45]

## CLEWs

Research on climate, land-use, energy and water strategies (CLEWs) developed an integrated systems approach. It investigates connections between these sectors to determine the impact changes in one has on the others, and identifies counter-intuitive feedback in the integrated systems. CLEWs studies provide insights into trade-offs between conflicting uses of natural resources and highlight potential synergistic solutions to overcome them. Importantly, they also provide relevant policy information. CLEWs case studies include a number of African countries, small island developing States and European transboundary basins, with emphasis on context-specific nexus issues, such as links between water availability, hydropower production, ecosystem services and agricultural intensification. Research is being done to develop a global CLEWs model that accounts for trade and other constraining resources, such as minerals.[46]

The model is information and resource intensive, requiring highly detailed data, and significant work is required to facilitate integration. Also, it is time consuming and not always compatible with short turnaround projects.[47]

## MuSIASEM

The multi-scale integrated analysis of societal and ecosystem metabolism (MuSIASEM) builds on concepts derived from bioeconomics and complex systems theory, such as the flow-fund model, multipurpose grammars and impredicative loop analysis. This allows technical, economic, social, demographic and ecological variables to be used to look at patterns of modern societies at different levels and scales. MuSIASEM can analyse the nexus between energy, food and water, considering factors such as population dynamics, GHG emissions and land-use changes at national or subnational level. Data inputs can be taken from national statistics and/or other datasets, such as FAO food balance sheets, with data from GIS. It can be employed for diagnostic and simulation purposes.

A distinctive characteristic of this model is that instead of performing a traditional input-output analysis (e.g. water footprint per crop, energy intensity of certain activities), the MuSIASEM approach calculates flows in relation to funds (e.g. energy input per hour of labour, water consumed per hectare of land in production, energy consumption per year per capita, GDP per year per capita).[48]

### The FAO tool

The FAO approach includes management of the nexus to help determine related national and local goals and ways to achieve them based on these resources. Water, energy and food sustainability are proposed with explicit components. The framework includes stakeholder dialogue with defined goals and interests, which enables stakeholders to jointly identify solutions for sustainable development. The tool proposes interlinking matrices as a tool to identify nexus synergies and trade-offs for the sustainability of the ecosystem and human system at different scales. It also includes visual representation of the bioeconomic pressure in the analysis, using sustainability indicators intended for specific elements, such as sustainable water, sustainable energy, food security, labour and capital.[49]

## Data gaps and capacity building

There is an urgent need to disseminate knowledge to improve understanding of the water-energy nexus. For nexus tools, lack of data is often a key difficulty; most require extensive data inputs, which in many cases are not available.

Obtaining data for the energy sector is relatively straightforward. Data on production, transmission and consumption is readily available from national and international agencies, and information on resources such as coal, oil and natural gas is available in trade databases and many regional and international institutions. Obtaining data for the water sector presents a greater challenge.[50] Similar markets do not exist for water, partly as a consequence of physical characteristics, such as transboundary water flows, making it difficult to assign water a correct value. While some data sets relating to water do exist, availability remains relatively limited.[51]

In addition, when considering the links between water and energy, it is more complex still to obtain accurate data on water consumption in electricity generation due to lack of information on cooling technology, the effects of local climate, and operational and maintenance issues. Hydropower and bioenergy are especially challenging, with the relation of water use to energy production unclear. For example, water evaporation from hydro cannot be related entirely to power generation, but can also be attributed to other services provided by the dam, such as flood control or irrigation.[52]

To address some of the gaps, the World Water Council and Électricité de France (EDF) launched the Water for Energy Framework initiative, which attempts to normalize water accounting methodologies in all involved sectors. The objective is to develop a framework and subsequent tools for assessing and reporting on the relations between energy production activity and its water environment.[53]

Generating accurate data is a challenge, but effectively transferring this knowledge into the policy sector is an area that needs further attention. The technical community should be able to provide the tools and information to encourage diversification in the national and regional portfolios for the nexus. Creating a common database platform among sectors is another tool for enhanced synergy and negotiation. Decision-making tools also need to create indicators to measure the impact of a policy, where costs and benefits can be evaluated.

# Water for energy production as a policy guide

The United Nations General Assembly declared 2014-2024 the Decade of Sustainable Energy for All (SE4All). The initiative aims to catalyse action around three objectives to be achieved by 2030:[54]

a. Ensure universal access to modern energy services;
b. Double the global rate of improvement in energy efficiency with respect to base year 2010;
c. Double the share of renewable energy in the global energy mix with respect to base year 2010.

According to the World Bank, 82 per cent of energy companies and 73 per cent of power utility companies have indicated that water is a considerable risk to their business operations, though most have not adopted an integrated management approach to tackle this. Power outages due to a lack of cooling water are already a reality in parts of the world.[55] Decisions affecting the sector need to include water considerations to avoid unintended environmental consequences on water resources. This can be addressed by integrated energy and water policy planning, as the availability of water in certain jurisdictions may limit these technologies and cooling system configurations.

There are pragmatic measures that can be taken to coproduce energy and water services, and exploit the benefits of synergies. These include combined power and desalination plants, combined heat and power plants, using alternative water sources for thermal power plant cooling, and energy recovery from sewerage water.[56] This is not possible in all locations, and trade-offs for water allocation have to be done between competing sectors.

## Conventional and unconventional oil and gas

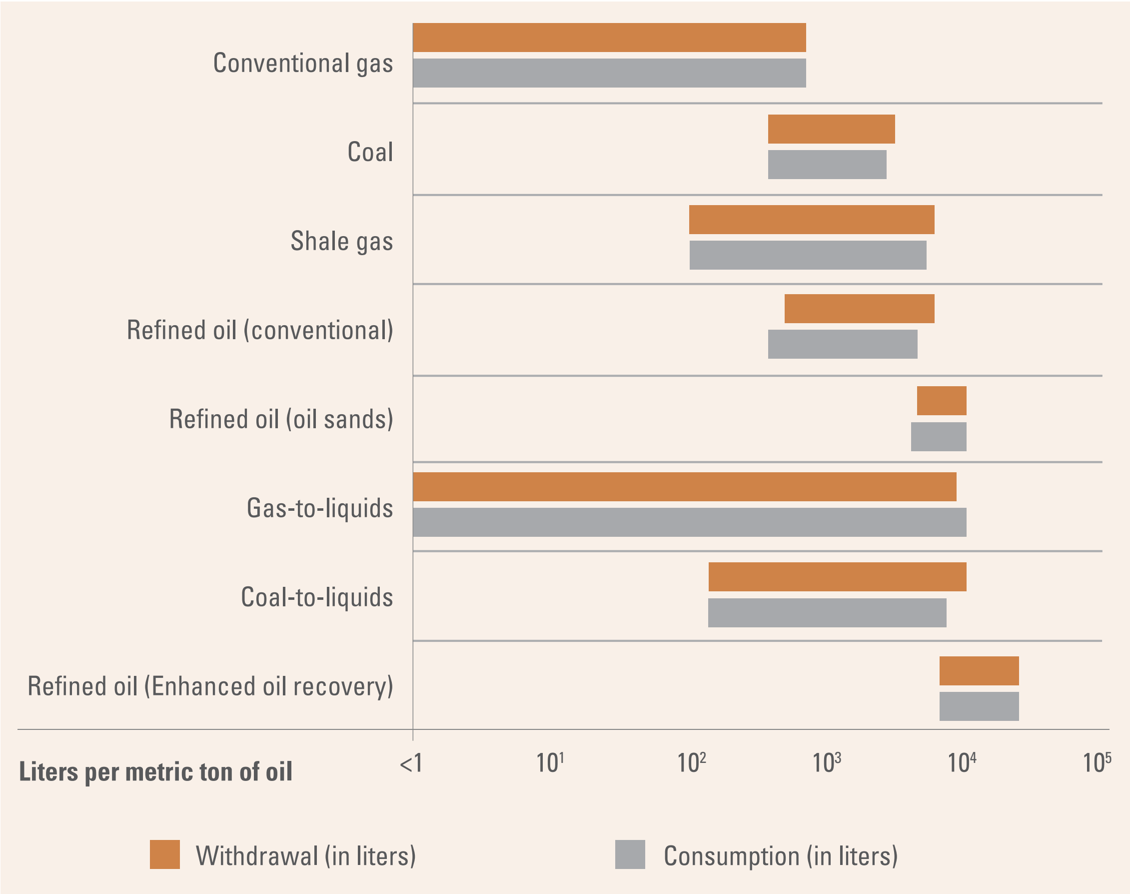
Water is essential for drilling, pressure maintenance and all stages of production in the oil and gas industry.

Producting unconventional fuels requires more water than conventional gas fuels, but less than conventional oils. On average, hydraulic fracturing in the United States requires an estimated 2-5 million gallons of water per well. Uncertainty about water use within an oil field that is under development can be as great or greater than the variability of water use between fields in different regions. As new projects expand across countries, industry officials and politicians have an opportunity to correlate the water needs of energy extraction with sustainable water management practices.[57]

The water needed to produce one barrel of oil from oil shale is reportedly 2.6 to 4 barrels, and from oil sands 2.3 to 5.8 barrels. The water required for shale gas production is four times higher than the water consumed by conventional natural gas, and a shale gas well can use up to 4 million gallons of water to drill and fracture.[58]

Within the oil industry, reliance on technological advances and the will to spend more on research and development to manage used and produced water is insufficient. Policymakers

**Figure 4.** Water use for extraction of different fuel types




**Source:** World Bank, 2016.

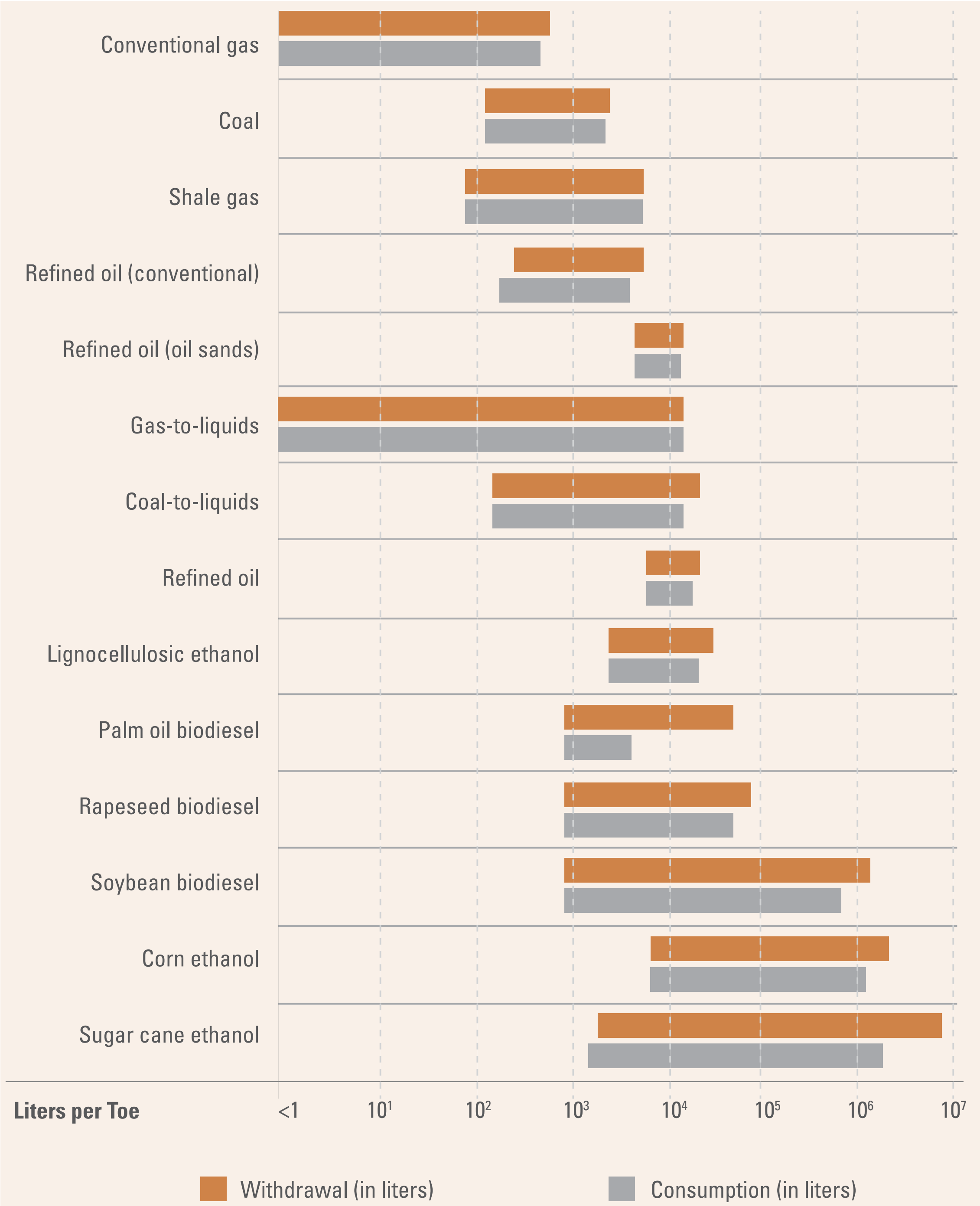
need to create an environment for nexus analysis through all stages of oil exploration involving reduced water use, especially fresh water. Reuse must be encouraged, disposal standards made more stringent, and alternative uses demanded for treated water produced by the industry.[59]

## Biofuels

Bioenergy production can require substantial amounts of water depending on the feedstock, the raw material to supply or fuel a machine or industrial process. Residue-based bioenergy requires less water compared with dedicated energy crops, where water consumption depends on whether irrigation is required and the method adopted, crop type, local climate and technology choices.[60]

Optimism about biofuels is tempered by concerns over their economic viability and implications for socioeconomic development, food security and environmental sustainability.[61] The outlook remains uncertain as biofuels are sensitive to changes in oil and gas prices, as well as government subsidies and blending mandates, which remain the main stimulus for use.[62]

**Figure 5.** Water needs for biofuels compared with conventional and unconventional oil fuels




**Source:** WWAP, 2014.
**Note:** Water needs for each crop vary significantly depending on irrigation requirements and regional aspects. Toe = ton of oil equivalent.

## Electricity generation: thermoelectric, hydroelectric, solar and wind

About 80 per cent of the world's electricity is generated in thermal power plants.[63] Cooling system choice may play an important role in our future electricity mix, especially their water footprint.

High Dam © Omar El Sharkawy - https://www.flickr.com

Cooling technologies have differing impacts on local and regional water resources; for example, recirculating tower systems that primarily use freshwater inland, and once-through technologies in coastal areas affect water availability and watersheds differently, depending on local conditions. Using alternative cooling technologies, such as dry cooling, combination hybrid parallel cooling and mirror washing, may be an energy security benefit, given uncertainties in future water availability and expected vulnerabilities of power plants. Reduced levels in bodies of water, or substantial increases in their temperature, may require thermal power plants to run at lower capacities or to shut down completely, as happened in France in 2003.[64] Using dry cooling or non-freshwater sources avoids some risks associated with these drought and climate change scenarios.

Despite the considerable growth of the renewable energy sector and the policy and institutional support at regional and global levels to diversify energy portfolios, the world still relies heavily on fossil fuels, and is expected to remain so for the foreseeable future.[65] An energy system with a substantial share of renewable energy could be less water-intensive, boosting water security by improving accessibility, affordability and safety.

Renewable energy power generating systems have great potential as small-scale, off-grid systems to supply power to one or more end users, a valuable alternative for a variety of services and users, especially in remote rural locations.

Several Arab countries, including Jordan, Saudi Arabia and the United Arab Emirates, are exploring nuclear energy for power generation. While feasibility studies are of good value, analysis of the water footprint and environmental impact should also be included.

## Regional and national grids

Improved cooperation between regional electrical grids and transboundary basin organizations operating in the same region, working with respective national governments, could help to better coordinate water management and the energy sector via hydropower development. Such cooperation can also aid the sustainable allocation of water to producers of other forms of energy and other water-use sectors in the region.[66]

Presently, there are three regional interconnection zones in the Arab region:[67]

a. The Eight interconnection, including Egypt, Iraq, Jordan, Lebanon, Libya and the Syrian Arab Republic. There is no exchange of loads between Lebanon and the Syrian Arab Republic. Iraq is locally interconnected with the Syrian Arab Republic and Turkey;
b. The Maghreb interconnection includes Algeria, Libya, Morocco and Tunisia. The link between Libya and Tunisia is not operational due to technical problems;
c. The GCC interconnection.


Ouarzazate Noor 1 solar power complex, Morocco, nearing inauguration (December 2015) © NASA Earth Observatory - https://commons.wikimedia.org

## **Box 1.** World's largest concentrated solar power plant, Morocco

Although Morocco is one of the sunniest places on earth, it depends on oil for 95% of its energy needs. To reduce this dependency, conserve water supplies and develop a renewable energy source that avoids GHG emissions, the Moroccan Agency for Solar Energy partnered with the African Development Bank in 2012 to build the largest concentrated solar power plant in the world. The Ouarzazate Solar Power Station in southern Morocco is expected to produce 580 megawatts at peak operating capacity by storing solar energy in the form of heated molten salt.

The volume of GHG emissions avoided through the combined operation of Noor I, Noor II and Noor III stations is estimated to be equivalent to 762,000 tonnes of carbon dioxide (CO2) per year, and 19 million tonnes over 25 years. The country's solar plan, with a total capacity of 2,000 megawatts, is part of a project to reduce emissions by up to 3.8 million tonnes of CO2 per year by 2020.

Ouarzazate is expected to generate annual water consumption savings of approximately 3.6 million $m^3$, a considerable sum given the arid climate of the region. ESCWA member countries can benefit from Morocco's lead on developing a national resource with economic benefits for the population, improved water-energy security and a competitive advantage in energy over the long term.

**Source:** African Development Bank, 2014. Environmental and social impact assessment. Morocco.

In addition, an interconnection project between Egypt and Saudi Arabia is expected to be operational in 2017, and a feasibility study for electricity interconnection between Egypt and the Sudan has been carried out. Also, Europe, via Spain, is interconnected with the Arab region via Morocco, which is also interconnected with Algeria and Tunisia. These regional grids have the potential to pursue energy security at a regional level using renewable sources, including solar, wind and hydropower.[68]

# Energy in water security as a policy guide

Energy costs can be an enormous burden on water utilities, adding up to 55 per cent of total operation costs.[69] Relying on a single energy source to supply water to multiple sectors of an economy can represent a risk to the water, energy and food sectors. Energy economics are, therefore, driving greater awareness inside the water-energy nexus.

Struggling to keep up with the demand of water and energy, especially in low- to middle-income countries in the region, many governments and institutions are seeking to redesign national portfolios towards renewable energy sources.

## Desalination

Gulf countries rely mostly on seawater desalination to supply their water demand, and the technology is being promoted given water scarcity in other Arab countries. Most countries in the region devote between 5 to 12 per cent of electricity consumption to desalination.[70]

### **Box 2.** Solar desalination initiative, Saudi Arabia

In the GCC countries, one of the most important water-energy nexus initiatives is the King Abdullah Initiative for Solar Water Desalination. Launched in 2010, it aims to use solar energy to desalinate seawater at a low cost, contributing to Saudi Arabia's water security and the national economy. The initiative will be implemented in three stages over nine years. In the three-year first phase, a desalination plant with a production capacity of 30,000 $m^3$ per day will be built to meet the drinking water needs of the town of Al Khafji. The plant will use reverse osmosis technology, powered by solar energy farms that are being built. The second phase aims to build another solar desalination plant with a production capacity of 300,000 $m^3$ per day. The third phase will involve the construction of several solar plants for desalination in all parts of the country. The ultimate goal is to enable all the country's seawater desalination to be carried out using only solar energy by 2019, and at the significantly lower cost of US$0.4 per $m^3$ compared with the current cost of US$0.67 per $m^3$ to US$1.47 per $m^3$ when using thermal methods. The technology will also be licensed outside Saudi Arabia.

**Source:** Al-Zubari, 2015.

## Water extraction, treatment and distribution

The distribution of water resources in the region is so diverse that the energy requirements for water vary greatly, depending on a country's geography.

In its sixth issue, the ESCWA Water Development Report grouped Arab countries according to the energy intensity of their water extraction and delivery systems. Figure 7 shows the energy required to deliver water from different sources. The groups are as follows:[71]

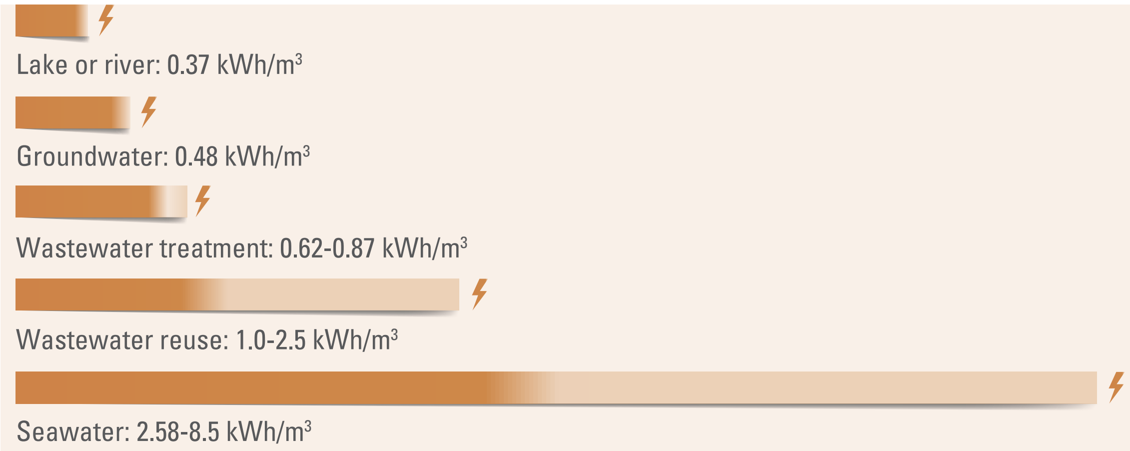
a. High-energy demand. Countries that depend on groundwater and desalination. This includes the GCC countries, which have a high energy demand for water production; Bahrain, for example, where desalination accounts for 30 per cent of total energy use, while in Libya and Saudi Arabia groundwater pumping accounts for 14 per cent and 10 per cent, respectively, of national fuel consumption;

b. Medium-energy demand. Countries that depend on a mix of sources, though mainly groundwater and, in smaller amounts, surface water. This category includes Jordan, Lebanon, Tunisia and Yemen. The Jordanian water sector consumes 14 per cent of the total annual electricity generated;

c. Low-energy demand. This category is for countries that largely depend on surface water and includes Egypt, Iraq and the Syrian Arab Republic.

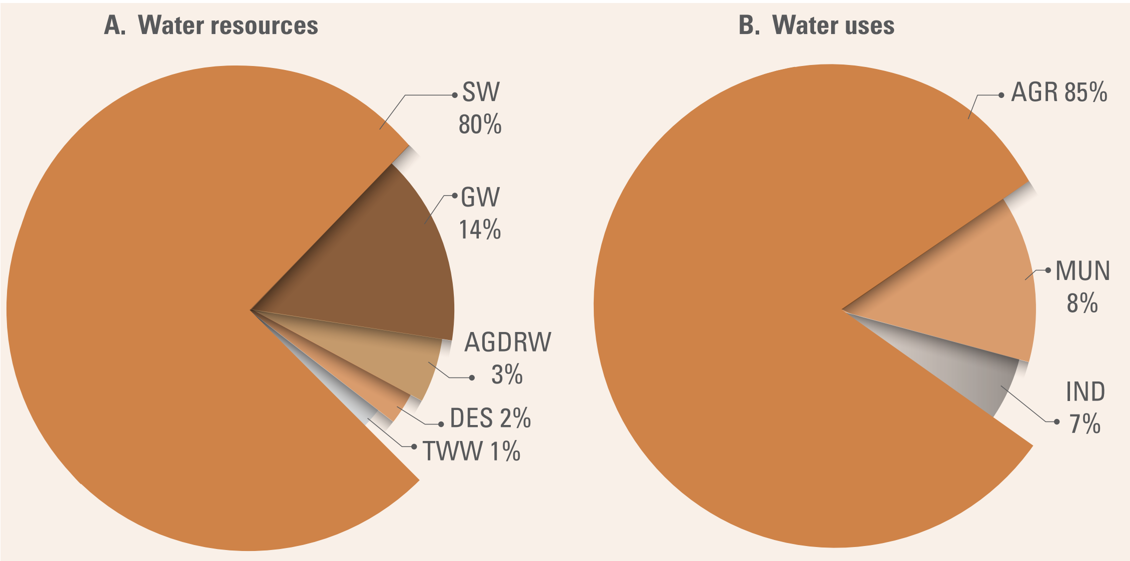
Solar panel for a well in the semi-desertic area of Rhamna, 50 km from Marrakech, Morocco © L.Mahin - https://commons.wikimedia.org

**Figure 6.** Amount of energy required to deliver 1m³ from various water sources




**Source:** United Nations, 2014.

**Figure 7.** Water resources by source and uses in the Arab region




a. Water resources (SW=surface water, GW= groundwater, AGDRW= reused agriculture drainage water, DES= desalinated water, TWW=treated wastewater)
b. Water uses (AGR = agricultural sector, MUN = municipal sector, IND= industrial sector)

**Source:** AFED, 2015.

Solar pumping can support the expansion of irrigation, reduce dependence on grid electricity or fossil fuel supply, mitigate local environmental impacts and reduce government subsidy burdens. Despite compelling savings promised by solar-energy water pumps, large-scale adoption is still hindered by various factors, including relatively high capital costs, inertia in adopting new technologies, establishing markets for the technology and ensuring adequate training for installers and operators. Risks are also associated with excessive water withdrawal, since operational costs of photovoltaic pumps are negligible.[72] The Ministry of Agriculture in Yemen has made finance available to farmers to acquire solar-powered pumps. This allows them to become more competitive as fuel, already subsidized, represents approximately 60 per cent of the total cost of agricultural production.[73]

## Wastewater treatment and reuse

Downstream, there is energy demand for wastewater treatment and discharge, which varies according to the level of treatment and technology used. Primary treatment has an energy requirement range of 0.1-0.3 kWh per $m^3$, whereas secondary treatment has a range of 0.27-0.59 kWh per $m^3$.[74]

Energy recovered from wastewater treatment plants is almost non-existent in the Arab region, even though most countries have the potential. Indeed, warmer temperatures in the region are more suitable for anaerobic treatment technologies that are less energy intensive and produce biogas that can fuel a treatment facility.[75]

# Key messages and recommendations

Despite the ESCWA region being heterogeneous in climate and socioeconomic and political governance structures, there are similarities and a common platform that can benefit from regional cooperation around nexus data and tools. The following key messages are drawn:

1. There is no one-size-fits-all model for production, consumption and governance of natural resources. Climate, geography, socioeconomic scenarios, transboundary issues, refugees, conflict, tribal governance and other political models have wide-ranging implications in the Arab region, with no magic approach to an integrated and sustainable management of resources. The water-energy-food nexus must be needs oriented and context sensitive. Cooperation around the knowledge, platform and process of implementing nexus solutions can create a win-win situation for the entire region.
2. Human rights and access to water, energy and food resources should be the foundation for the producing and managing of these primary resources. This will create regional cooperation and set common goals to achieve economic growth and development.
3. A people-centred approach grounded in the Sustainable Development Goals (SDGs) and defining the global and regional agendas will enable needs to be mapped and create cooperation.
4. There are clear interdependencies between the SDGs on poverty, health, economic growth, education, social justice, water, energy and food security. They are part of a continuum and managing them creates a nexus which must be dealt with holistically, using tools and data to achieve the goals.
5. Capacity of local structures and institutions must be built by creating indicators and local accountability mechanisms to bring global SDGs to a local scale. They must be synergized with existing programmes so they can start "speaking the same language".
6. The water-food-energy nexus governance can be implemented in existing institutional programmes that are country- and region-specific. However, they must be reformed, with the capacity for a holistic approach built at all levels, inclusively and transparently. Such reform must focus on better coordination between all sectors and levels of governance. Capacity building must include technical, social, negotiation and conflict-resolution skills.
7. The public sector should be viewed as a major stakeholder in nexus implementation. Accountability and transparency mechanisms that allow proactive society involvement, rather than passive-critical interventions, must be encouraged.

8. Strategies that allow Arab countries to implement national and international commitments on economic and sustainable development must be developed; for example, sustainable energy for all, reliable trade regimes, sustainable consumption and production protocols.
9. It is important to look at different types of governance for primary resources management, including decentralization. This can be achieved by better coherence among separate water and agricultural authorities, and promoting cooperatives or associations that pursue resource efficiency and pricing in the water and energy sectors.
10. Decision support tools/systems (DSS) for nexus management and interlinkages allow decision makers to look at scenarios in an objective and quantitative way. Policymakers can then allocate primary resources and make better technology choices for a specific water and energy portfolio. These analytical models also help to create platforms for trade-off discussions, negotiations and financing.
11. Decisions affecting the energy sector need to consider water resources to avoid strains in the water sector. This can be achieved by integrating energy and water policy planning. Water availability in each region should be a factor in determining the choice of technology for power production and cooling system configuration.
12. Energy costs in water utilities can rise to 55 per cent of total operating costs. Relying on one energy source to supply water nationally can represent a huge risk to the water, energy and food sectors. Energy requirements and the carbon footprint of water technologies such as desalination and treatment should be considered when planning policies in the water sector.
13. Poor infrastructure and technology choices, and deficient institutional support for water and energy supply, hinder human well-being and economic development. There is a huge potential for growth at local and regional levels when linked systems for water use, energy and food production are advanced in a coordinated, holistic way.

# Endnotes

1. Rosemarin and others, 2008.
2. IEA, 2012.
3. Mohtar, 2016.
4. WEF, 2016.
5. Mohtar, 2015.
6. IRENA, 2015.
7. Mohtar and Daher, 2012.
8. United Nations, 2014.
9. Daher and others, 2016.
10. Waughray and Boltz, 2015.
11. Scott and others, 2015.
12. UNEP, 2015.
13. Yilbas and others, 2015.
14. Qatar Environment and Energy Research Institute (QEERI), 2012.
15. ESCWA, 2015.
16. Mohtar and Daher, 2016.
17. United Nations, 2015.
18. Colgan, 2013.
19. Olsson, 2015.
20. Al-Zubari, 2015.
21. AFED, 2015.
22. UNDP, 2013.
23. Boersma and Griffiths, 2016.
24. Saudi Gazette, 2016
25. UNDP, 2013.
26. Granit, and others, 2013.
27. Sovacool, 2012.
28. Mohtar, 2016.
29. World Bank, n.d.b.
30. WEF, 2012.
31. OAPEC, 2015.
32. United Nations, 2014.
33. Ibid.
34. UNDP, 2013.
35. Ibid.
36. Ibid.
37. Arab Union of Electricity, 2015.
38. SEI, 2013.
39. IRENA, 2015.
40. Mohtar, 2016.
41. IRENA, 2015.
42. Daher and Mohtar, 2015.
43. SEI, 2013.
44. SEI, 2012.
45. Global Calculator (the), 2015.
46. Daher and Mohtar, 2015. Quantitative nexus framework WEF nexus tools. PPT.
47. Alfstad, 2013f.
48. FAO, 2013.
49. FAO, 2014. More details can be accessed from: http://www.fao.org/3/a-i3959e.pdf.
50. United Nations, 2014.
51. IRENA, 2015.
52. Ibid.
53. World Water Council, 2014.
54. ESCWA, 2015.
55. World Bank, 2016.
56. WWAP, 2014.
57. World Bank, 2016.
58. ESCWA, 2015.
59. Ibid.
60. IRENA, 2015.
61. WWAP, 2014.

62. WWAP, 2015.
63. IEA, 2013.
64. Ibid.
65. IEA, 2012.
66. United Nations, 2015.
67. Masdar, 2013.
68. ESCWA, 2015.
69. Darwish and Mohtar, 2016
70. UNEP, 2014.
71. ESCWA, 2015.
72. IRENA, 2015.
73. ESCWA, 2015.
74. ESCWA, 2015.
75. United Nations, 2014.

# Bibliography

Al-Zubari, Waleed (2015). Sustainable Water Consumption in Arab Countries. AFED online 2015: Water. Available from http://www.afedonline.org/Report2015/English/p108-133%20water%20english%20today.pdf.

Arab Union of Electricity (2015). *Statistical Bulletin 2015*, issue 24. Available from http://www.auptde.org/Article_Files/inside%202016.pdf.

Arab Forum for Economic Development (AFED) (2015). *Sustainable Consumption for Better Resource Management in Arab Countries.* Annual Report of the Arab Forum for Environment & Development (AFED). Available from http://www.afedonline.org/Report2015/English/p8-63%20report%20today.pdf.

African Development Bank (2014). *Ouarzazate Solar Power Station Project II.* Morocco. Available from https://www.afdb.org/fileadmin/uploads/afdb/Documents/Environmental-and-Social-Assessments/Morocco_-_Ouarzazate_Solar_Power_Station_Project_II_-_ESIA_Summary.pdf.

Alfstad, Thomas (2013). *Climate, Land-Use, Energy and Water (CLEW).* Presented at FAO Nexus Workshop in Rome, March 2013. Available from http://www.fao.org/energy/36620-07ac3d9d2b50a2f8f9fa8c740608cfbe9.pdf.

Bhaduri, Anik and others (2015). Sustainability in the Water-Energy-Food Nexus. *Water International*, vol 40, No. 5-6 (11), pp. 723-732. Available from http://www.tandfonline.com/doi/pdf/10.1080/02508060.2015.1096110?needAccess=true.

Boersma, Tim, and Steve Griffiths (2016). *Reforming Energy Subsidies: Initial Lessons from the United Arab Emirates.* Washington, D.C.: Brookings Energy Security and Climate Initiative and The Masdar Institute. Available from http://www.brookings.edu/~/media/research/files/papers/2016/01/reforming-energy-subsidies-uae/brookings_masdar_reforming_energy_subsidies_uae.pdf.

Colgan, Jeff D (2013). *Petro-Aggression: When Oil Causes War.* Cambridge, United Kingdom: Cambridge University Press.

Daher, Bassel T., and Rabi H. Mohtar (2015). Water–energy–food (WEF) Nexus Tool 2.0: guiding integrative resource planning and decision-making. *Water International*, DOI:10.1080/02508060.2015.1074148.

Daher, Bassel T., and others (2016). *Modelling the Water-Energy-Food Nexus: A 7-Question Guideline.* Water-Energy-Food Nexus: Theories and Practices (Salam and others. Eds.). In press.

Darwish, M. A., and Rabi Mohtar (2012). Qatar water challenges. Desalination and Water Treatment. Presented at the International Conference on Desalination for the Environment, Clean Water and Energy, European Desalination Society, 23-26 April 2012, Barcelona, Spain. Available from http://wefnexus.tamu.edu/files/2015/01/Qatar_water_challenge_Journal_paper.pdf.

Economic and Social Commission for Western Asia (ESCWA) (2015). *Water Development Report 6: The water, energy and food security nexus in the Arab region.* (E/ESCWA/SDPD/2015/2). New York: United Nations. Available from https://www.unescwa.org/sites/www.unescwa.org/files/publications/files/e_escwa_sdpd_15_2_e_0.pdf.

Ferroukhi, Rabia, and others (2015). *Renewable Energy in the Water, Energy & Food Nexus.* Abu Dhabi, UAE: International Renewable Energy Agency (IRENA). Available from http://www.irena.org/documentdownloads/publications/irena_water_energy_food_nexus_2015.pdf.

Flammini, Alessandro, and others. (2014). Walking the nexus talk: assessing the water-energy-food nexus in the context of the sustainable energy for all initiative. Rome: Food and Agriculture Organization (FAO). Available from http://www.fao.org/3/a-i3959e.pdf.

Giampietro, Mario, and others. (2013). An Innovative Accounting Framework for the Food-Energy-Water Nexus: Application of the MuSIASEM approach to three case studies. Environment and natural resources management working paper number 56. Rome: Food and Agriculture Organization (FAO). Available from http://www.fao.org/docrep/019/i3468e/i3468e.pdf.

Granit, Jakob, and others (2013). Unpacking the Water-Energy-Food Nexus: Tools for Assessment and Cooperation Along a Continuum. Part of a thematic report for Stockholm World Water Week 2013. In *Cooperation for a Water Wise World – Partnerships for Sustainable Development*, Jägerskog, A., and others, eds. Report 32. Stockholm International Water Institute, Stockholm. 45-50. ISBN: 978-91-978846-8-6.

Global Calculator (the) (2015). Available from http://uncached-site.globalcalculator.org/about-calculator.

International Energy Agency (IEA) (2013). *Word Energy Outlook 2013.* Paris: International Energy Agency (OECD-IEA). Available from http://www.iea.org/publications/freepublications/publication/WEO2013.pdf.

International Energy Agency (IEA) (2012). *Word Energy Outlook 2012.* Paris: International Energy Agency (OECD-IEA). Available from http://www.iea.org/

publications/freepublications/publication/English.pdf.

Masdar (2013). Renewable Energy Readiness Assessment Report: The GCC Countries 2011-2012. Masdar Institute, UAE.

Mohtar, Rabi H. (2015). Ven Te Chow Memorial Lecture. Localizing water and food security. *Water International*, vol. 40, No. 4 (9), pp. 559–567, doi10.1080/02508060.2015.1084209.

Mohtar Rabi H. (2016). *The Water–Energy–Food Nexus: Who Owns it?* Policy brief presented at the OCP Policy Center. Rabat, April.

Mohtar, Rabi H and Daher, B. (2012). Water, Energy, and Food: The Ultimate Nexus. *Encyclopedia of Agricultural, Food, and Biological Engineering*, Second Edition. DOI: 10.1081/E-EAFE2-120048376.

Mohtar, R. and Bassel T. Daher (2016). Water-Energy-Food Nexus Framework for facilitating multi-stakeholder dialogue, *Water International*, DOI: 10.1080/02508060.2016.1149759.

Mohtar, Rabi H, and Richard Lawford (2016). Present and future of the water-energy-food nexus and the role of the community of practice. *J Environ Stud Sci*, DOI 10.1007/s13412-016-0378-5.

Muir, Magdalena A., and others (2014). Using the UN Sustainable Development Goals to Achieve Integrated Approaches to Water Scarcity, Agriculture and Energy of West Asia and North Africa. Available from https://sustainabledevelopment.un.org/content/documents/7066SDSN-ICSDP-ConferencePaper-Muir-Areikat-Vandenbroek.pdf.

Olsson, Gustaf. (2015). *Water and Energy: Threats and Opportunities*. Second Edition. Vol. 14. DOI: 10.2166/9781780406947.

Organization of Arab Petroleum Exporting Countries (OAPEC) (2015). Annual Statistics Report 2015. Kuwait. Available from http://www.oapecorg.org/media/4897ce10-7de6-4c78-83b7-f66f3a60797d/-902085559/Annual%20Statistical%20Report/Annual%20Statistical%20Report%202015%20-new.pdf.

Qatar Environment and Energy Research Institute (QEERI) (2012). Strategic Plan. Doha: Qatar Foundation.

Rosemarin, Arno, and others. (2008). *Pathways for Sustainable Sanitation Achieving the Millennium Development Goals*. Water Intelligence Online. Vol. 7, 2008, DOI: 10.2166/9781780401850.

Saudi Gazette (2016). Full Text of Saudi Arabia's Vision 2030. 26 April, 2016. Available from http://english.alarabiya.net/en/perspective/features/2016/04/26/Full-text-of-Saudi-Arabia-s-Vision-2030.html.

Scott, Christopher A., and others (2015). The Water-Energy-Food Nexus: Enhancing Adaptive Capacity to Complex Global Challenges. In *Governing the Nexus*, Mathew. Kurian and Reza Ardakanian, eds. Switerland: Springer International Publishing. DOI 0.1007/978-3-319-05747-7_2.

Stockholm Environment Institute (SEI) (2012). *Integrating the WEAP and LEAP systems to support planning and analysis at the water-energy nexus*. Available from https://www.sei-international.org/mediamanager/documents/Publications/Air-land-water-resources/SEI-2012-WEAP-LEAP-Factsheet.pdf.

Stockholm Environment Institute (SEI) (2013). *Launching a New Analytical Platform to Explore the Water Energy Nexus*. Paper presented at a workshop on Moving Ahead to Implement the Nexus Approach. FAO, Rome.

Sovacool, Benjamin K. (2012). Deploying off-grid technology to eradicate energy poverty. *Science* 338; pp 47-48.

United Nations (2010). The human right to water and sanitation. Resolution adopted by the General Assembly on 28 July 2010. Available from http://www.un.org/es/comun/docs/?symbol=A/RES/64/292&lang=E.

United Nations Department of Economic and Social Affairs (UNDESA) (2015). The Sustainable Development Goals (SDGs). New York. Available from https://sustainabledevelopment.un.org/sdgs.

United Nations Development Programme (UNDP) (2013). *Water Governance in the Arab Region: Managing Scarcity and Securing the Future*. New York. Available from http://www.undp.org/content/dam/rbas/doc/Energy%20and%20Environment/Arab_Water_Gov_Report/Arab_Water_Gov_Report_Full_Final_Nov_27.pdf.

United Nations Environmental Programme (UNEP) (2015). Policy Coherence of the Sustainable Development Goals: A Natural Resource Perspective. An International Resource Panel Report.

United Nations World Water Assessment Programme (WWAP) (2014). *The United Nations World Water Development Report 2014: Water and Energy*. Paris: UNESCO. Available from http://unesdoc.unesco.org/images/0022/002257/225741E.pdf.

United Nations World Water Assessment Programme (WWAP) (2015). *The United Nations World Water Development Report 2015: Water for a Sustainable World*. Paris: UNESCO. Available from http://unesdoc.unesco.org/images/0023/002318/231823E.pdf.

Waughray, Dominic and Fred Boltz (2015). At last global leaders are really talking about water - we need to seize the day. *The Guardian*, 24 September. Available from http://www.theguardian.com/global-development-professionals-network/2015/sep/24/water-shortage-drought-economy-energy-agriculture.

World Bank (n.d.b). World DataBank, world development indicators. Available from http:// databank.worldbank.org/data/reports.aspx?source=world-development-indicators&preview=on. Accessed 27 July 2016.

World Economic Forum (WEF) (2012). *The Global Competitiveness Report 2012 – 2013*. The World Economic Forum, Switzerland. Available from http://reports.weforum.org/global-competitiveness-report-2012-2013/#.

World Economic Forum (WEF) (2016). *The Global Risks Report 2016 11th Edition*. The World Economic Forum (WEF). Available from http://www3.weforum.org/docs/GRR/WEF_GRR16.pdf.

World Bank (2016). *Thirsty Energy (II): The Importance of Water for Oil and Gas Extraction*. Available from https://openknowledge.worldbank.org/bitstream/handle/10986/23635/Thirsty0energy0I0and0gas0extraction.pdf?sequence=1&isAllowed=y.

World Water Council (2014). Water and Energy. Available from http://www.worldwatercouncil.org/programs/water-energy/.

Yilbas, Bekir Sami, and others (2015). Influence of dust and mud on the optical, chemical, and mechanical properties of a pv protective glass. Sci. Rep. 5, 15833; DOI: 10.1038/srep15833.

# Increasing Efficiency

4 Module

# Contents



## List of figures



## List of tables

# Abbreviations and explanatory notes

| | |
|---|---|
| **Bbl** | barrel of oil |
| **DW** | desalinated water |
| **EP** | electrical power |
| **ESCWA** | Economic and Social Commission for Western Asia |
| **FAO** | Food and Agricultural Organization |
| **FSC** | food supply chain |
| **GCC** | Gulf Cooperation Council |
| **GDP** | gross domestic product |
| **GHG** | greenhouse gas |
| **GW** | gigawatt |
| **IWRM** | integrated water resource management |
| **KAPSARC** | King Abdullah Petroleum Studies and Research Center |
| **kWh/m$^3$** | kilowatt-hour per cubic metre |
| **Mbbl** | one thousand barrels of oil |
| **MED-TVC** | multi-effect thermal vapour consumption |
| **MENA** | Middle East and North Africa region |
| **MJ** | megajoule |
| **MSF** | multi-stage flash distillation |
| **NCPC** | national cleaner production centres |
| **PPP** | purchasing power parity |
| **PV** | photovoltaic |
| **RD** | research and development |
| **RO** | reverse osmosis |
| **RSP** | regional solar programme |
| **SCP** | sustainable consumption and production |
| **SCPDP** | self-consistent point dipole polarizability |
| **SDG** | Sustainable Development Goal |
| **SE4All** | Sustainable Energy for All |
| **SWRO** | salt water reverse osmosis |
| **10YFP** | 10-year framework of programmes |
| **TSS** | total suspended solids |
| **TWW** | treated wastewater |
| **TWWP** | treated wastewater production |
| **WEF** | water-energy-food |
| **WWT** | wastewater treatment |
| **WWTP** | wastewater treatment plant |

# Background and objectives of this module

For decades, enhancing the efficiency of water and energy use has been a target of policy, industry and research. Given the Arab region lags behind other regions in this regard, greater efforts to address this imbalance are imperative. While efficiency initiatives have focused on technological and managerial ways to reduce resource loss, there is no guarantee these will result in reduced use. The Sustainable Development Goals (SDGs) may offer the opportunity to re-examine water and energy efficiencies, with a fresh perspective on how these primary resources can be coherently used. Goals 6 and 7 are particularly applicable: the former seeks by 2030 to increase water-use efficiency across all sectors, plus sustainable withdrawals and freshwater supplies to reduce the number of people experiencing water scarcity; the latter targets enhanced international cooperation to enhance access to clean energy research and technology, including energy efficiency, and promote investment in infrastructure.[1]

This module reviews efficiency efforts and status in the region. Definitions of efficiencies are explored to demonstrate the need for a more holistic approach to measuring progress. The module also defines a pathway for resource efficiency through a long-term sustainability lens, highlighting social, economic, environmental and resource-use factors. Such a comprehensive framework for defining efficiency can more objectively describe resource use and better document progress towards national targets and sustainable use.

The module also presents a case study on food waste in ESCWA member countries Lebanon, Morocco and Qatar. Food waste is an ideal example of resource efficiency in the water-energy-food nexus since food production is a major water and energy consumer, and reducing food waste contributes to water and energy savings, and has a direct contribution to food security. All three segments of this resource continuum are critical SDG targets. Additionally, food waste is highlighted in Goal 12, and specifically, in target 3, which seeks to halve per capita global waste at retail and consumer levels and reduce food losses along production and supply chains, including post-harvest losses.

A case study on appropriate water desalination technologies is also presented. Currently, the bulk of water demand in the Gulf States is met through seawater desalination. Due to expected future drought conditions in the Arab region, this will become more widespread across other countries, and learning about energy-water trade-offs is important for their water security portfolios. Plans to build desalination facilities are in place in Algeria, Egypt and Morocco, among other countries in the region.

# Water and energy efficiency across sectors: production, use and beyond

## Efficiency, productivity and the nexus

There is broad consensus that improving efficiency in energy and water sectors will not only generate economic gains but increase access to services for larger parts of the population. The United Nations Sustainable Energy for All Initiative (SE4All) has set the objective of doubling the global rate of improved energy efficiency by 2030, with implied energy savings and productivity gains (increasing efficiency by 2.4 per cent per year instead of the 1.2 per cent of the previous 30 years). The International Energy Agency (IEA) emphasizes the importance of improving or choosing technologies that can improve energy efficiency and decrease by almost half the projected increase in global energy consumption by 2030, thereby avoiding unnecessary investments in infrastructure.[2]

Energy efficiency is defined as reducing input to achieve the same output, or maintaining the same input to achieve greater output, but it is affected by scale, processes, infrastructure, technology, management, intended services and right of access to energy. As a result, efficiency carries multiple definitions, making it hard to quantify progress towards targets.

Similarly, water efficiency is defined as reducing water input for the same output, or maintaining input for a greater output. As with energy, this definition has constraints, but water has a different value. For example, while agriculture may not be the most water-efficient user, food production has a high value to society, especially if local farmers are a subsistent community. Typically, these farmers have historical water rights that are protected by law, which complicates the framework for water efficiency.

These constraints define different sets of efficiencies that depend on scale, value and process. The term efficiency is also limited to measuring economic and resource losses, and does not include other social, environmental and sustainability factors. It is limited to the resource in question and does not reflect the natural links between water and energy. A more inclusive and integrated view of efficiency is needed and is explored in the sections below.

Productivity in the water-energy nexus should capture the total value of resources, products and services. It should integrate its policymaking with industry, urban and agriculture policy and planning. If the energy, water and food sectors implement efficiency programmes in silos, isolated from other sectors, then gains will be limited. Business stakeholders, for example, will want to see more in an energy audit than one that looks only at energy savings and neglects larger productivity issues.

This applies to the manufacturing (supply chain) and the utility sectors. In the energy and water production sectors, productivity analysis can examine decentralized generation, including renewables, versus centralized generation, and the overall productivity of the supply chain. An example of a nexus productivity approach is in the food sector, where attention is on the whole supply chain, from farm to fork, the greatest potential optimization benefits are identified and efforts focused there.[3]

It is important to clarify that efficiency is one dimension of productivity, which addresses the total value to the user and broader economy by better applying resources; it is not just the efficiency of a plant or equipment.[4] The main reasons to look at this broader, more integrated approach include:

a. Conserve resources;
b. Reduce production and operating costs;
c. Sustain fuel supply;
d. Improve product quality;
e. Protect the environment;
f. Improve safety and productivity.

## Economic efficiency or resource productivity

Energy productivity is defined as the amount of economic output possible at a given level of energy input.[5] It was first attributed in 1865 to English economist William Stanley, whose work led to more economic use of coal and increased use of the steam engine.

The concept of primary resource productivity and sustainability has since been expanded. Mosovsky and others (2010) looked into supply chain inefficiencies and introduced suitability into the discussion. Although the framework for competitiveness and market dominance includes environmental impacts, it remains centred on industries and business. Limited to economic and resource sustainability, it ignores national and social factors, such as accessibility, and links between water, energy, land and human resources. Consequently, despite its advantages for better use of resources, the productivity concept lacks a clear breakdown of responsibilities for providing products, services and safe access to these primary resources, all important aspects of the SDGs. The challenge remains to balance resources efficacy and productivity, environmental impact, equity and access.

Ain Beni Mathar Integrated Thermo Solar Combined Cycle Power Plant, Morocco © Philippe Roos - https://www.flickr.com

**Scale of efficiency.** The scale of resources efficiency is vital; measured locally in many instances, at a plant, in a household or in the field, mapping of national and regional resource availability and allocation must be undertaken. Whatever is done to save water and energy on the ground has to be translated into national savings. An aggregation framework needs to translate the local into the bigger picture. Work conducted at Saudi Arabia's King Abdullah Petroleum Studies and Research Center (KAPSARC)[6] is leading regional efforts and can be leveraged.

At the national scale, the role and impact of energy efficiency and productivity on the economy must be ascertained. This is an important driver, especially given that past economic growth correlated directly with higher resource use. Reducing energy use and allowing for higher value of energy should stimulate economic growth.

A study by KAPSARC showed sectoral energy productivity increases from 1995-2009 were primarily responsible for economy-wide improvements in Saudi Arabia. Countries with similar demographic and economic characteristics were also shown to have similar energy productivity levels and rates of improvement. Econometric analysis reinforced long-standing hypotheses that higher energy prices and income per capita are associated with aggregate energy productivity improvements, and that these occur primarily through sectoral energy productivity effects rather than shifts in the economy.[7]

In the United States, a study by the Alliance Commission on National Energy Efficiency Policy to double energy productivity by 2030 recommended three action areas:

a. Investment in productivity throughout the economy in cost-effective energy saving;
b. Modernizing policies and infrastructure to improve productivity;
c. Developing human capital through educating the public, business leaders and policymakers on energy productivity.

**Primary resource efficiency framework.** Based on the evolution of the resources efficiency concept, and the gaps discussed above, this section presents a vision for water and energy efficiency for Arab region countries. The elements of the proposed framework include:

**1. Reducing losses**

Continue efforts to reduce losses in water and energy resources while providing critical services and products to stakeholders. Efficiencies in production and delivery lag far behind global standards, necessitating the following investments:

a. Adaptable technologies;
b. Production, storage and delivery infrastructure;
c. Development of local know-how/human capacity;
d. Increased public awareness on the value of conservation;
e. Public policy on pricing and incentives to conserve resources.

**2. Define services and access targets**

Define services and products, delineating roles and responsibilities of public and private sectors, to ensure equitable access to these primary resources. This must be looked at as a human rights issue.

### 3. Transfer from local to national efficiency

Create a multi-scale framework to transfer local efficiency in water and energy into national resources efficiency. While the earlier is measurable at production and delivery scales, resources suitability and implementation of the SDGs must be assessed at regional and national scale.

### 4. Define efficiency

Define the resources efficiency with the following dimensions:

Economic efficiency

a. Water footprint for services or products provided;
b. Energy footprint for services or products provided;
c. Land footprint for services or products provided;
d. Economic resources used for services or products provided.

Social efficiency

a. Access infrastructure related to services;
b. Prices, equity and affordability of services.

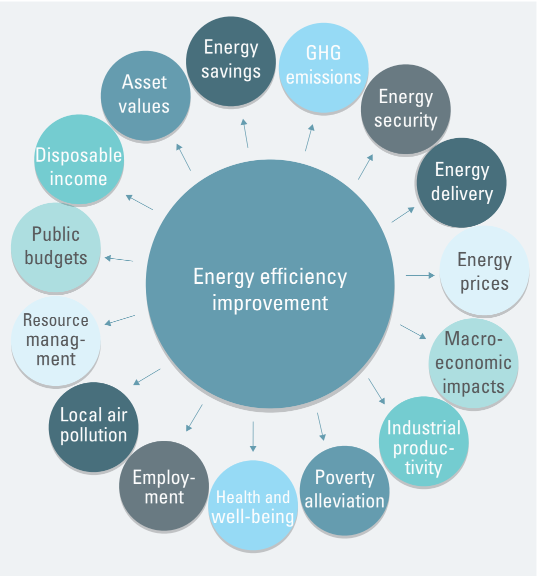
Environmental efficiency

a. Long-term sustainability of resources;
b. Air, soil and water pollution from production and use of the resource.

It is crucial these metrics are precisely defined and monitored so progress in resource efficiencies can be easily and accurately assessed.

Prioritizing integrated energy efficiency generates benefits at a larger scale than optimizing the use or production of water and energy alone. The International Energy Agency has analysed the impact of a broader approach to energy efficiency beyond greenhouse gas (GHG) emissions and energy savings. The aspects illustrated in figure 1 are not exhaustive but give a comprehensive idea of how decision makers should look at efficiency. The degree to which it can impact on all aspects of national decision-making is not well understood[8] and this is where a nexus approach to supply and demand is critical.

**Figure 1.** Benefits of integrated energy efficiency improvement



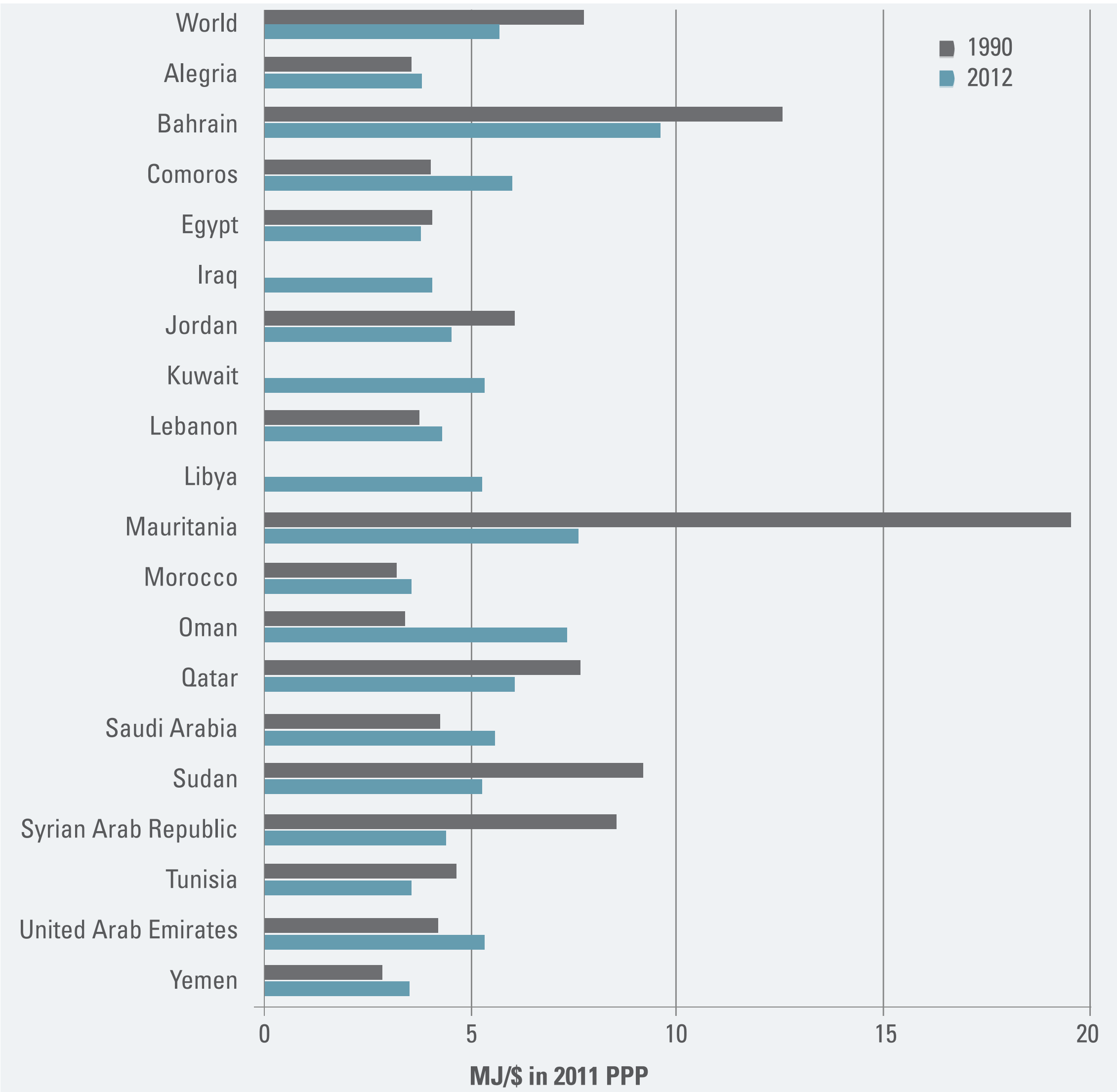

**Source:** IEA, 2014.

## Energy intensity

One way to measure the energy productivity of a country is via the primary energy intensity. It is defined as the ratio between primary energy consumption and the country's gross domestic product (GDP); in other words, it measures how much energy is needed to produce one unit of GDP. This ratio is usually adjusted to account for the differences in cost of living in countries, also called purchasing power parity (PPP).[9]

Figure 2 shows that the energy intensity for several countries in the Arab region (Bahrain, Comoros, Mauritania, Oman, Qatar and Saudi Arabia) was higher than the global average in 2012. Some countries (Bahrain, Egypt, Jordan, Mauritania, Qatar, the Sudan, the Syrian Arab Republic and Tunisia) improved their energy intensity between 1990 and 2012, though it is not clear whether this was due to adjustments in energy efficiency in the production sector or a more integrated approach.[10] Further research in the region to determine causes would benefit future policy and strategic planning.

**Figure 2.** Energy intensity




**Source:** International Energy Agency and the World Bank, 2015.

## Efficiency in the water industry: desalination as an energy-water nexus case study

Qatar has one of the highest income per capita in the world and is one of the biggest consumers of water (each person uses about 600 litres per day) and electric power (16,500 megawatt-hours per day).[11] Qatar has two predominant problems: a severe water scarcity, with desalinated seawater constituting 99 per cent of municipal water demands, and humid, hot summers when demand for electrical air cooling in buildings is high. Significant amounts of natural gas and oil are being consumed to secure water and energy needs in a country where these resources are finite. Groundwater is extremely limited, over-exploited, deteriorated and non-replenished.

Growth in water and energy demand exceeded 15 per cent between 2004 and 2010, and failed to slow through to 2014. Between 2000 and 2010, excessive energy consumption drained fuelled resources (wealth) at a higher rate than production. During the same period, oil production increased by 20 per cent, consumption by 120 per cent.[12]

Saudi Arabia consumed oil at a rate of 1.578 Mbbl (one thousand barrels of oil) per day in 2000, and 2.86 Mbbl/day in 2011. The consumed oil per year, per capita in 2011 was 37.2 bbl, compared with 5 in Brazil and 10.5 in Germany. At current production and consumption rates, Saudi Arabia may cease to export oil by 2040. The GCC region is in water deficit, with withdrawal exceeding renewable water.[13] More than 52 per cent of global desalination capacity is in the MENA region, most of which is in the GCC countries, and this trend is expected to continue.

High electric power consumption in the Gulf region is due to low cost. In Abu Dhabi, for example, the electric power price per kilowatt-hour in 2006 was 1.4 cents for nationals and 4 cents for expatriates; nationals each consumed 71,000 kWh per year, compared with 26,500 for expatriates.[14]

The Ras Abu Fontas power and desalination plant near Wakrah, just south of Doha, Qatar. The photo was taken in 2007 as work on expansion of the facility was nearing completion © Paul Cowan - Shutterstock_126399980.

**Water and energy relation in desalinated water production**

The thermal energy requirements for multi-stage flash distillation (MSF) desalinating technologies is on average 16 kWh per cubic metre (equivalent to 300 megajoules (MJ) per $m^3$), and 4 kWh/$m^3$ for pumping energy (electrical), an energy footprint of 20 kWh per cubic metre of desalinated water produced. Considering the cost of US$0.12 per kWh, this translates to a total cost of US$2.4/$m^3$ for energy only, adding up to US$3/$m^3$ in production costs.[15]

For membrane technologies, specifically salt water reverse osmosis (SWRO) technology, a total 5 kWh/$m^3$ for pumping energy is required, which translates to US$0.6/$m^3$ for energy only, totalling up to US$1/$m^3$ in production costs.[16]

Table 1 represents the electrical power consumed and produced from several water production technologies. Desalinated water consumes about 18 per cent of the total equivalent electrical power and about 28 per cent of net electrical power. Treated wastewater production represents 0.55 per cent of the net electrical power, groundwater abstraction only 0.27 per cent.

**Table 1.** Electrical power (EP) consumed and produced in thermal desalination in Qatar

| | Water capacity | EP: consumed (C) and produced (P), GWh |
|---|---|---|
| Thermal desalination | 1.275 $Mm^3$/d, (465 $Mm^3$/y) | 9,300 (C) |
| TWWP | 0. 635 $Mm^3$/d, (231.7 $Mm^3$/y) | 184 (C) |
| Groundwater | (250 $Mm^3$/y) | 90 (C) |
| Total EP produced | | 33,520 (P) |
| Total equiv. EP, net EP and DW equiv. | | 42,820 (P) |

**Source:** Darwish and Mohtar, 2012.
**Note:** GWh = gigawatt hours; TWWP = treated wastewater production; DW = desalinated water.

Membrane technologies can save 75 per cent of energy and cut water production costs by two thirds compared with thermal technologies. Failure to move to membrane technology stem from a lack of human capacity, robustness and integration of water production with electricity generation, plus the high salinity and total suspended solids (TSS) in the Gulf seawaters that require pretreatment. The total energy footprint for membrane technologies is five times less than thermal technologies, with emissions proportionally less (table 2).

**Table 2.** Summary of energy requirements and $CO_2$ emissions of desalination technologies

| Technology | Mechanical equivalent to thermal energy input, kWh/$m^3$ | Pumping energy input, kWh/$m^3$ | Consumed fuel in MJ/$m^3$ | Consumed fuel in CPDP, kg/$m^3$ | $CO_2$ in kg/$m^3$ D | Cost in US$/$m^3$ |
|---|---|---|---|---|---|---|
| MSF (Boiler operated) | 27 | 4 | 344 | 7.5 | 27.48 | 3 |
| MSF in CPDP | 16 | 4 | 200 | 4.36 | 15.98 | - |
| TVC-MED | 18 | 2 | 200 | 4.36 | 15.98 | - |
| SWRO | NA | 5 | 50 | 1.09 | 3.99 | 1 |

**Source:** Darwish and Mohtar, 2012.
**Note:** MED-TVC= multi-effect thermal vapour consumption.

Desalinating water by MSF and multi-effect thermal vapour compression (MED-TVC) has similar energy requirements. Both are energy inefficient and costly and should be replaced by SWRO (4-6 kWh/$m^3$). Such a shift could save up to 75 per cent of fuel energy used and consequently reduce costs. The pretreatment needs for reverse osmosis (RO) systems are not energy intensive, so additional operational costs are not significant, though will add capital costs and predesigned, site-specific technology. As a non-conventional water resource for the region, treated wastewater (TWW) should be considered. Energy use for secondary treatment of TWW ranges from 1000 to 2000 kWh/million gallons, depending on the type of treatment technology used. Additional energy is consumed for non-agricultural uses, including treating colour, organic chemicals, metals, phosphorus and nitrogen. Another way to reduce the cost of thermal technologies is by using relatively cheap natural gas fuel rather than oil.

Of utmost importance is the final use for desalinated water. High quality and high-cost, it should be limited to cooking and drinking. Treated wastewater should be used for applications that do not call for high quality, such as toilet flushing and gardening.

It is imperative to reduce per capita water use: 600 litres for daily municipal water is far beyond basic needs. The average in the United States is 246 litres, in Sweden 215 and in the Netherlands 104. Oman, with 146 litres per person per day, has the lowest consumption in the GCC region.

## Sustainable consumption and production

SDG 12 establishes targets to ensure sustainable consumption and production (SCP) patterns. Target 1 seeks a 10-year framework programme, with all countries taking specific actions towards the goal. This has to be supported by sustainable management and efficient use of natural resources (target 2), alongside waste-reduction policies through prevention, recycling and reuse (target 5).

Sustainable consumption and development is geared towards reducing environmental footprints and costs, strengthening markets, becoming more competitive, and alleviating and reducing poverty. The main objective is to dissociate economic growth and environmental degradation by improving resources efficiency in producing, distributing and using products, while keeping energy, material and pollution intensity activities within the carrying capacities of natural ecosystems.[17] This assumes a nexus approach, to guarantee the sustainability of resources and bolster efforts to address social and economic challenges.[18]

The Arab region first approached SCP in 2009 through regional policies. An Arab strategy was drafted prior to the RIO+20 summit in 2012, which resulted in the 10-year framework of programmes on sustainable consumption and production (10YFP). The region, in 2013, was the first to develop a roadmap, but neither the roadmap nor the SCP regional strategy has been implemented. A few programmes have integrated elements of SCP policies in national development plans, such as the Sustainable Development Strategy in Tunisia, and Bahrain's Vision 2030, and a number of countries have adopted integrated policies in the energy, water and food sectors, and in waste management and poverty eradication. For example, National Cleaner Production Centres (NCPCs) in Egypt, Jordan, Lebanon, Morocco and the United Arab Emirates were created to provide technical assistance to industries, evaluate resource-efficient practices, provide capacity building and advise on policy, data and technology transfer.[19]

High voltage electrical lines passing by a massive skyline in Dubai © JOAT - Shutterstock_329088791.

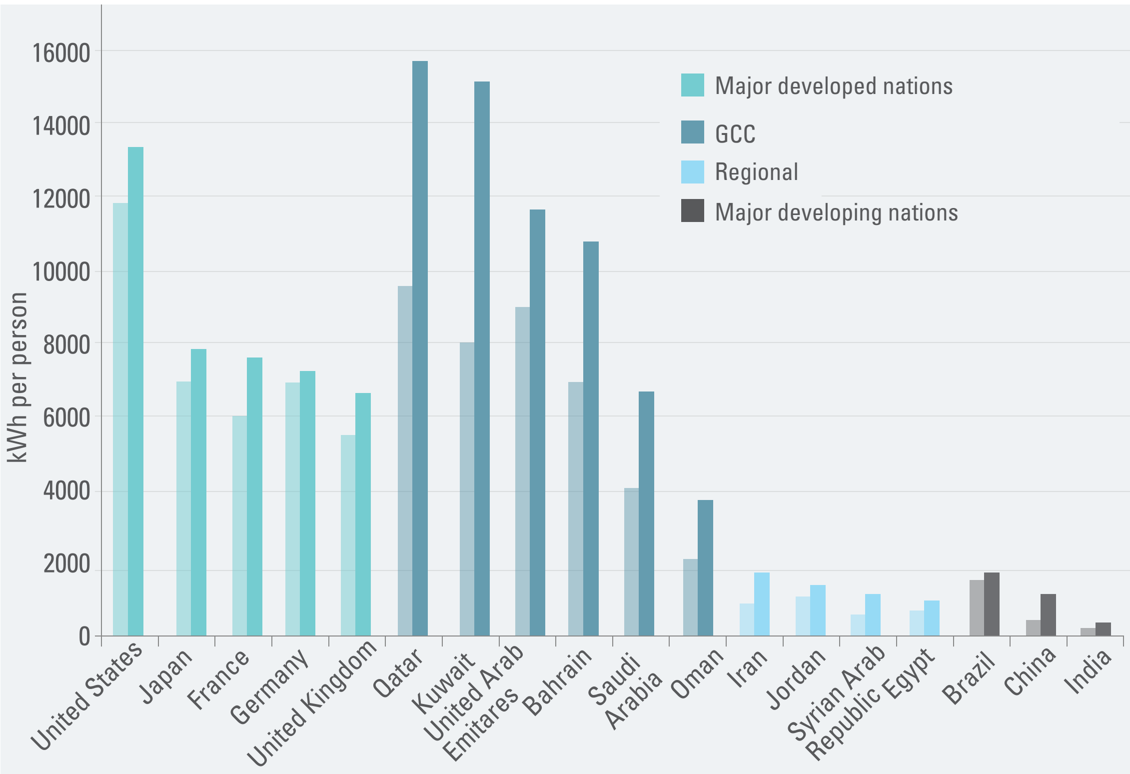
## Energy consumption patterns in the Arab region

Energy consumption per capita in the Arab region ranges from the highest in the world (Qatar) to among the lowest (Somalia and the Sudan), as shown in figure 3 Subsidies are partly to blame for high consumption and inefficiency patterns in most Arab countries, while the availability of fossil fuels at low production costs has encouraged some oil-producing countries to use energy-intesive technologies for water desalination and petrochemicals, among others.

Energy requirements for water production are high in water-scarce countries, and the difference from the energy footprint of non-conventional technologies, such as desalination and wastewater treatment (WWT), is significant. Deciding how to make processes more efficient is not enough; from an energy standpoint, WWT and reuse can be more energy efficient and productive than desalination.

Likewise, the link between energy and food must be observed. If energy subsidies are lifted, the increase in fuel costs will directly impact on food prices, and the social and economic dimensions should be examined in detail. Affordable access to water and food must be looked at holistically before energy subsidies are lifted in the ESCWA countries.

**Figure 3.** Per capita annual electricity consumption of selected countries for 1990 (lighter, left-hand bars) and 2003 (darker, right-hand bars)




**Source:** Darwhish and Mohtar, 2013

## Water consumption patterns in the Arab region

It is well documented that increasing efficiency in the water and energy sectors may reduce losses, but may not reduce total usage. Indeed, SDG 12 encourages developing countries to strengthen their scientific and technological capacity towards more sustainable patterns of consumption and production.

In the water sector, consumption patterns in the Arab region vary considerably. Domestic water demand in the region averages 200 litres per person, per day; in the GCC countries it is more than 500 litres and has been increasing over the past decade. The reasons are due mainly to government subsidies and changing lifestyles.[20]

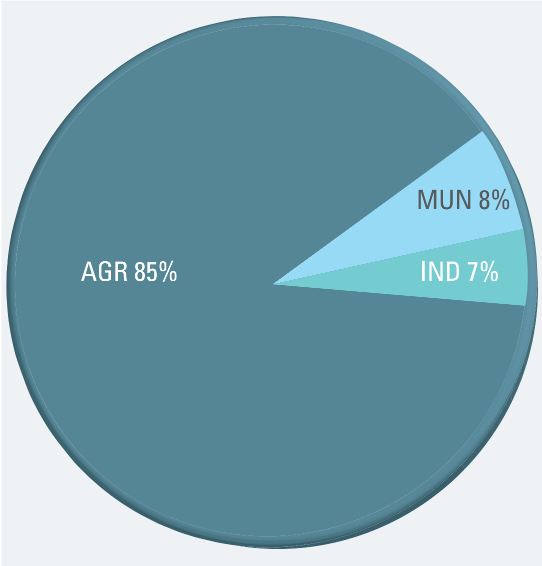
In general, governments in the region have given more weight to increasing production to meet demand than to efficiency, conservation and changes in consumption behaviours.[21] Low water tariffs provide no incentive for consumers to save water. More pertinently, water consumption per capita is directly proportional to income. Unless advice on how to manage water use efficiency and demand are clearly written into policies and regulations, the increasing consumption trend will continue.

However, while domestic consumption patterns are important, the major water consumer in the region is the agricultural sector (figure 4). Average irrigation efficiency in the Arab countries is below 46 per cent; pushing this to 70 per cent would save 50 billion cubic metres of water per year.[22]

Growing crops that demand less water or have higher value are ways to increase water productivity, though such switches imply a shift in consumption habits to less water-intensive crops with similar nutritional value. Due to the uncertainty surrounding growing and eating habits, the social and economic dimensions of such measures should be studied closely before any change of practice.

Surface irrigation is the most widely used technique in the Arab region, covering approximately 80.3 per cent of the region's irrigated area in 2006. More efficient systems, such as micro-irrigation, are practised on only 2.8 per cent of the area, representing a huge water loss at farm level, either through deep percolation or surface run-off. Even when run-off water is recovered or returned to water systems, these losses represent missed opportunities, with their arrival downstream delayed and quality compromised.[23]

**Figure 4.** Water uses in the Arab region




**Source:** AFED, 2015.
**Note:** AGR = agricultural; IND=industrial; MUN = municipal.

Food waste © g215 - Shutterstock_55181569.

## Case study on food waste, and the implications for water and energy

Food waste is a concern for food, water and energy security worldwide. According to the Food and Agricultural Organization (FAO), if the amount of wasted food was reduced by 25 per cent, there would be enough to feed all malnourished people.[24] Globally, 30-50 per cent of farm-produced food has never been used.[25,26] Retail, food services, home and municipal categories are lumped together for developing countries.[27] In addition, 3.3 billion metric tons of embodied $CO_2$ is generated from food wastage.[28] It is a concern recognized by the SDGs, target 3 of Goal 12 seeking to halve per capita global waste and reduce food losses by 2030.

**Table 3.** Waste percentages for commodity groups in each step of the food supply chain for Arab countries

| | Agricultural production % | Post-harvest handling and storage % | Processing and packaging % | Distribution % | Consumption % | Total waste and loss % |
|---|---|---|---|---|---|---|
| Cereals | 6 | 8 | 5 | 4 | 12 | 31 |
| Roots and tubers | 6 | 10 | 12 | 4 | 6 | 33 |
| Oilseeds and pulses | 15 | 6 | 8 | 2 | 2 | 29 |
| Fruits and vegetables | 17 | 10 | 20 | 15 | 12 | 55 |
| Meat | 6.60 | 0.20 | 5 | 5 | 8 | 23 |
| Fish and seafood | 6.60 | 5 | 9 | 10 | 4 | 30 |
| Milk | 3.50 | 6 | 2 | 8 | 2 | 20 |

**Source:** FAO, 2011.

This case study highlights food waste in three ecozones of ESCWA and the implications for water and energy waste. Table 3 illustrates the estimated percentage of waste that occurs throughout the food supply chain (FSC) in Middle East and North African countries.

Production, import and export data for Qatar, Lebanon and Morocco is from 2013, using FAO data sets.[29,30] Consumption totals coupled with percentage of food loss were used to calculate the food waste at each step of the FSC in tons (table 4, table 5 and table 6). The totals are summarized in table 7.

**Table 4.** Qatar food waste and loss by step in the food supply chain

| | Agricultural production | Post-harvest handling and storage | Processing and packaging | Distribution | Consumption | Total |
|---|---|---|---|---|---|---|
| Cereals | 175 | 219 | 126 | 5,886 | 16,951 | 23,356 |
| Roots and tubers | 7 | 11 | 12 | 2,156 | 3,105 | 5,291 |
| Oilseeds and pulses | 0 | 0 | 0 | 452 | 443 | 894 |
| Fruits and vegetables | 8,494 | 4,147 | 7,465 | 61,183 | 41,605 | 122,894 |
| Meat | 1,532 | 43 | 1,082 | 7,300 | 11,097 | 21,054 |
| Fish and seafood | 796 | 563 | 963 | 3,761 | 1,354 | 7,438 |
| Milk | 870 | 1,439 | 451 | 9,710 | 2,233 | 14,703 |

**Table 5.** Lebanon food waste and loss by step in the food supply chain

| | Agricultural production | Post-harvest handling and storage | Processing and packaging | Distribution | Consumption | Total |
|---|---|---|---|---|---|---|
| Cereals | 10,725 | 13,442 | 7,729 | 45,646 | 131,461 | 209,002 |
| Roots and tubers | 24,769 | 38,805 | 41,909 | 7,578 | 10,912 | 123,974 |
| Oilseeds and pulses | 5,347 | 1,818 | 2,279 | 2,069 | 2,027 | 13,540 |
| Fruits and vegetables | 308,809 | 150,771 | 271,389 | 135,246 | 91,967 | 958,183 |
| Meat | 9,532 | 270 | 6,731 | 8,375 | 12,730 | 37,638 |
| Fish and seafood | 289 | 205 | 350 | 3,525 | 1,269 | 5,638 |
| Milk | 13,617 | 22,526 | 7,058 | 29,924 | 6,883 | 80,008 |

**Table 6.** Morocco food waste and loss by step in the food supply chain

| | Agricultural production | Post-harvest handling and storage | Processing and packaging | Distribution | Consumption | Total |
|---|---|---|---|---|---|---|
| Cereals | 592,452 | 742,540 | 426,961 | 504,599 | 1,453,244 | 3,719,796 |
| Roots and tubers | 117,311 | 183,787 | 198,490 | 58,803 | 84,677 | 643,070 |
| Oilseeds and pulses | 231,103 | 78,575 | 98,481 | 25,079 | 24,577 | 457,815 |
| Fruits and vegetables | 1,574,706 | 768,827 | 1,383,889 | 612,595 | 416,564 | 4,756,581 |
| Meat | 74,170 | 2,099 | 52,376 | 50,324 | 76,492 | 255,461 |
| Fish and seafood | 83,189 | 58,862 | 100,654 | 52,881 | 19,037 | 314,623 |
| Milk | 84,294 | 139,446 | 43,693 | 173,907 | 39,999 | 481,340 |

**Table 7.** a- Tons of food waste per country

| | Qatar (tons) | Lebanon (tons) | Morocco (tons) |
|---|---|---|---|
| Cereals | 23,356 | 209,002 | 3,719,796 |
| Roots and tubers | 5,291 | 123,974 | 643,070 |
| Oilseeds and pulses | 894 | 13,540 | 457,815 |
| Fruits and vegetables | 122,894 | 958,183 | 4,756,581 |
| Meat | 21,054 | 37,638 | 255,461 |
| Fish and seafood | 7,438 | 5,638 | 314,623 |
| Milk | 14,703 | 80,008 | 481,340 |

**Sources:** FAO, 2016a; FAO, 2016b.

b- Cubic meters of water wasted from food loss and waste

| | Qatar ($m^3$) | Lebanon ($m^3$) | Morocco ($m^3$) |
|---|---|---|---|
| **Cereals** | 39,809 | 2,445,232 | 135,079,097 |
| **Roots and tubers** | 110 | 396,307 | 1,876,979 |
| **Oilseeds and pulses** | 0 | 962,469 | 41,598,522 |
| **Fruits and vegetables** | 791,102 | 91,552,046 | 155,072,290 |
| **Meat** | 602,241 | 3,840,300 | 28,908,357 |
| **Fish and seafood** | 0 | 0 | 0 |
| **Milk** | 74,799 | 1,171,044 | 7,249,284 |
| **Total** | **1,508,061** | **100,367,397** | **369,784,529** |

**Source:** Mekonnen and Hoekstra, 2010.

**Table 8.** Average water footprint per product

| Product | Blue water footprint per product ($m^3$/ton) |
|---|---|
| **Cereals** | 228 |
| **Roots and tubers** | 16 |
| **Oilseeds and pulses** | 180 |
| **Fruits and vegetables** | 147 (fruits), 43 (vegetables) |
| **Meat** | 313 (chicken), 459 (pig), 457 (sheep), 550 (cattle) |
| **Fish and seafood** | 0 |
| **Milk** | 86 |

**Source:** Mekonnen and Hoekstra, 2010.

**Figure 5.** Qatar percentage of food waste by commodity

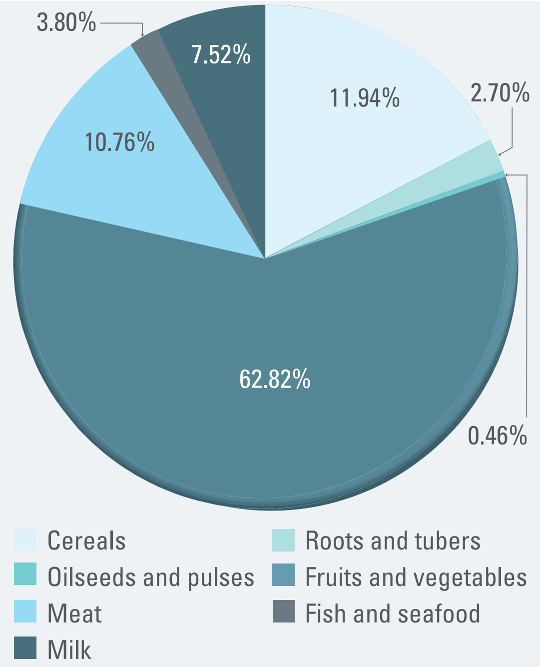



Table 8 shows the blue water (freshwater) footprint of each product due to food loss and waste by multiplying the average water footprint per product by the quantity produced within the country.

**Figure 6.** Lebanon percentage of food waste by commodity

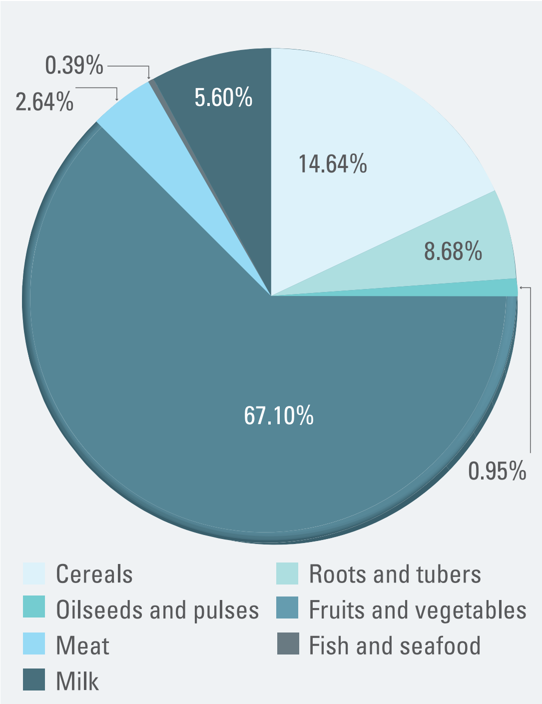



**Figure 7.** Morocco percentage of food waste by commodity

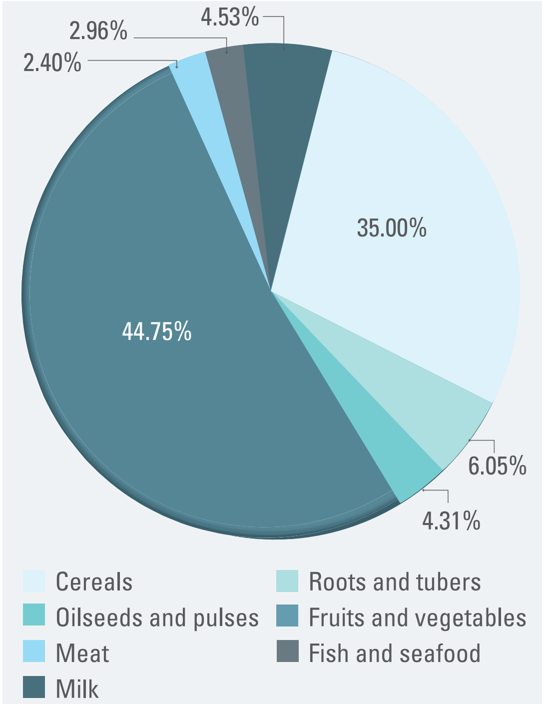



Figure 5, figure 6 and figure 7 show the breakdown of food waste by commodity in the three subject countries.

**A scenario of food waste reduction by 20 per cent**

If food loss and waste were reduced in Qatar, Lebanon and Morocco, there would be savings in water. Table 9 shows the potential savings if food waste was reduced by 20 per cent.

Panorama valley of Wadi Al Mujib river and dam, Jordan © vvoe - Shutterstock_98271155.

**Table 9.** Water footprint of food waste (total and 20 per cent)

| Qatar | Total produced food wasted (tons) | 20% of total | Wasted water from food waste ($m^3$) | Water saving with 20% reduction in food waste | Country total ($m^3$) |
|---|---|---|---|---|---|
| Cereals | 175 | 35 | 39,809 | 7,962 | 301,612 |
| Roots and tubers | 7 | 1 | 110 | 22 | |
| Oilseeds and pulses | 0 | 0 | 0 | 0 | |
| Fruits and vegetables | 8,484 | 1,699 | 791,102 | 158,220 | |
| Meat | 1,531 | 306 | 602,241 | 120,448 | |
| Fish and seafood | 796 | 159 | 0 | 0 | |
| Milk | 870 | 174 | 74,799 | 14,960 | |
| **Lebanon** | **Total food waste (tons)** | **20% of total** | **Wasted water from food waste ($m^3$)** | **Water saving with 20% reduction in food waste** | **Country total ($m^3$)** |
| Cereals | 10,725 | 2,145 | 2,445,232 | 489,046 | 20,073,479 |
| Roots and tubers | 24,769 | 4,954 | 396,307 | 79,261 | |
| Oilseeds and pulses | 5,347 | 1,069 | 962,469 | 192,494 | |
| Fruits and vegetables | 308,809 | 61,762 | 91,552,046 | 18,310,409 | |
| Meat | 9,532 | 1,906 | 3,840,300 | 768,060 | |
| Fish and seafood | 289 | 58 | 0 | 0 | |
| Milk | 13,617 | 2,723 | 1,171,044 | 234,209 | |
| **Morocco** | **Total food waste (tons)** | **20% of total** | **Wasted water for food waste ($m^3$)** | **Water saving with 20% reduction in food waste** | **Country total ($m^3$)** |
| Cereals | 592,452 | 118,490 | 135,079,097 | 27,015,819 | 73,956,906 |
| Roots and tubers | 117,311 | 23,462 | 1,876,979 | 375,396 | |
| Oilseeds and pulses | 231,103 | 46,221 | 41,598,522 | 8,319,704 | |
| Fruits and vegetables | 1,574,106 | 314,941 | 155,072,290 | 31,014,458 | |
| Meat | 74,170 | 14,834 | 28,908,357 | 5,781,671 | |
| Fish and seafood | 83,189 | 16,638 | 0 | 0 | |
| Milk | 84,294 | 16,859 | 7,249,284 | 1,449,857 | |

Reducing food waste by 20 per cent would also result in significant energy savings, as shown in table 10. In countries where food production is considerable, it would save almost 3 per cent of the total water used nationally for agriculture (in the case of Lebanon, for example) or nearly 2 per cent of the total national electricity generated (in the case of Morocco).

**Table 10.** Energy footprint of food waste (total and 20 per cent reduction)

| Qatar | Total food waste (tons) | 20% of total | Conversion factor (MJ/ton) | Wasted energy for food waste (MF) | Energy saving with 20% reduction in food waste | Country total (MJ) |
|---|---|---|---|---|---|---|
| Cereals | 175 | 35 | 11,700 | 2,042,820 | 408,564 | |
| Roots and tubers | 7 | 1 | 1,000 | 6,900 | 1,380 | |
| Oilseeds and pulses | 0 | 0 | 19,800 | 0 | 0 | |
| Fruits and vegetables | 8,494 | 1,699 | 3,000 | 25,482,150 | 5,096,430 | **27,339,046** |
| Meat | 1,531 | 306 | 50,000 | 76,583,100 | 15,316,620 | |
| Fish and seafood | 796 | 159 | 30,000 | 23,882,760 | 4,776,552 | |
| Milk | 870 | 174 | 10,000 | 8,697,500 | 1,739,500 | |
| **Lebanon** | **Total food waste (tons)** | **20% of total** | **Conversion factor (MJ/ton)** | **Wasted energy for food waste (MF)** | **Energy saving with 20% reduction in food waste** | **Country total (MJ)** |
| Cereals | 10,725 | 2,145 | 11,700 | 125,478,990 | 25,095,798 | |
| Roots and tubers | 24,769 | 4,954 | 1,000 | 24,769,200 | 4,953,840 | |
| Oilseeds and pulses | 5,347 | 1,069 | 19,800 | 105,871,590 | 21,174,318 | |
| Fruits and vegetables | 308,809 | 61,762 | 3,000 | 926,427,240 | 185,285,448 | **360,799,274** |
| Meat | 9,532 | 1,906 | 50,000 | 476,609,100 | 95,321,820 | |
| Fish and seafood | 289 | 58 | 30,000 | 8,672,400 | 1,734,480 | |
| Milk | 13,617 | 2,723 | 10,000 | 136,167,850 | 27,233,570 | |
| **Morocco** | **Total food waste (tons)** | **20% of total** | **Conversion factor (MJ/ton)** | **Wasted energy for food waste (MF)** | **Energy saving with 20% reduction in food waste** | **Country total (MJ)** |
| Cereals | 592,452 | 118,490 | 11,700 | 6,931,690,506 | 1,386,338,101 | |
| Roots and tubers | 117,311 | 23,462 | 1,000 | 117,311,160 | 23,462,232 | |
| Oilseeds and pulses | 231,103 | 46,221 | 19,800 | 4,575,837,420 | 915,167,484 | |
| Fruits and vegetables | 1,574,106 | 314,941 | 3,000 | 4,724,118,780 | 944,823,756 | **4,679,212,045** |
| Meat | 74,170 | 14,834 | 50,000 | 3,708,507,000 | 741,701,400 | |
| Fish and seafood | 83,189 | 16,638 | 30,000 | 2,495,655,360 | 499,131,072 | |
| Milk | 84,294 | 16,859 | 10,000 | 842,940,000 | 168,588,000 | |

**Figure 8.** Qatar water (left) and energy (right) savings in m³/year and MJ/year, respectively, with 20 per cent reduction in food waste

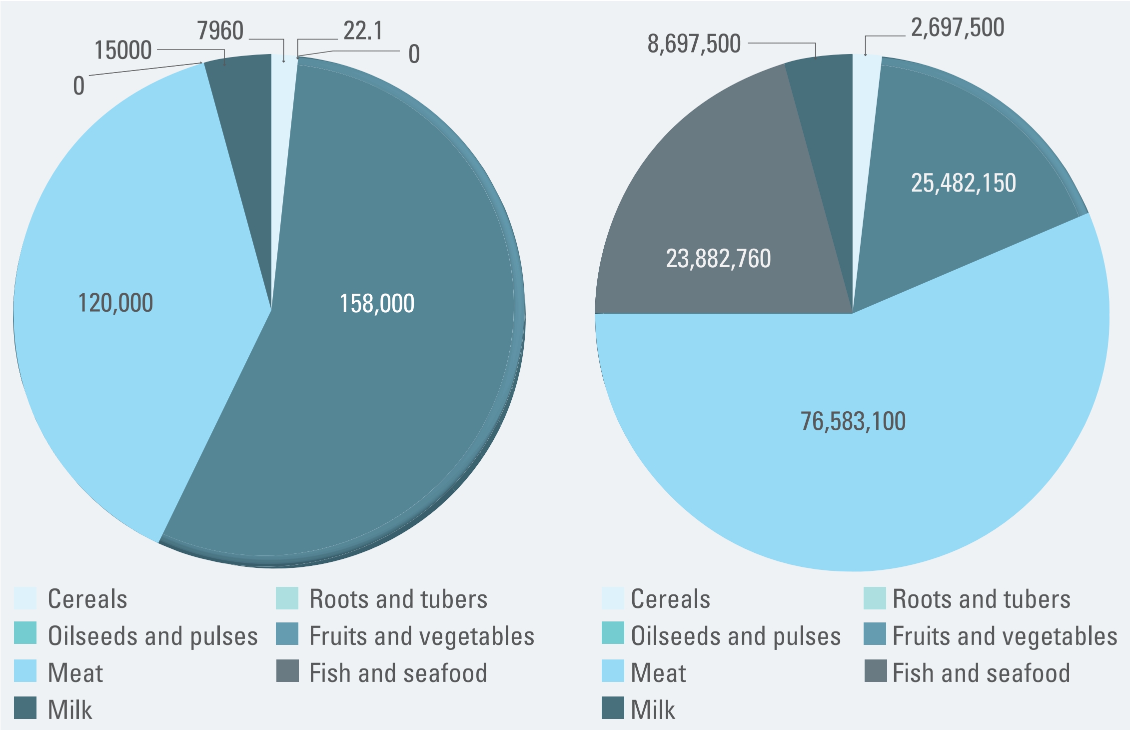



**Figure 9.** Lebanon water (left) and energy (right) savings in m³/year and MJ/year, respectively, with 20 per cent reduction in food waste

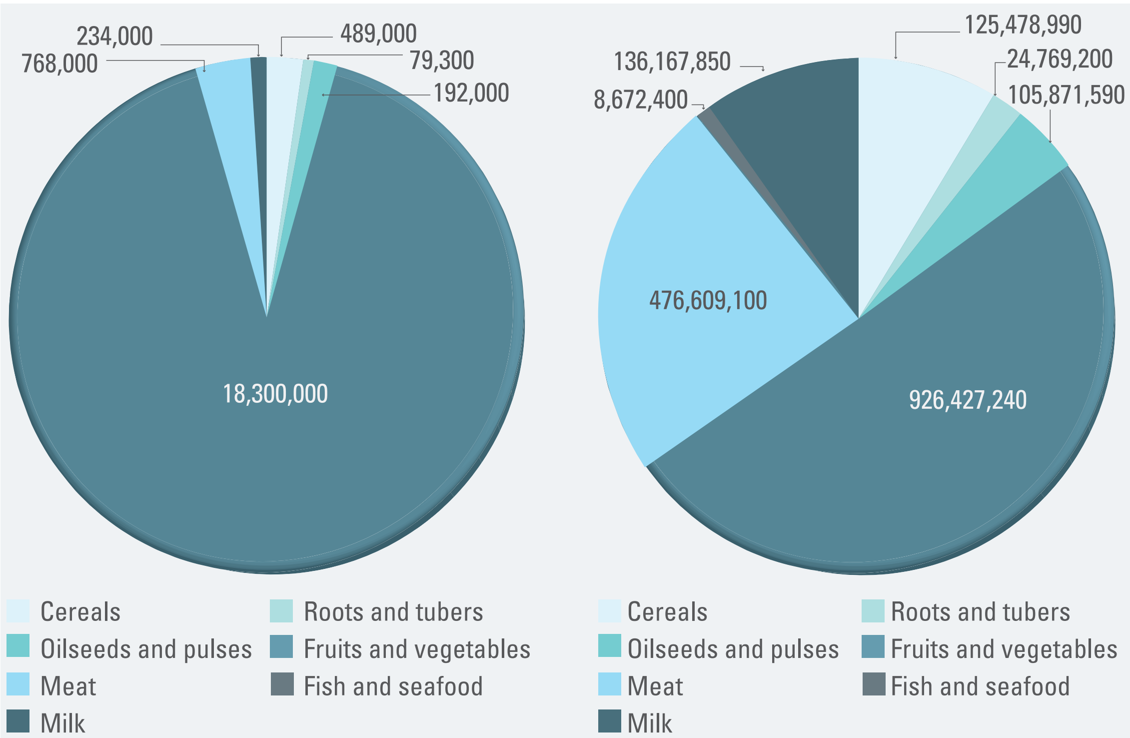
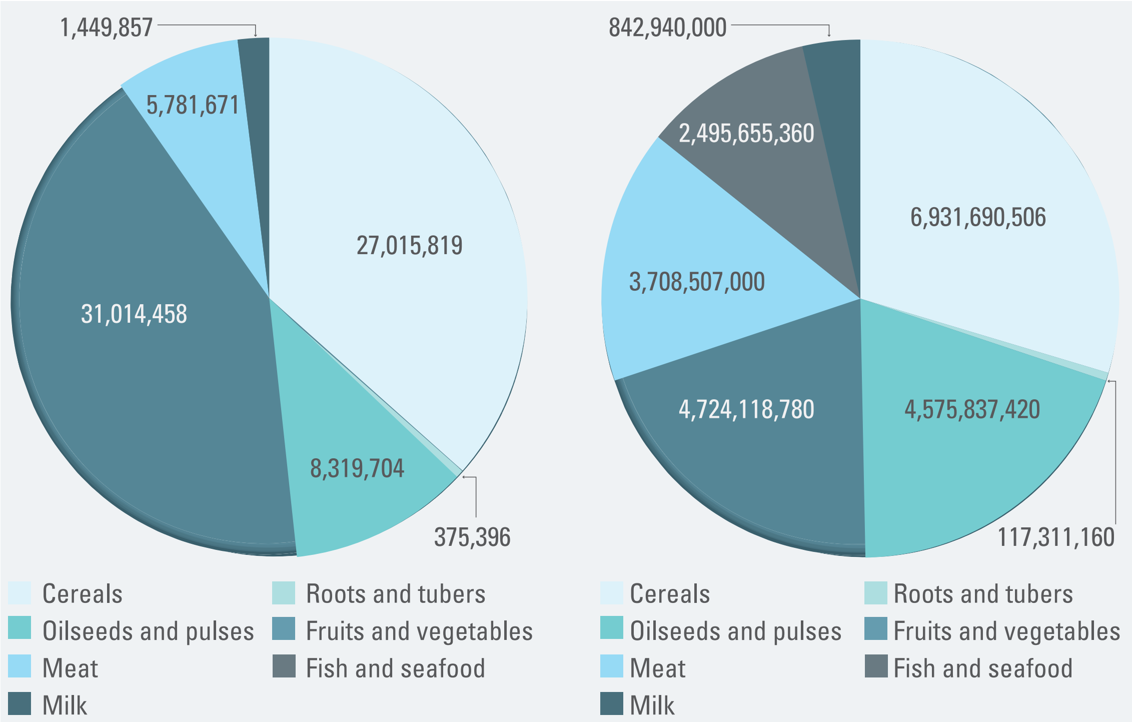


**Figure 10.** Morocco water (left) and energy (right) savings in m³/year and MJ/year, respectively, with 20 per cent reduction in food waste




**Reducing food loss and waste**

For simplicity, the food supply chain can be divided into farms, food manufacturers, consumer businesses and homes. At the farm level, it makes economic sense to leave behind crops that are imperfect (in size or shape) and till them. Changing equipment and machinery, or packaging just parts of the food can lead to food being thrown out. High customer standards often lead to consumer businesses discarding food before it is bad. In the home, the main reasons for wasting food are lack of cooking knowledge, purchasing wrong quantities and no opportunity to recycle food.

The following solutions to reduce waste are proposed for Arab region countries, based on a 10-year study in the United States:[31]

a. Consumer education campaigns;
b. Waste tracking and analysis;
c. Standardized date labelling;
d. Produce specification (imperfect produce);
e. Packaging adjustment;
f. Smaller plates and tray-less public dining;
g. Secondary resellers;
h. Spoilage prevention packaging;
i. Improved inventory management;
j. Manufacturing line optimization;
k. Cold chain management.

The Rethink Food Waste study found the most promising solutions were standardized date labelling, consumer education campaigns and adjusted packaging, as well as centralized composting and anaerobic digestion systems, and a water resource recovery facility with an anaerobic digestion system. The first three solutions have the greatest economic value by ton of waste, while the latter three have the most diversion potential. These results were obtained by looking at four factors over a 10-year period: potential to reduce waste by food product category and stakeholder, upfront and ongoing implementation costs, cost savings, and new revenue opportunities. These factors contributed to output variables of economic value, annual waste diversion, business profit potential, job creation, greenhouse gas reductions, water savings, and meal recovery.

Although prevention (reducing surplus at the source) and recovery solutions (reusing for human consumption) are the most cost-effective, they lack scalability, and other ideas must also be considered. As well as reducing food waste, the proposed solutions would create jobs in recovery and recycling initiatives, and reduce greenhouse gas emissions and annual freshwater withdrawal.

**Closing remarks**

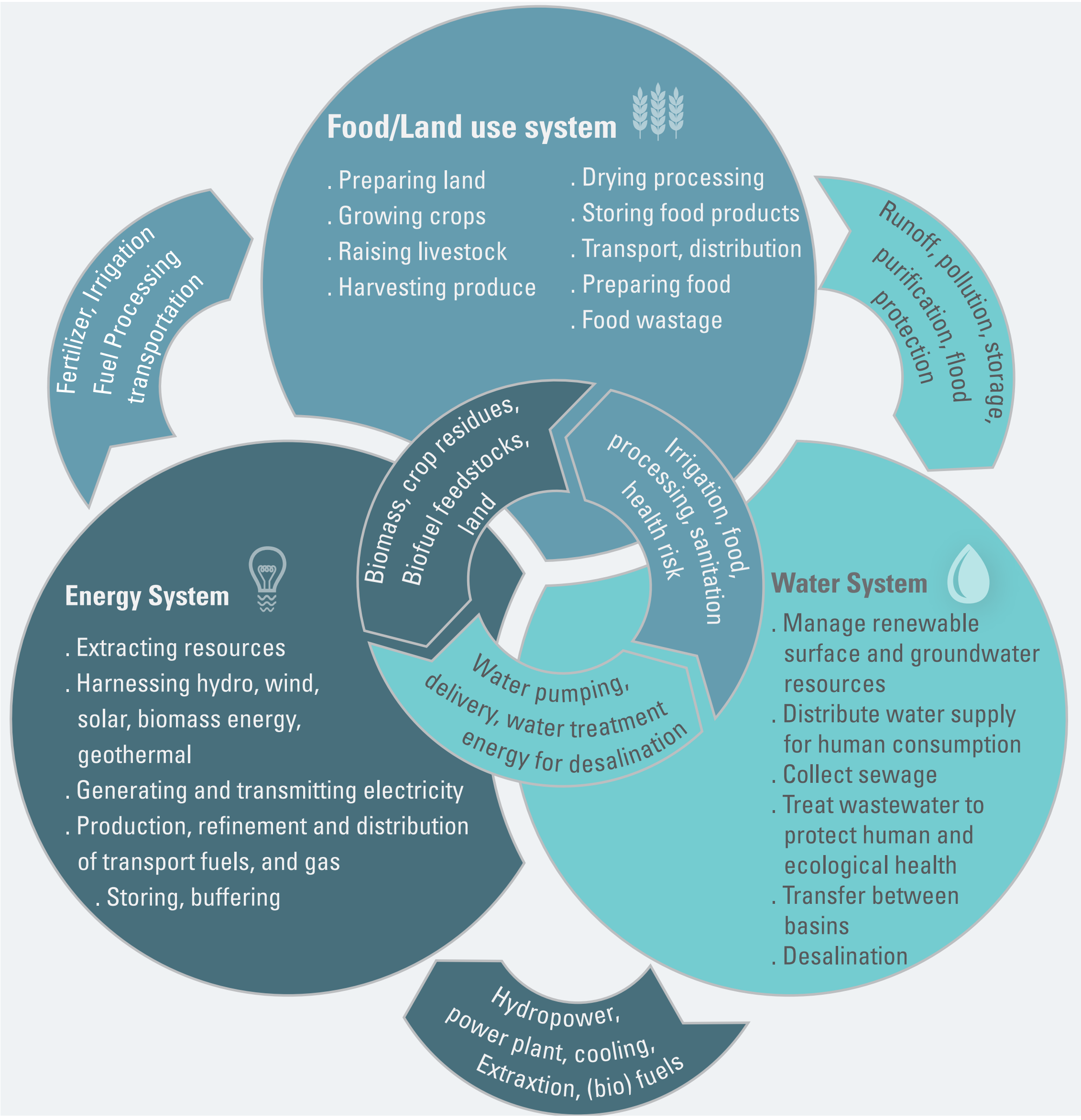
Food waste represents a major loss of resources worldwide, including in the Arab region. It must be addressed at source, and through recycling and reuse. Reducing it is critical to bridge the global food gap, and national water and energy gaps, and requires a multi-stakeholder effort involving policy, education and awareness, infrastructure and incentives for all those involved.

Dropping a welded pipe into a trench with a crane while laying the Iraq Petroleum Company›s pipe line across Palestine’s Plain of Esdraelon, July 1933. Completed in 1934 © Everett Historical - Shutterstock_244405399

# Integrated water-energy efficiency programmes

A wide range of operations are interlinked in water and energy systems, and have a direct effect on the efficiency of resource production, distribution and use. Figure 11 shows how the choice of technology and efficiency of processes not only affects supply and economic aspects, but also the availability of resources (land use, storage, energy requirements for fertilizer production), environmental impact and the implied loss and cost of recovery and treatment (run-off water and pollution), and health risks (sanitation requirements, water quality).

**Figure 11.** Water-Energy-Food nexus and efficiency




**Source:** SE4All, n.d.

## Integrated water resources management, efficiency and the nexus: so what is new?

Integrated water resources management (IWRM) has been a useful platform for increasing water use efficiency. Like the water-energy-food nexus, it is based on the view that segmented planning will likely lead to unsustainable development pathways and inefficiencies in allocating resources. Both appreciate the need to coordinate sectors that produce and consume resources, and to recognize that decisions made in one can impact on the others. IWRM and the water-energy-food nexus also both emphasize the need to change policymaking and decision-making to improve human welfare and social equity, allow sustainable growth and protect essential environmental resources. The key difference is that IWRM starts with water when considering the relationships between water, food and energy, while ideally the nexus approach looks at all three elements as an interrelated system, despite data and modelling challenges. In reality, nexus thinking normally starts from one perspective. That this could be energy or food security makes the concept appear more relevant to these sectors than IWRM.[32]

Improving water efficiency will reduce power demand, and improving energy efficiency will reduce water demand. Greater efficiency in the use of energy or water will help stretch finite supplies of both, and reduce costs for water and power consumers.

The nexus conceptually links multiple resource-use practices previously handled in an isolated way. Resource recovery is an essential part of implementing the nexus. This is fundamentally different from efficiency and productivity, although nexus practices aim for increased output from limited resources.[33]

## Dynamic management of demand and supply

Dynamic demand and supply management is an approach whereby allocation and pricing, or valuing of the resources, follows a dynamic protocol to regulate demand according to resources. For example, during peak water or energy demand (daily or seasonally) for domestic users, industry can be encouraged through variable pricing regimes to switch their use to off-peak times through variable pricing regimes. Managing demand this way ensures higher efficiency (providing more services) without the need for higher infrastructure costs, making the policy worthwhile. It will, however, require expertise, training and a willingness among service providers to change their business model.

# Regional aspects of water-energy efficiency

## Regulatory and policy aspects of efficiency

SDG 12 includes a target encouraging governments to streamline fossil fuel subsidies “that encourage wasteful consumption” by removing market distortions based on national circumstances, including through phasing out harmful subsidies and restructuring taxation.[34] Alternative, targeted subsidies that ensure a balance between access to primary resources and efficient use should be explored. This will require differential assessment of sectors – the residential, industry and services sectors, for example – and appropriate pricing structures.

Infrastructural investment projects, such as educational and primary resources development, can be financed by revenues from natural resources. These can also be used to reduce government debt. Such plans will help minimize wasting resource wealth with short-term objectives, while ensuring investment that will last for future generations. Deployment of revenue will also improve human capital and build strong social safety-nets.[35] Investment by government helps increase efficiency of local water and energy use as they will be perceived as public goods, but it is a long-term process. A stepped approach by low-income countries can alleviate the waiting time and the absorptive capacity problem, though it involves all resources being invested into a specific sector to spearhead the economy. Similarly, investments in human capital can be made to train employees to supply the industry as opposed to advanced training for graduates who may well migrate, unable to find the right jobs.

Other regulatory and policy interventions that can be explored in the Arab region include dynamic pricing of water and energy that not only help in reducing losses and improving efficiencies but also in regulating demand, which can have a huge implication on reducing the overhead costs of infrastructure and network capacity.

## Incentives for investing in water-energy efficiency

According to the International Energy Agency, energy productivity projects generate total benefits usually 1.5 to 2 times the energy savings.[36] The Arab region needs the means to identify ways to transition to sustainable consumption and production, based on national socioeconomic circumstances. An enabling environment requires good governance, integrated policy planning, sound regulatory regimens, the use of market-based instruments, capacity development, access to finance and investments, research and development, public awareness and green procurement.[37]

Economic tools that can quantify economic and resource efficiencies are useful. This could be at multiple levels, such as tax incentives at the policy level, or investing in new technologies at a local level. Standards and codes can be used as tools to address these efficiency measures. Incentives for investing in water and energy efficiencies include:

a. Resource conservation and reducing the cost of commodity production for private and public sectors, leading to increasing profits and improve resilience;
b. Sustaining fuel supply in the oil - and gas - producing countries, and reducing imports in other countries where no fossil fuel resources are available;
c. Reducing cost and increasing profit to enhance product quality and consumer satisfaction for private and public sectors;
d. Reducing water and energy use to protect the environment and conserve natural resources, and improve safety and productivity of operations.

# Key messages and recommendations

This module explores definitions of resource efficiency and productivity, and the gaps in the definitions that limit their impact on national and sustainable development goals. A new vision of efficiency is proposed, one that integrates scale, human rights and access to primary resources, and acknowledges that the productivity and availability of water, energy and land vary enormously between regions, and production systems.

The water-energy-food security nexus thinking offers real opportunities for synergies – coordinated investments in infrastructure and resource management opportunities related to water, food and energy – and innovation to improve resource-use efficiency. This should be coupled with the use of socioeconomic instruments for stimulating investment, including pricing of resources and ecosystem services, maximizing the beneficial uses of water and energy among competing demands, applied research to enhance adaptation to climate change in the agricultural sector, capacity building and sharing of good practice at national and regional levels, and bridging the present science-policy gap. None of this, however, should be at the expense of equity and access to these resources, key elements in the resource efficiency framework presented in this module.

Pumping fossil water or desalinated water for irrigation, as practised in many Arab countries, is not sustainable over the long term. Unless there is radical progress in managing water, particularly irrigation efficiency and food waste in the agriculture sector, the region might be increasingly dependent on imported water to nourish its population.

Removing water and energy subsidies is necessary for more efficient and sustainable consumption and production patterns, though the social and economic impact on more vulnerable populations must be considered. Tension between domestic pressure for consumption spending and a country's long-term growth objectives can be resolved through new labour markets and job creation.

Industry and agriculture must move from low- to high-productivity activities, a challenge in countries with natural resource dependencies. Competing development needs means priorities have to be determined and trade-offs made. But the inherent values of each country will dictate the balance between economic and human factors. While the framework presented can be generalized, its application and preferences cannot, and it must be adapted to each nation and region depending on their values. This is where national capacity is critical, to guide the implementation of the Sustainable Development Goals and resource efficacy targets.

Finally, a readiness to adapt changing technology is paramount. Rather than reinventing the wheel, we can work on technology transfer and adopt efficient processes that are already developed, and invest to adapt them to regional and local specificities as and when required.

# Endnotes

1. UNDESA 2015.
2. SE4All, 2012.
3. GOIC, 2013.
4. Ibid.
5. Castle, 2013.
6. Atallah and Bean, 2015.
7. Ibid.
8. IEA, 2014.
9. AFED, 2015.
10. Ibid.
11. Darwish and Mohtar, 2013.
12. Ibid.
13. Darwish and Mohtar, 2012.
14. Ibid.
15. IRENA, 2011.
16. Darwish and Mohtar, 2012.
17. United Nations, General Assembly, 2015.
18. AFED, 2015.
19. Ibid.
20. Ibid.
21. World Bank, 2007.
22. AFED, 2015.
23. Dabbour, 2006.
24. Lyons, 2015.
25. FAO, 2011.
26. Lundqvist and others, 2008.
27. Godfray and others, 2010.
28. FAO, 2013.
29. FAO, 2016a.
30. FAO, 2016b.
31. ReFED, 2016.
32. Mohtar, 2014.
33. Scott and others, 2015.
34. United Nations, General Assembly, 2015.
35. Mohtar, 2016.
36. AFED, 2015.
37. Ibid.

# Bibliography


Arab Forum for Environment and Development (AFED) (2015). *Sustainable Consumption for Better Resource Management in Arab Countries: 2015 Annual Report of the Arab Forum for Environment & Development (AFED).* Beirut. Available from http://www.afedonline.org/Report2015/English/p8-63%20report%20today.pdf .

Atallah, Tarek, and Patrick Bean (2015). *Determinants of energy productivity: a comparison of 39 countries.* Riyadh: King Abdulla Petroleum Studies and Research Center (KAPSARC). Available from https://www.kapsarc.org/wp-content/uploads/2015/10/KS-1518-DP012A-Determinants-of-energy-productivity_A-comparison-of-39-countries_low-res.pdf.

Castle, Steven (2013). Goodbye Energy Efficiency, Hello Energy Productivity, 14 February 2013 GreenTech Advocates. Available from http://greentechadvocates.com/2013/02/14/goodbye-energy-efficiency-hello-energy-productivity/.

Dabbour, Nabil. (2006). Water resources and their use in agriculture in Arab countries. *Journal of Economic Cooperation* 27, 1 (2006) 1-38. Available from http://www.sesrtcic.org/files/article/25.pdf.

Darwish, Mohamed A., and Rabi Mohtar. (2012). Qatar water challenges, desalination and water treatment. Presented at the International Conference on Desalination for the Environment, Clean Water and Energy, European Desalination Society, 23-26 April 2012, Barcelona, Spain. Available from http://wefnexus.tamu.edu/files/2015/01/Qatar_water_challenge_Journal_paper.pdf.

Darwish, Mohamed A., and Rabi Mohtar (2013). Prime Energy Challenges for Operating Power Plants in the GCC. Energy and Power Engineering. *Energy and Power Engineering*, 5, 109-128. Available from http://dx.doi.org/10.4236/epe.2013.51011.

Food and Agricultural Organization (FAO) (2011). *Global food losses and food waste: extent, causes and prevention*. Rome. Available from http://www.fao.org/docrep/014/mb060e/mb060e.pdf.

Food and Agricultural Organization (FAO) (2013). *Food wastage footprint. Impacts on Natural Resources*. Available from http://www.fao.org/docrep/018/i3347e/i3347e.pdf.

Food and Agricultural Organization (FAO) (2016a). Food and Agriculture Organization of the United Nations. Faostat3 Database. Available from http://faostat3.fao.org/download/Q/QC/E. Accessed 20 February 2016.

Food and Agricultural Organization (FAO) (2016b). Food and Agriculture Organization of the United Nations. Global Production Statistics 1950-2014: Volume of Aquatic Species Caught. Available from http://www.fao.org/fishery/statistics/global-production/query/en. Accessed 23 March 2016.

Godfray, H. Charles and others (2010). Food Security: The Challenge of Feeding 9 Billion People. Science, vol. 327, No. 5967, pp. 812-818. Available from http://science.sciencemag.org/content/327/5967/812.full.pdf.

Gulf Organization for Industrial Consulting (GOIC) (2013). *Energy Efficiency Guidebook.* A GOIC Publication for GCC Industries. Doha, Qatar. Available from http://www.goic.org.qa/documents/Energy%20Guide%20Book-2013.pdf.

International Energy Agency (IEA) (2014). *Capturing the multiple benefits of energy efficiency.* Paris. Available from http://www.iea.org/publications/freepublications/publication/Captur_the_MultiplBenef_ofEnergyEficiency.pdf.

Lyons, Kate. Cutting food waste by a quarter would mean enough for everyone, says UN. *The Guardian*, 12 August 2015. Available from http://www.theguardian.com/environment/2015/aug/12/cutting-food-waste-enough-for-everyone-says-un.

Lundqvist Jan, and others (2008). Saving water: from field to fork. Curbing losses and wastage in the food chain. In SIWI policy brief. Stockholm, Sweden: SIWI. Available from http://dlc.dlib.indiana.edu/dlc/bitstream/handle/10535/5088/PB_From_Filed_to_Fork_2008.pdf?sequence=1&isAllowed=y.

Mohtar, Rabi H. (2014). Opportunities and Challenges for Innovations in Qatar. Muslim World, vol. 105(1). 46-57. Available from http://onlinelibrary.wiley.com/doi/10.1111/muwo.12079/pdf.

Mohtar, Rabi H. The Water-Energy-Food Nexus: Who Owns it? Policy Brief, January 2016, PB-16/03. OCP Policy Center. Available from http://www.ocppc.ma/sites/default/files/OCPPC-PB-1603.pdf.

Mekonnen, Mesfin M., and Arjen Y. Hoekstra (2010). *The green, blue and grey water footprint of farm animals and animal products*, Value of Water Research Report Series No.48. Delft, the Netherlands: UNESCO-IHE Institute for Water Education. Available from http://waterfootprint.org/media/downloads/Report-48-WaterFootprint-AnimalProducts-Vol1.pdf.

Rethinking Food Waste through Economics and Data (ReFED) (2016). A Roadmap to Reduce U.S. Food Waste by 20 Percent. Available from http://www.refed.com/?sort=economic-value-per-ton.

Scott, Christopher A., and others (2015). The Water-Energy-Food Nexus: Enhancing Adaptive Capacity to Complex Global Challenges. In *Governing the Nexus*, Kurian, M. and R. Ardakanian, eds. Springer International Publishing, Switzerland. Available from http://www.springer.com/cda/content/document/cda_downloaddocument/9783319057460-c2.pdf?SGWID=0-0-45-1486976-p176660640.

SE4All (2012). *Sustainable Energy for All: A Framework for Action*. The Secretary-General's High-level Group on Sustainable Energy for All, January 2012. Available from http://www.se4all.org/sites/default/files/l/2013/09/SE_for_All_-_Framework_for_Action_FINAL.pdf.

SE4All (n.d.). *Water-Energy-Food Nexus Infographic*. Available from http://www.se4all.org/sites/default/files/l/2015/03/1.-Mohinder.pdf.

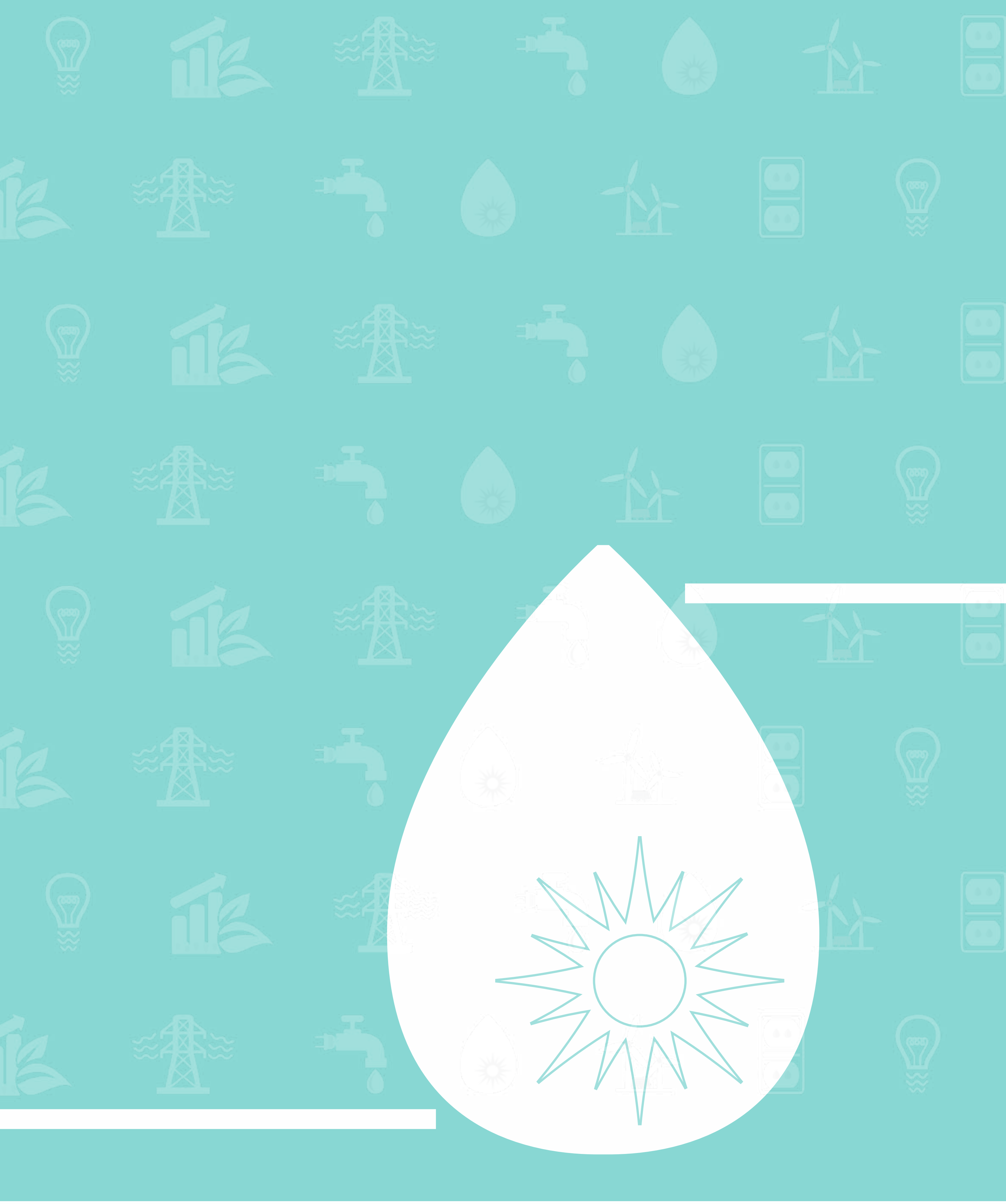
United Nations Department of Economic and Social Affairs (UNDESA) (2015). *The Sustainable Development Goals (SDGs)*. Accessed online on May 2016 at https://sustainabledevelopment.un.org/sdgs.

United Nations, General Assembly. Transforming our world: the 2030 Agenda for Sustainable Development (A/RES/701). Resolution adopted 25 September 2015. Available from http://www.un.org/ga/search/view_doc.asp?symbol=A/RES/70/1&Lang=E.

World Bank (2007). Energy Efficiency for Sustainable Development: Scale Up Strategy and Action Plan. Washington, D.C. Available from https://openknowledge.worldbank.org/bitstream/handle/10986/12906/696760ESW0P1010Scale0Up0Action0Plan.pdf?sequence=1&isAllowed=y.

World Bank and International Energy Agency (2015). *Sustainable energy for all. Progress toward sustainable energy 2015: global tracking framework report.* Washington, D. C. Available from http://www.se4all.org/sites/default/files/l/2013/09/GTF-2105-Full-Report.pdf.

World Intellectual Property Organization (WIPO) (2011). Desalination Technologies and the Use of Alternative Energies for Desalination. Patent Landscape Reports Project by CambridgeIP in cooperation with the International Renewable Energy Agency (IRENA) with participation of the Global Institute for Water, Environment and Health (GIWEH). Geneva. Available from http://www.wipo.int/export/sites/www/patentscope/en/programs/patent_landscapes/documents/patent_landscapes/948-2E-WEB.pdf.



# Informing Technology Choices

5 Module

# Contents



## List of figures



## List of tables

## List of boxes



# Abbreviations and explanatory notes

| | |
|---|---|
| **DW** | Desalinated water |
| **EIA** | United States Energy Information Administration |
| **ESCWA** | Economic and Social Commission for Western Asia |
| **IRENA** | International Renewable Energy Agency |
| **GCC** | Gulf Cooperation Council |
| **G8** | Group of Eight (Canada, France, Germany, Italy, Japan, Russia, the United Kingdom and the United States of America) |
| **GW** | gigawatt |
| **kWh/y** | kilowatt-hour per year |
| **MED** | multiple-effect distillation |
| **MENA** | Middle East and North Africa |
| **MJ** | megajoule |
| **MSF** | multi-stage flash distillation |
| **PV** | photovoltaic |
| **RD** | research and development |
| **RO** | reverse osmosis |
| **RSP** | regional solar programme |
| **TSS** | total suspended solids |
| **SCPDP** | solar cogeneration power desalination plant |
| **SDG** | Sustainable Development Goal |
| **SE4All** | Sustainable Energy for All |
| **SWRO** | salt water reverse osmosis |
| **UNDP** | United Nations Development Programme |
| **UNFCCC** | United Nations Framework Convention on Climate Change |
| **WEF** | water-energy-food |
| **WWF** | World Wildlife Fund |
| **WWDR** | World Water Development Report |
| **WWTP** | wastewater treatment plant |

# Background and objectives of this module

Sustainable Development Goals (SDGs) 6 and 7 address targets for the water and energy supplies and services. Specifically, 6a states:

> *By 2030, expand international cooperation and capacity-building support to developing countries in water- and sanitation-related activities and programmes, including water harvesting, desalination, water efficiency, wastewater treatment, recycling and reuse technologies.*

In the same spirit, SDG 7a states:

> *By 2030, enhance international cooperation to facilitate access to clean energy research and technology, including renewable energy, energy efficiency and advanced and cleaner fossil-fuel technology, and promote investment in energy infrastructure and clean energy technology.*

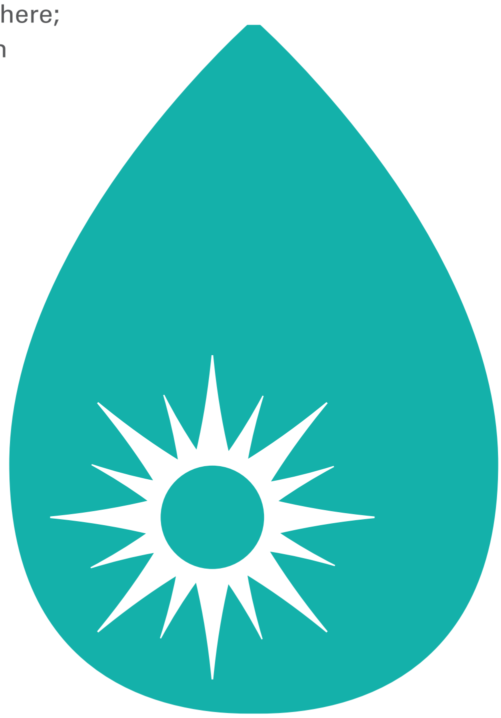
And SDG 7b states:

> *By 2030, expand infrastructure and upgrade technology for supplying modern and sustainable energy services for all in developing countries, in particular least developed countries, small island developing States, and land-locked developing countries, in accordance with their respective programmes of support."*[1]

In an era of growing demand and limited supply, choosing the best systems to produce and access water and energy should be based not merely on economic considerations, nor on popularity or availability. Choosing technology in the water and energy sectors that will support the SDGs – and address current local and regional challenges – must take account of:

a. Primary resource requirements of water, energy and land;
b. Economic and financial aspects;
c. Environmental impacts to land, water and atmosphere;
d. Human resources needed to develop and maintain technologies;
e. Technical suitability to local conditions and robustness;
f. Social and cultural suitability to local practices.

In this module, we present an overview of water and energy technologies and propose a simple, integrated tool – a scorecard – that integrates the six factors listed above to guide policy-making and technology choices. We will demonstrate how the tool applies to several current and potential technologies, and present potential trade-offs between primary resources.



Further studies are needed to incorporate other attributes and expand this tool to more technologies. However, even in its current state, the tool is particularly useful when dealing with trade-offs and eliminating subjective technology choice.

Some critical data that needs to be collected locally and cannot be generalized is missing from the scorecard. The tool provides a framework to guide the choice of technology and further data collection, rather than an exhaustive database for various technologies.

# Overview of water and energy production technologies

The water-energy nexus has attracted more attention in recent years but there is no clear method to incorporate quantification into policymaking and technology choices.

The fundamental target in water and energy production is to meet a growing demand. The United Nations has indicated that 2 billion people do not have access to safe water, while the number of people deprived of their right to water is estimated to be 3.5 billion. It has been reported that more than 1.3 billion people lack access to electricity, most of them in sub-Saharan Africa and developing Asia. In Yemen, for example, more than 48 per cent of the population did not have access to electricity in 2015,[2] 45 per cent had no access to reliable sources of water, and more than 35 per cent used solid fuel for cooking in 2011 (table 1).[3]

It is no accident that populations that lack access to water also lack access to electricity and are most vulnerable to disease and food insecurities. It is clear how the water-energy nexus works in local and regional crises and how one aspect can exacerbate a problem in another. Access to these resources is a human rights issue, one that should be taken more seriously by governments and the international community. This is not an easy task, especially in the Arab region where several million refugees from Iraq, Palestine and the Syrian Arab Republic are left without access to water, sanitation, and energy resources.

**Table 1.** Access of population to electricity, water and sanitation in selected countries

| | Population (2011 – Millions) | Population without access to electricity (2011) (%) | Population without access to improved water (2011) (%) | Population without access to improved sanitation (2011) (%) | Population using solid fuel for cooking (%) |
|---|---|---|---|---|---|
| **Algeria** | 36.7 | 0.0 | 16.0 | 12.0 | 0.0 (2015) |
| **Iraq** | 32.7 | 2.0 | 15.1 | 16.1 | 5.0 (2005) |
| **Kuwait** | 36.9 | 5.9 | 1.0 | 0.0 | 0.0 (2015) |
| **Sudan** | 3.2 | 67.4 | 44.0 | 76.0 | 72.1 (2015) |
| **Syrian Arab Republic** | 20.8 | 7.2 | 10.1 | 4.8 | 0.3 (2005) |
| **Yemen** | 24.8 | 60.1 | 45.2 | 47.0 | 36.0 (2006) |
| **World** | 6950.7 | 18.1 | 11.1 | 35.9 | 38.0 (2012) |

**Sources:** WWAP, 2014 and SE4ALL, 2015.

# Water production

Groundwater is extremely limited, over-exploited, deteriorated and non-replenished. This has led to other sources being sought. Non-conventional resources include desalinated water, treated wastewater, harvested rainwater, cloud seeding and irrigation drainage water. In the Gulf region, desalinated water constitutes 99 per cent[4] of municipal water, while in general treated wastewater is little used in the Arab region.

Many Arab countries overexploit their groundwater resources, including fossil/non-renewable aquifers. They are being used for agriculture, mostly without integrated planning, and contribute to the salinization of natural water springs. The Arab region possesses more than half of global desalination capacity and it is expected to grow from 1.8 per cent of the region's water supply to an estimated 8.5 per cent by 2025, mostly in the Gulf Cooperation Council (GCC) countries. The challenge has been to invest in infrastructure and research, and develop in parallel solar and other renewable energies, to make desalination technologies more sustainable and reduce production costs.[5]

The reuse or reclamation of treated wastewater in urban areas offers many potential benefits. However, the lack of social awareness and acceptance of this resource, the challenges of quantifying and controlling risks and long-term impacts, and institutional and political constraints on policies and regulatory frameworks have hindered the expansion of treatment facilities.

Rainwater harvesting is another option in rural and urban areas, but it, too, faces significant constraints. Major research, capacity building and policy development and implementation are required make its widespread uptake feasible. Among other Arab countries, Egypt and the Syrian Arab Republic have been relying on reused irrigation drainage waters. However, these waters can be a major source of pollution, so must be monitored and subject to strict standards to regulate their quality.[6]

## Wastewater treatment

About 43 per cent of the wastewater generated in the MENA region is treated but only a few countries have been able to implement reuse programmes. According to a study in 2010,[7] the major constraints are:

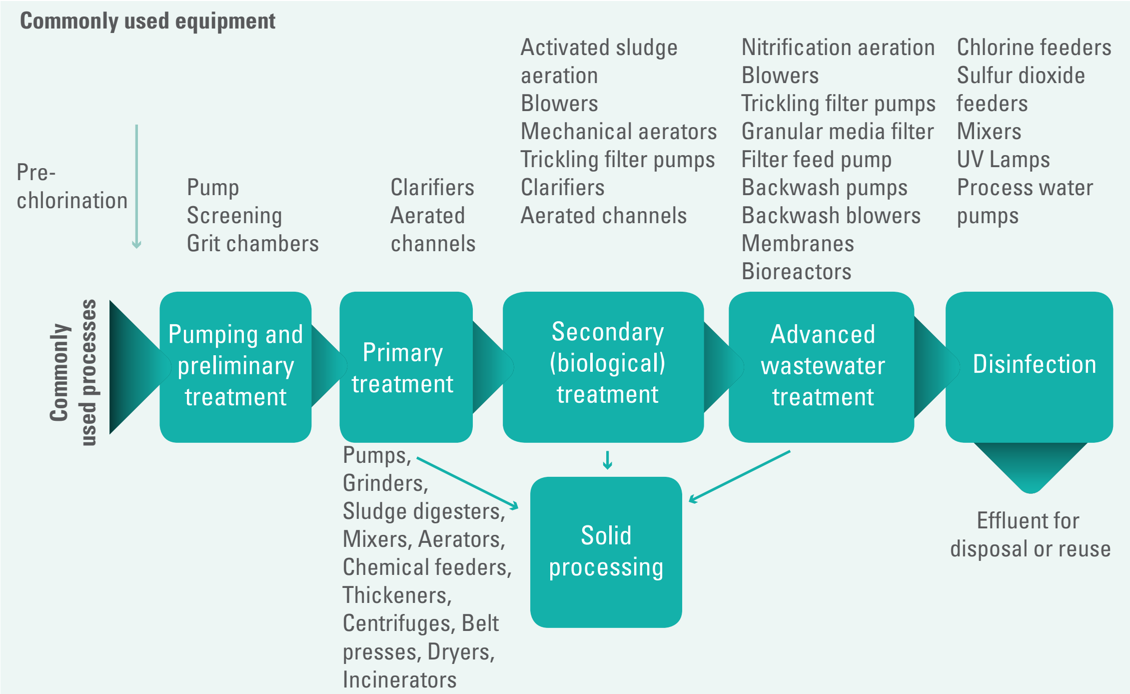
a. Lack of knowledge: not enough information on the effluents for appropriate reuse and the possible environmental and health impacts, and a lack of analysis of the feasibility of treatment options.
b. Economic: high capital costs and low returns on wastewater treatment facilities and inefficient cost-recovery mechanisms.
c. Lack of institutional support for wastewater treatment programmes and water management schemes that include potential wastewater reuse.
d. Water pricing: subsidies that make wastewater cost-ineffective.
e. Social acceptance: preference for freshwater over wastewater.

However, some countries, such as Jordan, Palestine and Tunisia, consider use of treated wastewater an essential aspect of strategic water and wastewater planning and management.

**Wastewater treatment technologies**

Systems commonly used for treating urban wastewater comprise a primary treatment (usually mechanical treatment by settling), a biological second stage, and a tertiary treatment by disinfection, in some cases following a filtration process (figure 1). A detailed technical description of each of these technologies is outside the scope of this module.

**Figure 1.** Typical wastewater treatment layout




**Source:** Darwish and Mohtar, 2012.

In a typical wastewater treatment plant, energy is used mostly for aeration in the biological processes (figure 2), consuming about 60 per cent of the total energy requirement in the facility.

Biological material in wastewater is energy rich. Consequently, in developed countries many wastewater treatment plants are becoming energy recovery units and energy neutral, whereby all the energy needed to run these facilities is derived from energy (the biogas) generated within these systems. Once these systems become more economically and technically feasible, much of the energy burden to operate wastewater facilities will be removed. Anaerobic systems have a lower energy footprint and are suited to the warmer climate in the Arab region.

The following treatment processes are typical of a wastewater treatment plant:

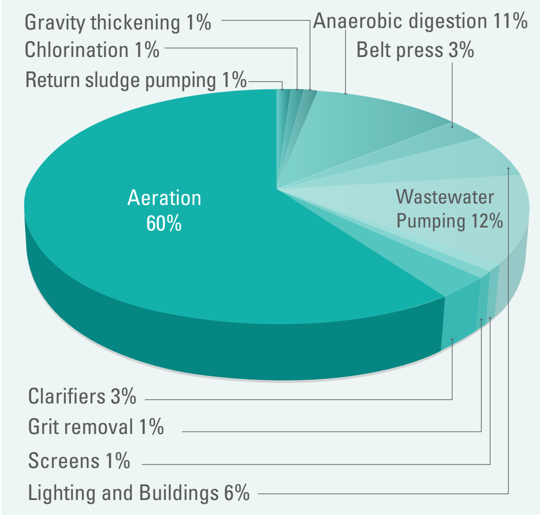
**Primary sedimentation:** an efficient process for removing coarse solids. Some technologies use flocculants to remove finely dissolved organic matter in wastewater.

The sludge separated by these physical and chemical processes is then subjected to chemical or biological treatment (secondary). Sludge incineration and land application are also common but carry concerns about emissions (air quality) and contamination of ground and surface waters due to leachate.

**Secondary treatment:** the systems mostly used to remove solids, organic matter and pathogens are the activated sludge process, trickling filters, aerated lagoons, high-rate oxidation ponds and stabilization ponds.

Stabilization ponds, also known as aerated lagoons, are widely used in the MENA region. The most often used ponds in domestic wastewater treatment are the stabilization pond and facultative lagoon. The stabilization pond is designed to be aerobic throughout its depth and the facultative lagoon will be anaerobic at the bottom and aerobic at the top. They are designed mostly for high concentration industrial wastes.

**Figure 2.** Typical wastewater system energy consumption




**Source:** Darwish and Mohtar, 2012.

The activated sludge process, or one of its many modifications, is most often used for larger installations. It is a biological treatment to break down organic matter into carbon dioxide, water and other inorganic compounds. The process has three basic components: an aerated reactor in which the microorganisms are kept in suspension, and in contact with the effluent; liquid-solid separation; and a sludge recycling system to return activated sludge to the start of the process. The energy requirements for this process can vary, depending on the aeration method, the sludge recycling system and the land requirements.[8]

Trickling filters are a secondary treatment process, within the group of fixed-film processes, whereby wastewater "trickles" over rock or honeycombed-shaped plastic media. Biomass and slimes containing microorganisms form on the media and utilize the organic matter for growth and energy. There is much innovation in developing new and more efficient film media. Trickling filters can be coupled with other secondary processes (such as activated sludge) and have been successfully implemented to minimize the weakness of one technology and exploit the strengths of another.[9]

**Anaerobic systems:** The high content of organic matter in wastewaters is an important source of chemically bound energy that can be converted to biogas under anaerobic conditions. This biogas has been used as a domestic fuel for combustion (cooking and heating) and, after further treatment, in internal combustion engines (fuel for engines) or to produce energy inside the treatment facility or other industrial premises. These anaerobic digestion technologies are particularly suitable for the

**Table 2.** Comparison of lagoon systems with activated sludge process

| | Advantages | Disdvantages |
|---|---|---|
| **Lagoon systems** | lower operating costs (operators and chemicals)<br>large settling zone<br>minimal operator attention | harder to remove accumulated solids<br>poor removal efficiencies (especially in cold weather)<br>higher land requirements |
| **Activated Sludge** | lower land requirements<br>faster process<br>higher removal efficiency<br>higher bacterial population | higher capital cost<br>higher operational cost<br>higher competence required<br>susceptible to bulking |

**Source:** World Bank, 2016.

warmer climates of the Arab region, but remain largely unexplored as a potential source of green energy and the means to reduce sludge production. Arab countries have mostly adopted aerobic treatment systems commonly used in cooler climates in Europe and the United States of America.

Anaerobic wastewater treatment offers improved energy conservation and the potential to reduce greenhouse gas emissions, provided the methane produced is treated and used for energy production. A technology to recover dissolved methane would make anaerobic treatment favourable for almost all influent strengths. The digested sludge cake can be processed into agricultural fertilizers, making this a financially attractive option once specific regional needs are taken into account.[10]

The feasibility of this technology is best illustrated by the As-Samra wastewater treatment plant in Jordan, which is financed by a public-private partnership. The effluent enters the treatment facility at high pressure due to difference in elevation. The hydraulic pressure in the wastewater flow is used to generate hydraulic energy, through turbines, which is then used on site. The treated effluent is used again to power hydraulic energy before it is released into the King Talal Dam. The sludge is treated in anaerobic digesters where biogas is generated and used as a renewable source of thermal and electrical energy on site. The plant is almost self-sufficient and requires little power from the grid.[11]

Wastewater treatment can be extended for reclamation and can be an unlimited water source if properly treated.

The power consumed in treating wastewater depends on the initial composition of the effluent, how much of the contaminants are removed, the type of equipment used, the plant size and type of treatment. Table 3 shows an overview of consumed energy for different plant sizes and types. Typically, about 60 per cent of electrical power is consumed by aeration, 12 per cent by wastewater pumping, and 11 per cent by anaerobic digestion; other minor processes, such as clarifiers, consume the remainder, as described in figure 2.[12] The treatment processes mostly used in the MENA region are shown in table 4.

Table 4 shows the sewerage rates for countries in the MENA region and the types of treatment mostly used in each country.

**Table 3.** Electricity consumption of four major wastewater treatment processes

| | Unit electricity consumption (kWh/m$^3$) | | | |
|---|---|---|---|---|
| **Treatment plant size (m$^3$/day)** | **Trickling filter** | **Activated sludge** | **Advanced wastewater treatment** | **Advanced wastewater treatment nitrification** |
| 3,785 | 0.479 | 0.591 | 0.686 | 0.780 |
| 18,925 | 0.258 | 0.362 | 0.416 | 0.509 |
| 37,850 | 0.225 | 0.318 | 0.372 | 0.473 |
| 75,700 | 0.198 | 0.294 | 0.344 | 0.443 |
| 189,250 | 0.182 | 0.278 | 0.321 | 0.423 |
| 378,500 | 0.177 | 0.272 | 0.314 | 0.412 |

**Source:** Darwhish and Mohtar, 2012

**Table 4.** Sewerage provision in urban and rural areas and wastewater treatment rate in MENA region countries

| Country | Urban sewerage rate (% people served by house connection)[b] | Wastewater treatment rate (% collected)[b] | Reuse purposes after treatment [b] (% per purpose type) | Wastewater treatment type and description |
|---|---|---|---|---|
| Bahrain | 99.5 | 99.5 | Agriculture (27.8), direct discharge (71.6) | Tertiary (99.5%)[b] Activated sludge[a] |
| Egypt | 96.98 | 82.7 | Agriculture (2.6), direct discharge (25.3) | Primary (16.9%), secondary (63.2%), tertiary (2.7%)[b] Activated sludge ponds, trickling filters[a] |
| Iraq | 40.4 | 27.1 | Direct discharge (15) | Secondary (27.1%)[b] |
| Jordan | 70.1 | 70.1 | Agriculture (70.1) | Primary (70.1%)[b] Secondary and tertiary: lagoons and activated sludge; frequent overloading [a] |
| Kuwait | 98.4 | 71.8 | Agriculture (54.6), domestic uses (17.2) | Secondary (12.2%), tertiary (59.6%)[b] |
| Libya | 56.3 | 9.6 | Agriculture (3.1), direct discharge (6.5) | Secondary (9.6%)[b] and tertiary[a] |
| Oman | 15.3 | 15.3 | Agriculture (13.3), groundwater recharge (1.5), other uses (.5) | Tertiary (15.3%)[b] Secondary (activated sludge or aerated ponds) followed by secondary and tertiary[a] |
| Palestine | 63.0 | 47.8 | Agriculture (.001), direct discharge (37.3) | Primary (0.19%), secondary (47.7%), tertiary (.001%)[b] Primary and secondary: ponds, frequent overloading[a]; |
| Qatar | 94.3 | N/A | | Secondary and tertiary[a] |
| Tunisia | 80.2 | 80.2 | Agriculture (22.4%), direct discharge (35.3%), other uses (22.4%) | Secondary (75%), tertiary (5.2%)[b] Secondary: mostly activated sludge; ponds; moving to tertiary[a] |
| UAE | 35.7 | 35.7 | Agriculture (16.5%), direct discharge (16.7%), other uses (2.5%) | Tertiary (35.7%)[b] Tertiary moving to advanced[a] |

**Sources:** [a] Qadir and others, 2010. [b] League of Arab States and others, 2015.

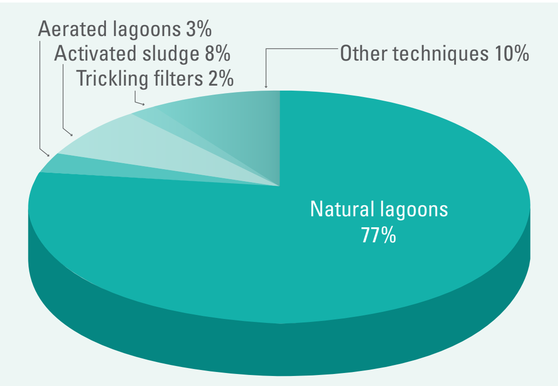
### **Box.** Morocco: Technology choices for rural and urban wastewater treatment

Approximately 48 per cent of wastewater in Morocco is discharged to rivers or applied to land for irrigation. The rest is pumped into the ocean. A large amount of the wastewater produced inland is not treated and is then reused for irrigation. This has led to many cases of waterborne diseases. The graph below shows the distribution of wastewater technologies in Morocco. The main limitations are financial. There is low connectivity to sewage lines in households and, therefore, the most popular treatments are lagoons because they can be localized.

Many of Morocco's treatment plants are not operational, mainly due to:

a. Financial problems: electricity and equipment are expensive, and insufficient budget for proper operation and maintenance;
b. Social concerns: the location of some plants within city boundaries has created unrest due to foul odours;
c. Lack of experienced staff;
d. Lack of regulations and monitoring in treatment plants.

Wastewater treatment technologies in Morocco




Stabilization ponds and aerated lagoons have proved a good choice in small communities in Morocco; even though they use more land, they have a lower energy footprint and operational cost. In the case of large inland cities where land is not so readily available, more complex biotechnologies, such as activated sludge or digesters, would seem the better choice.

Morocco operates what is considered the first wastewater treatment plant (WWTP) in North Africa that integrates wastewater treatment, biogas production and recovery, electricity and heat cogeneration, air treatment and water reuse. The Marrakesh WWTP, operational since 2011, treats about 120,000 cubic metres per day in four stages: pre-treatment; primary treatment in sedimentation tank; secondary treatment (i.e. aerobic sludge treatment); and tertiary treatment, (microfiltration by sand filter and disinfection by ultraviolet lamp units). The electricity consumed by the plant is about 30 GWh/year, while the electricity generated by four cogeneration units with a power of 862 kW amounts to about 10.5 GWh/year. More than 70 per cent of the treated water from this WWTP is reused for recreational purposes (e.g. golf courses, palm groves). Morocco has set a national target of 60 per cent effluent treatment by 2020; choosing the most suitable technologies for rural and urban settings is a big step towards meeting this goal. The challenge remains to overcome socioeconomic and institutional barriers that hinder wastewater treatment expansion in the region.

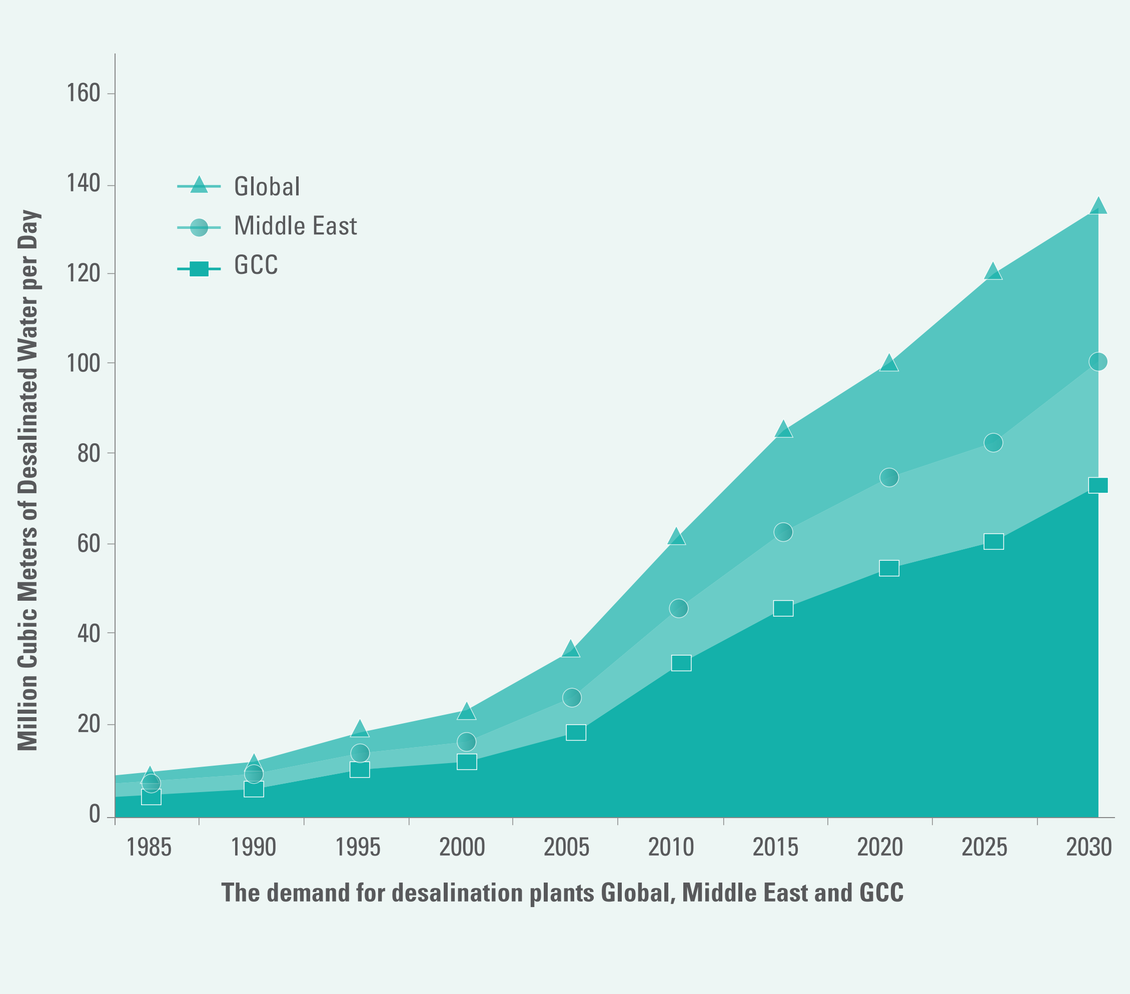
**Source:** Mandi and Ouazzani, 2016.

## Desalination

More than 52 per cent of global desalination capacity is in the MENA region – most of this in GCC countries – and the trend is expected to remain.[13]

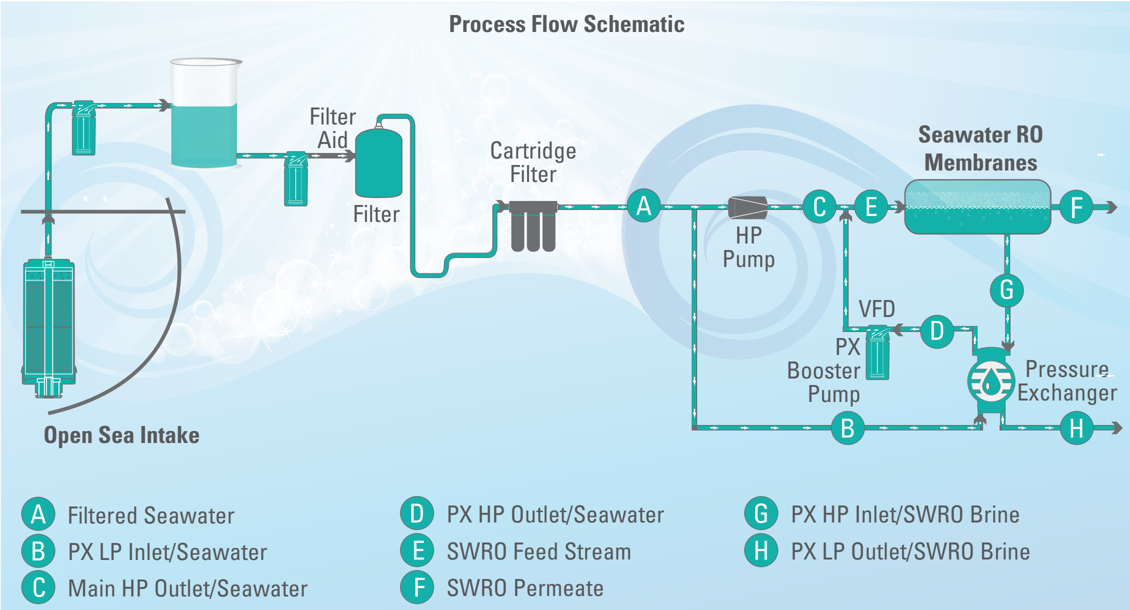
The main types of desalination technologies can be classified as membrane-based and thermal-based. Thermal-based technologies entail simply heating and distilling the water. These are robust technologies that have been used for centuries. Their energy requirements are naturally high, but in many cases, they run using steam generated by power production, as in Qatar and many GCC countries. There are many variations of these technologies, depending on the heat recovery system used. Membrane-based technologies do not use steam and are usually run by electricity to push water through a membrane. They tend to be more energy efficient, though they suffer from fouling and are not suitable under high salinity and turbidity levels where they require additional pretreatment options. The processes of membrane technology water treatment are shown in figure 4.

**Figure 3.** Demand for desalination plants in the world and the Middle East




**Source:** Darwish and Mohtar, 2012.

**Figure 4.** Diagram of a typical membrane (RO) desalination process




**Source:** Darwish and Mohtar, 2012.
**Note:** PX= Pressure Exchanger; HP= High Pressure; LP= Low Pressure; VFD= Variable Frequency Drive.

Membrane technologies can save up to 75 per cent on energy use and cut the cost of water production by two thirds. Moving to membrane systems requires sufficient human capacity to operate and maintain them, robust systems and integrated water production and electricity generation as in the case of many of the GCC countries, where the high salinity and total suspended solids (TSS) necessitates pretreatment technologies. Thermal energy input in megajoules per cubic metre ($MJ/m^3$) is approximately 270 for all technologies except salt water reverse osmosis (SWRO).

In order to reduce the water usage and energy footprint of water production in many parts of the GCC region, the following key recommendations can be drawn:

1. Distilled water quality is high, but so, too, is its cost. Therefore, its use should be limited to cooking and drinking. Treated wastewater should be used for applications that do not need high quality water, such as toilet flushing and gardening.
2. Reduce per capita water use. 600 l/d.ca daily municipal water use is far beyond basic needs; it is 246 l/d.ca in the United States, 215 in Sweden, and 104 in Netherland. The lowest for the Gulf region is in Oman, at 146 l/d.ca.
3. Subsidies should be reconsidered to stop water being wasted, and limit its use to basic needs.
4. Shift to technologies that have a lower energy footprint (table 7), such as membrane technologies, cogeneration options, or hybrid solutions, such as solar-powered systems.

## Oil and gas produced water

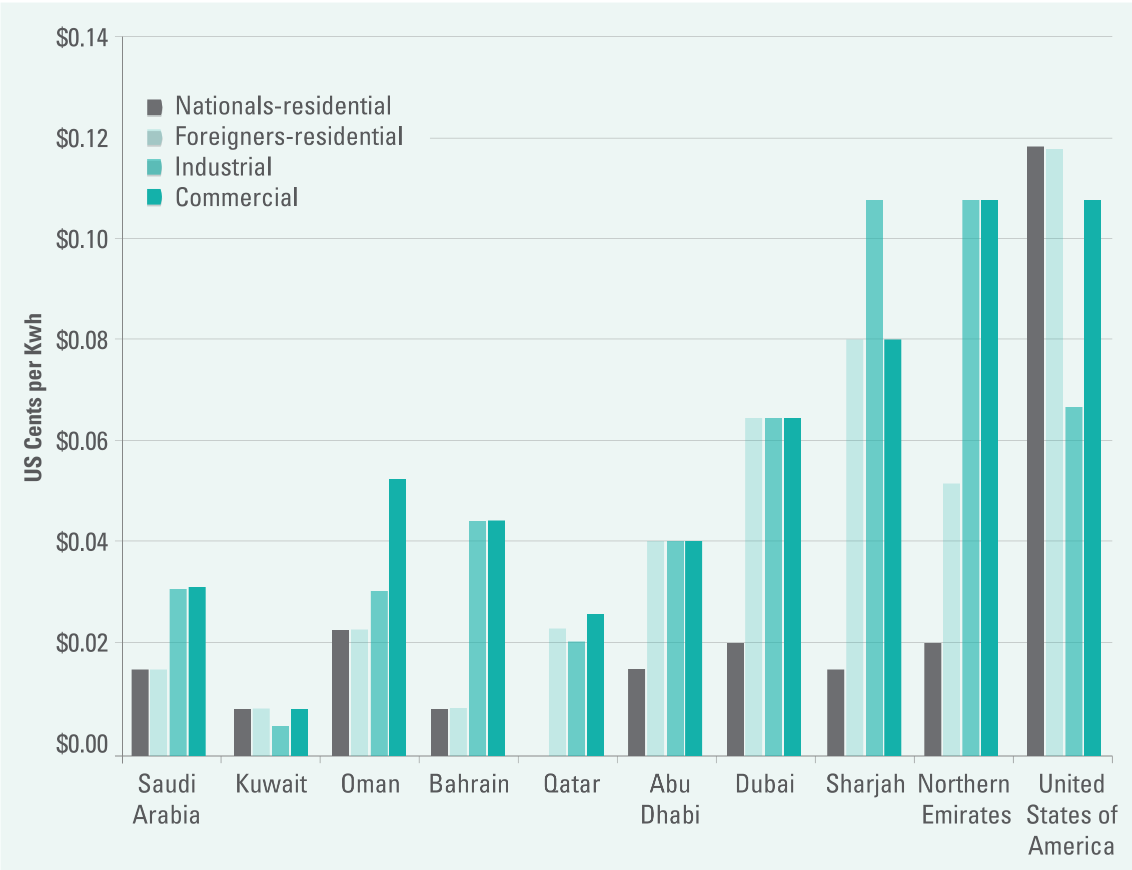
During oil and gas extraction and production, large volumes of water are produced. It may include water from the reservoir, water injected into the formation, and any chemicals added during the drilling, production and treatment processes. The quality of “produced water” varies significantly, depending on the location, type of hydrocarbon produced and the geochemistry of the producing formation. In general, produced water contains salt, oil and grease, inorganic and organic chemicals, and naturally occurring radioactive material. The types of contaminants found in produced water and their concentrations, as well as the location and the final use of the effluent, will determine the degree and cost of treatment required. Treated produced water can be used for crop irrigation, livestock watering, streamflow augmentation, and municipal and industrial purposes. Produced water also can be stored in aquifers for future use.[14]

Reservations remain about the reuse of produced water due to high treatment costs and the risk of exposure to the chemicals it contains. However, as treatment technologies become less expensive and freshwater resources more scarce, produced and other types of water may be a good option for industrial and other uses that do not involve human exposure.

# Energy production

Between 2000 and 2010, excessive energy consumption in GCC countries drained fuel resources and wealth reserves. The rate of increase greatly outpacing production; the oil production rate, for example, increased by 20 per cent, while consumption rose by

**Figure 5.** Electricity prices in GCC compared with the United States of America in 2011




**Source:** EIA, 2015.

Bahrain - March 2016 : Old rusted oil pump unit in the oil field, March 05 - 2016 in Bahrain, Middle East © Murty - Shutterstock_ 386205286

120 per cent.[15] Based on current rates of consumption, there are projections Saudi Arabia will cease to export oil since most of its production will be consumed domestically by 2040.[16] Apart from Qatar, all GCC countries already import natural gas to run their power generation.[17]

Water and energy use in the Arab region, particularly in GCC countries, is among the highest in the world. This high use of resources is due in large part to water and energy subsidies. Figure 5 indicates high electricity consumption is due to its low cost. In Abu Dhabi, for example, the cost of electricity, measured in kilowatt-hours (kWh), was 1.4 cents for nationals and 4 cents for expatriates in 2006. Nationals consumed 71,000 kilowatt-hours per year (kWh/y) whereas expatriates' average consumption was approximately 26,500 kWh/y.[18]

## Renewable energy

Renewable energy makes up 19 per cent of the global final energy consumption, of which 9 per cent is traditional biomass.[19] This percentage will grow for two reasons: countries are realizing the benefits of renewable energy to enhance energy security, improve energy access and boost socioeconomic development; and climate change mitigation.

There is consensus that, globally, addressing potentially catastrophic climate change must involve a substantial expansion in renewable energy. During the United Nations Framework Convention on Climate Change (UNFCCC) meeting in Paris in November 2015, all member countries pledged to reduce emissions and make renewable energy a goal. This will move forward the renewable energy agenda. For the Arab region, this presents challenges in adapting technologies and building human resources capacity to implement the renewable energy targets.

The United Nations Sustainable Energy for All initiative aims to double the share of renewable energy in the global energy mix by 2030 to 36 per cent of the total global energy produced. An energy system with a substantial share of renewables would affect the food and water sectors in different ways than one based mainly on fossil fuels. Therefore, decision makers will need to consider other factors when choosing technology. Some of the questions they will need to pose include:

a. What are the trade-offs between renewable energy production and other resources, such as food, water and land? How much water and land would be required to deploy a specific renewable energy technology?
b. How might resources needed for new energy sources compete with food and water systems?
c. What are the short- and long-term costs and benefits for this new energy portfolio? How much savings would such a shift generate?

Answering these questions requires an analytical framework that quantifies the links between water and energy resources, which will be the basis for trade-off analysis.

## Solar energy

Solar-based pumping solutions offer a cost-effective alternative to pump sets that run on grid electricity or diesel. Solar pumps can bring multiple benefits, including water distribution to remote communities, irrigation and domestic uses. The Regional Solar Programme (RSP), launched by the Permanent Interstate Committee for Drought Control in the Sahel in 1986, has deployed 995 solar pumping stations and 649 community systems, providing improved access to water and electricity for 2 million people. By the end of the second phase (RSP 2) in 2009, the population without access to safe drinking water had dropped by 16 per cent in the Sahel countries of West Africa.[20] Many governments in the Arab region used the price of electricity or diesel fuel to regulate groundwater withdrawal. Without such disincentives to pump water,

**Figure 6.** Proposed solar cogeneration pilot plant

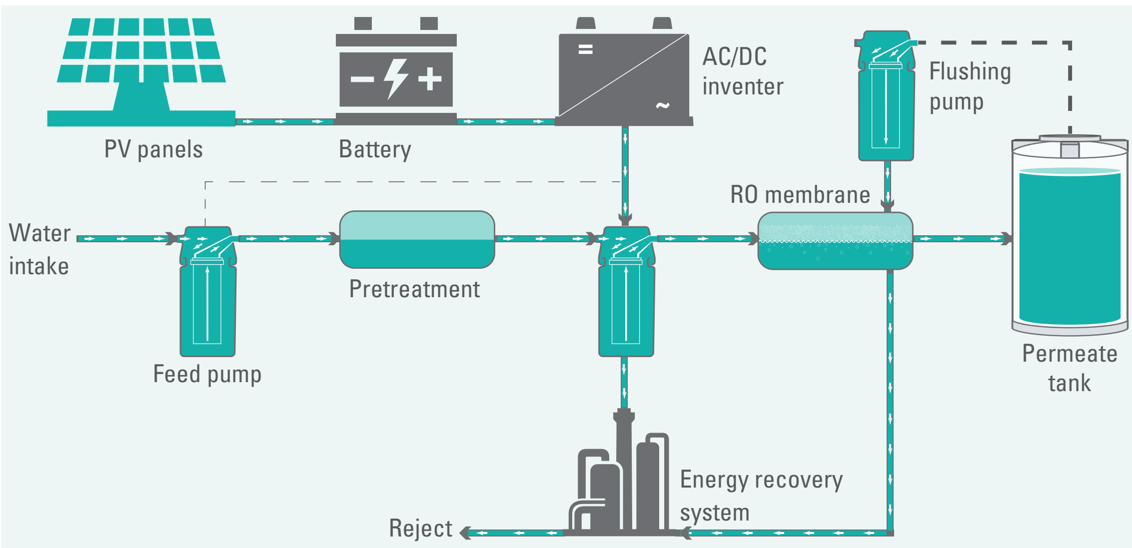


**Table 5.** Major types of energy production technologies

<table>
<tr><th colspan="5">Energy Production Technologies</th></tr>
<tr><th>-</th><th>Type</th><th>US$/ kW hour produced[a]</th><th>$m^3$ (consumed water) /kWh produced[b]</th><th>ha/kWh produced[c]</th></tr>
<tr><td>Wind</td><td>Onshore</td><td>0.04-0.07</td><td>0.00056</td><td>24,300</td></tr>
<tr><td>Wind</td><td>Offshore</td><td>0.10-0.17</td><td>0.00056</td><td>-</td></tr>
<tr><td>Solar</td><td>Photovoltaic</td><td>>0.20</td><td>0.00169</td><td>3,000</td></tr>
<tr><td>Hydro</td><td>Hydroelectric</td><td>0.04</td><td>0.01780</td><td>-</td></tr>
<tr><td>Oil</td><td>CP – Primary</td><td rowspan="6">0.05</td><td>1.55</td><td>-</td></tr>
<tr><td>Oil</td><td>CP - Secondary</td><td>68.78</td><td>-</td></tr>
<tr><td>Oil</td><td>EOR – Tertiary</td><td>-</td><td>-</td></tr>
<tr><td>Oil</td><td>EOR – SI</td><td>43.27</td><td>-</td></tr>
<tr><td>Oil</td><td>EOR – $CO_2$ inj.</td><td>24.41</td><td>-</td></tr>
<tr><td>Natural Gas</td><td>CP</td><td>0.00</td><td>-</td></tr>
</table>

**Sources:** [a] Delucchi and Jacobson, 2011; Knoema, 2016. [b] Feng, et al., 2014; Mielke, et al.,2010; [c] Entergy, n.d.
Note: CP= conventional production; EOR= enhanced oil recovery; SI= steam injection; ha= hectare.

solar pumps require extra robust oversight, policies and other nexus-regulating mechanisms to control groundwater pumping.

Given that using direct solar energy to power desalination plants is not economically viable, solar cogeneration power desalination plants (SCPDP) should be used. Integrating concentrated solar power with conventional natural gas-fired power plants could also be a real solution.

Table 5 shows the major types of technologies responsible for producing power in the region. Photovoltaic solar energy has the highest price per kilowatt-hour (kWh) produced while oil production has the highest water requirement. Another consideration is the large land-use footprint of wind and solar energy. The advantage of oil and natural gas production is that the well pads take up minimal space and all but a small portion of the land can be recovered for its original use. The price calculated for oil recovery was taken as the break-even price of oil in Qatar for 2015. Assumptions for converting units to kWh were taken from EIA.[21]

## Cooling systems

The various cooling technologies compared in table 6 are based on United States estimates from a report by EPRI (2012). There are four types of cooling systems that are analysed: wet, dry direct, dry indirect and hybrid. There are three types of power generation plants investigated: coal fired steam plant, nuclear steam plant and gas-fired, combined-cycle plant. Wet cooling technology is the most cost-effective but the least water conscious. Dry indirect cooling has the highest financial burden but requires zero water for cooling.

**Table 6.** Cost of cooling systems

| Cooling systems | | | | | | |
|---|---|---|---|---|---|---|
| - | Coal fired steam plant | | Nuclear steam plant | | Gas-fired, combined-cycle plant | |
| | US$/kWh | $m^3$/kWh | US$/kWh | $m^3$/kWh | US$/kWh | $m^3$/kWh |
| **Wet** | 0.00080 | 0.00160 | 0.00087 | 0.002145 | 0.00037 | 0.00078 |
| **Dry direct** | 0.00335 | 0 | - | - | - | - |
| **Dry indirect** | 0.00544 | 0 | 0.00585 | 0 | 0.00162 | 0 |
| **Hybrid** | 0.00267 | 0.00068 | 0.00561 | 0.001123 | 0.00126 | 0.00036 |

**Source:** EPRI, 2012.

# Technology scorecard: synergies and trade-offs between technology choices

The choice of technology, and resource allocation, should not be made by resources managers alone but incorporate the views of a range of stakeholders, including those from the food, industrial and economic development, public health, financing and energy security, and environment sectors.[22] We propose a simple tool to compile, compare and evaluate available data of different technologies to enable decision makers to make choices aligned with their national goals and priorities. This tool, or scorecard, is holistic in nature, incorporating the water-energy-food nexus framework, robust and requires minimal data input. This section describes the tool and its application to key water and energy production technologies. While this scorecard includes the major considerations when choosing a technology, further refinement is required for use in specific and localized cases.

### The concept of a scorecard

In June 2008, in advance of the G8 summit in Japan, the World Wildlife Fund (WWF) released a report on the progress of each of the G8 countries in addressing climate change.[23] The report ranked the G8 countries – Canada, France, Germany, Italy, Japan, Russia, the United States and the United Kingdom – on quantitative indicators, such as emissions trends since 1990 and progress towards each country's emissions target under the Kyoto Protocol. The report evaluated performance in three specific policy areas: energy efficiency, renewable energy and development of carbon markets. It also examined the climate and energy policies of five emerging economies: Brazil, China, India, Mexico and South Africa.[24]

Inspired by the concept of scorecards defined by WWF, we propose a framework for a scorecard with some examples of technologies in water and energy resources. The examples are intended to demonstrate the concept; they are not meant to provide an exhaustive checklist for technologies. Some of the local and site-specific data for these technologies are missing and warrant further study. The technology scorecard suggested here should give a good comparison between technologies, taking into account the following:

a. Resource requirements (sustainability): water and energy footprint;
b. Economic aspects: cost of production, operating costs, maintenance costs, land requirements and associated cost;
c. Environmental impact: carbon footprint and international regulations, air quality, water pollution, solid discharges, effects on soil quality (i.e. sludge);
d. Human capacity requirements: number of people required to run the process and their level of competence (personnel skills);
e. Technical requirements and robustness: capacity of the technology to respond to weather conditions (seasonal effects such as dust, humidity, etc.) and shock, corrosion, fouling and operator faults, among others. Pre-treatment requirements for feed. Capacity for automation. Chemicals needed. Characteristics of the product/effluent. Flexibility to scale or integrate existing technologies or grids. Small-scale/local solution;
f. Sociocultural criteria: awareness, information requirements, institutional requirements, local development and responsibility.

In addition to the objective analytical data listed above, the scorecard allows for the subjective preferences of decision makers. This enables the user to choose how to weigh the six quantitative attributes above. These individuals are best suited to prioritize the attributes based on local constraints. The combination of quantitative (technical) and qualitative (policy) information provides the user with a systematic and reproducible assessment and ranking tool to quantify trade-offs between various technologies.

The scorecard enables simple analytical and objective evaluation of technology options as well as the analytical framework for trade-offs among the six outcomes outlined above. Table 6 shows a proposed scorecard with the elements to be evaluated for each technology.

When assigning scores or weights to each of the attributes for different technologies, it is important to frame the right questions. The biggest criteria for choosing a technology are commonly economic, especially for wastewater. Nevertheless, the priorities can differ drastically among decision makers at different levels. For example, at the local level, a community could be more concerned about sustainability and reuse of water even when there are no regulations; at the State level, decision makers might be focused mostly on cost and/or meeting national and international standards. If a technology requires higher initial investment but will bring savings in water and energy requirements, this can be weighed and evaluated in more depth; and when decision makers have given a higher weight to the carbon footprint but find their chosen technology requires high human capacity, they can then seek to identify trade-offs, where savings or aid money can finance the costs of hiring operators with higher skills.

This simple qualitative evaluation of technologies can help expand the scope of decision-making, so solutions can be approached in a more integrated manner. This concept of system parameters can show how, in many instances, decisions simply move problems in time and space rather than solve them.[25] That is, if the economic aspects are the only criteria used for choosing a technology, the neglected environmental, social and technical aspects will most probably deteriorate with time and create a crisis.

The following section demonstrates the technology scorecard for energy and water technologies. Again, the list is not intended to include all attributes, nor all technologies. Further analysis is needed for specific technologies for a given location.

**Table 7.** Technology Scorecard

| Attribute | Attribute Weight |
|---|---|
| **1. Resource Requirements:** | |
| Water footprint | |
| Energy footprint | |
| **2. Economic aspects:** | |
| Capital cost | |
| Production cost | |
| Operating cost | |
| Maintenance cost | |
| Land requirement | |
| **3. Environmental impact:** | |
| Carbon footprint | |
| Air quality | |
| Water quality | |
| Soil quality | |
| Solids discharge | |
| **4. Human capacity requirements:** | |
| Competence required (personnel skills) | |
| Number of operators required | |
| **5. Technical requirements and robustness:** | |
| Response to seasonal effects (dust, humidity, etc), operator faults, fouling, etc. | |
| Pre-treatment requirements | |
| Capacity for automations | |
| Chemicals needed | |
| Flexibility to scaling or integrating to existing technologies/grids | |
| Small scale/local solution | |
| **6. Social-cultural criteria:** | |
| Awareness required to adopt technology | |
| Responsibility requirements from decision makers | |
| Institutional support requirements | |
| Local development potential (“home-made technology”) | |
| Job creation potential | |

# Desalination technologies scorecard: sample card for a few desalination technologies

Below is a suggested scorecard for comparing desalination technologies.

**Table 8.** Scorecard for various desalination technologies available

| Desalination | Technologies | | | |
|---|---|---|---|---|
| **1. Resource Requirements:** | **RO** | **MSF** | **MED** | **MSF Cogen.** |
| Water footprint | 40% of feed | | | |
| Energy footprint (kWh/m³) | 3 - 11 | 53 - 80 | 43 - 80 | 4.7 |
| **2. Economic aspects:** | | | | |
| Production cost (US$/m³) | 0.50 | 0.9 - 1.5 | 1.00 | 0.85 |
| Operating cost (US$/m³) | | | | |
| Maintenance cost (US$/m³) | | | | |
| Land requirement | Medium | Medium | Medium | Medium |
| **3. Environmental impact:** | | | | |
| Carbon footprint (kg $CO_2$eq/m³) | 0.4–6.7 Salt water 0.4–2.5 Brackish | 23 - 35 | 18 - 27 | |
| Air quality impact | Low | High | High | |
| Water quality impact (temperature) | Low | High | High | |
| Soil quality impact | | | | |
| Solids discharge | High | Low | Low | |
| **4. Human capacity requirements:** | | | | |
| Competence (personnel skills) | High | Medium | Low | Medium |
| Number of operators required | Similar - dependent on plant capacity | | | |
| **5. Technical requirements and robustness:** | | | | |
| Response to seasonal effects (dust, humidity, etc), operator faults, fouling, etc. | Low | Medium | High | Medium |
| Pre-treatment requirements | Medium | | Medium | |
| Capacity for automations | Medium | Medium | Medium | Medium |
| Chemicals needed | | | | |
| Flexibility to scaling or integrating to existing technologies/grids | High | High | High | High |
| Small scale/local solution | | | | |
| **6. Social-cultural criteria:** | | | | |
| Awareness required to adopt technology | Medium | High | Medium | High |

| | | | | |
|---|---|---|---|---|
| Responsibility requirements from decision makers | | | | |
| Institutional support requirements | Medium | Medium | Medium | High |
| Local development potential (“home-made technology”) | High | High | High | High |

**Sources:** Author’s data; Miller, 2003; Al-Mutaz, 2001; Raluy et al., 2004 and IRENA, 2011.

## Wastewater treatment technologies scorecard

The scorecard below compares three wastewater treatment technologies. As mentioned previously, anaerobic systems are a particularly relevant technology for consideration; the resource requirements, environmental impact and robustness of the anaerobic digestion of effluents and solid residues offer distinct advantages in the Arab region.

Sewage pipes discharging treated wastewater into the Dubai Creek at night. Dubai, United Arab Emirates
© Philip Lange - Shutterstock_ 250248352

**Table 9.** Scorecard for various wastewater treatment technologies available

| Wastewater Treatment | Technologies | | |
| --- | --- | --- | --- |
| **1. Resource Requirements:** | **Mechanical** | **Lagoon** | **Terrestrial (Land Treatment)** |
| Water footprint | | | |
| Energy footprint (kWh/m³) | 0.099-0.629 | 0.013-0.153 | 0.016-0.040 |
| **2. Economic aspects:** | | | |
| Production cost | 3.25-10.75 | 1.00-4.00 | 2.50-8.50 |
| Operating cost<br>Maintenance cost | 0.75-2.90 | 0.10-0.75 | 0.10-0.80 |
| Land requirement | 0.0001 | 0.001 -0.043 | 0.001 - 0.185 |
| **3. Environmental impact:** | | | |
| Carbon footprint | | | |
| Air quality | | | |
| Water quality | | | |
| Soil quality | Medium | High | High |
| Solids discharge | | | |
| **4. Human capacity requirements:** | | | |
| Competence (personnel skills) | High | Low | Low |
| Number of operators required | High | Medium | Medium |
| **5. Technical requirements and robustness:** | | | |
| Response to seasonal effects (dust, humidity, etc), operator faults, fouling, etc. | | | |
| Pre-treatment requirements | | | |
| Capacity for automations | | | |
| Chemicals needed | | | |
| Small scale/local solution | Medium | High | High |
| **6. Social-cultural criteria:** | | | |
| Awareness required to adopt technology | | | |
| Responsibility requirements from decision makers | | | |
| Institutional support requirements | | | |
| Local development potential ("home-made technology") | | | |

**Sources:** Author's data; Muga and Mihelcic, 2008.

## Electrical power technologies: an example for a scorecard

**Table 10.** Scorecard for various electrical power generation technologies available

| Electric Power Production | Technologies | | | | | | |
|---|---|---|---|---|---|---|---|
| | OIL | | Natural Gas | Solar | Hydropower | Wind | |
| | Primary-Secondary | EOR-Tertiary | Conventional | Photovoltaic | Hydroelectric | Onshore | Offshore |
| **1. Resource Requirements:** | | | | | | | |
| Water footprint ($m^3$/kWh) | 2.1E-03 | 2.1E-03 | 3.2E-05 | 8.4E-04 | 1.7E-02 | 2.8E-04 | 2.8E-04 |
| Energy footprint (kWh/$m^3$) | N/A | | | | | | |
| **2. Economic aspects:** | | | | | | | |
| Production cost (US$/kWh produced) | 0.5 | 0.5 | 3.25-10.75 | >0.2 | 0.04 | | 0.04-0.07 |
| Operating cost (US$/kWh produced) | | | | 0.0023 | | 0.013 | 0.013 |
| Maintenance cost (US$/kWh produced) | | | | | | | |
| Land requirement | Low | Low | Low | High | N/A | Medium | N/A |
| **3. Environmental impact:** | | | | | | | |
| Carbon footprint (ton $CO_2$/GWh) | 1337.5 | | 943.5 | 84.1 | 14.6 | 51.1 | 51.1 |
| Air quality | Medium | | Medium | N/A | N/A | N/A | N/A |
| Water quality risk | Medium | Medium | Medium | N/A | Low | N/A | N/A |
| Soil quality risk | Medium | Medium | Medium | N/A | N/A | N/A | N/A |
| Solids discharge | N/A | N/A | N/A | N/A | N/A | N/A | N/A |
| **4. Human capacity requirements:** | | | | | | | |
| Competence (personnel skills) | | | | | | | |
| Number of operators required | | | | | | | |

| Electric Power Production | Technologies | | | | | | |
|---|---|---|---|---|---|---|---|
| | OIL | | Natural Gas | Solar | Hydropower | Wind | |
| | Primary-Secondary | EOR Tertiary | Conventional | Photovoltaic | Hydroelectric | Onshore | Offshore |
| **1. Technical requirements and robustness:** | | | | | | | |
| Response to seasonal effects (dust, humidity, etc), operator faults, fouling, etc. | Low | Low | Low | Medium | Low | Medium | Medium |
| Pre-treatment requirements | N/A | N/A | N/A | N/A | N/A | N/A | N/A |
| Capacity for automation | | | | | | | |
| Chemicals needed | Low | Medium/ High | Low | N/A | N/A | N/A | N/A |
| Flexibility to scaling or integrating to existing technologies/grids | High | High | High | Low | Medium | Low | Low |
| Small scale/local solution | Low | Low | Low | High | High | High | High |
| **2. Social-cultural criteria:** | | | | | | | |
| Awareness required to adopt technology | High | Medium | High | Low | Low | Low | Low |
| Responsibility requirements from decision makers | Low | Low | Medium | Medium | | | |
| Institutional support requirements | Medium | Medium | Medium | Medium | High | High | High |
| Local development potential ("home-made technology") | | | | | | | |

**Sources:** Feng et al., 2014; US NRC, 2010; Delucchi and Jacobson, 2011.

# Institutional support for adopting technologies that promote water-energy security nexus

The abovementioned water and energy production technologies, along with the systematic processes to rank and assess them, are key to the water-energy security nexus. In this section we consider other factors crucial to these technologies being successfully implemented.

## Incentives for investment in research and development

To be successful, technologies need to adapt to local environmental conditions, constraints and governance. In most developing countries, technologies are developed locally. While the public sector typically invests in long-term research capacity that later becomes the foundation of technological innovation, the private sector is increasingly involved in short-term investment in research and development. The role of both sectors is crucial. Funding streams and policies to protect innovation and intellectual property are essential. These lessons must be transferred to the Arab region, which urgently needs to develop a culture of innovation.

## Investment in human capital

Human capital is essential for technological innovation. Long-term investment is needed to build capacity at the institutional, academic, technical, vocational and outreach levels, and should include the major supply chain of the water and energy industry.

A greater knowledge pool needs to be developed to increase understanding of the water-energy nexus. To this end, using decision-support nexus tools can be beneficial, but such tools require extensive data inputs, and in many cases, the required data are not available. The interaction between academia, decision makers and the private sector should be strengthened through training programmes that promote the use of nexus tools. These tools can create scenarios using various technology options and provide a quantitative overview of their impact on aspects of the water-energy security nexus.

## Technology and knowledge transfer

This process, usually overlooked, links the two ends of the knowledge supply chain: the research and development community and end users of these technologies. While the focus of this module has been on technologies, the biggest lever in water and energy conservation is conservation itself. This is where public engagement and technology and knowledge transfer efforts are most effective.

Greater efforts are needed to generate and transfer accurate data into the policy sector. The technical community should be able to provide the relevant tools and information to encourage diversification in the national and regional portfolios of the nexus. Having a common database among sectors is another way to create synergies and promote productive negotiations.

Overlook Water Desalination Plant of Dubai © shao weiwei - Shutterstock_ 15511060

The decision-making tools need to create further indicators to measure the impacts of an implemented policy, where costs, benefits and impacts can be evaluated.

## Financing the implementation

Often, water-energy nexus solutions cross the sectoral divide, and deciding which sector pays for these solutions needs to be explored. It is estimated that developing countries need

**Table 11.** The projected long-term rate of return on investments in the water sector

| Country | Required investments in water and sanitation services (US$ million) | Potential benefit (US$ million) | Rate of return (%) | Average annual rate of return (%) |
|---|---|---|---|---|
| **Algeria** | 3,622.3 | **19,303.3** | **432.9** | **39.4** |
| **Comoros** | 218.7 | 400.9 | 83.3 | 7.5 |
| **Djibouti** | **284.4** | **320.9** | **12.8** | **1.2** |
| **Egypt** | 4,484.4 | 11,073.6 | 146.9 | 13.4 |
| **Iraq** | **8,217.1** | **22,653.3** | **175.7** | **16.0** |
| **Jordan** | 135.3 | 1,635.5 | 1108.7 | 100.8 |
| **Mauritania** | **2,146.3** | **1,722.9** | **-17.4** | **-1.6** |
| **Morocco** | 8,484.2 | 9,608.4 | 13.3 | 1.2 |
| **Oman** | **259.7** | **1,756.0** | **576.1** | **52.4** |
| **Sudan** | 30,187.1 | 18,634.3 | -38.3 | -3.5 |
| **Tunisia** | **1,461.9** | **2,438.0** | **66.8** | **6.1** |
| **Yemen** | 12,722.4 | 9,767.5 | -23.2 | -2.1 |
| **Total** | **72,224.0** | **99,364.5** | **37.6** | **3.4** |

**Source:** UNDP, 2013.

more than US$1 trillion to meet the growing demand for infrastructure, excluding climate change impact,[26] which is more than their annual spending. Implementing the Sustainable Development Goals will be difficult without proper investment in this infrastructure. Financing mechanisms must be set in place to increase water and energy access in the Arab region.

# Key messages and recommendations

Choosing technologies for the water and energy sectors should not be based merely on economic or technical feasibility, nor on popularity, availability and convenience. The suitability and sustainability of a technology should be assessed holistically, taking into account:

a. Primary resource requirements of water, energy and land;
b. Economic and financial aspects;
c. Environmental impacts to land, water and atmosphere;
d. Human resources needed to develop and maintain technologies;
e. Technical suitability to local conditions and robustness;
f. Social and cultural suitability to local practices.

This module incorporates these factors in a technology scorecard. Technological solutions are presented, having considered the local environment, governance and ecology. What works in one area will not work in another, which is reflected in the different scorecard ratings. This tool for evaluating technologies can be seen as a roadmap, not a one-size-fits-all solution.

Choosing a technology becomes a locally grounded exercise, weighing up all relevant factors. For example, a higher water footprint for cooling might be acceptable in the eastern Mediterranean region where water is relatively readily available; however, it may not be suitable for GCC countries, where solar energy might be the more suitable option.

Other examples presented include desalination as an alternative source of water, which is of utmost importance to the Arab region. Nevertheless, investment in desalination technologies should be undertaken in parallel with investment in renewable energy systems to power energy-intensive water production technology and reduce the carbon and energy footprint. Similarly, the water footprint of energy production should be used as a criterion for energy production technologies.

# Endnotes

1. UNDESA, 2015.
2. Arab Union of Electricity, 2015.
3. WWAP, 2014.
4. UNDP, 2013.
5. Ibid.
6. Ibid.
7. Qadir et al., 2010.
8. World Bank, 2016.
9. WEF, 2007.
10. WWAP, 2014.
11. Ibid.
12. Darwish and Mohtar, 2012.
13. Ibid.
14. Guerra and others, 2011.
15. Darwish and Mohtar, 2012.
16. Mohtar and Daher, 2014.
17. Mohtar and Daher, 2014.
18. EIA, 2015.
19. REN21, 2014.
20. IRENA, 2015.
21. EIA, 2015.
22. WWAP, 2014.
23. WWF, 2008.
24. Ibid.
25. Kirk and others, 2005.
26. World Bank, 2014.

# Bibliography


Al-Mutaz, Ibrahim S. (2001). The continued challenge of capacity building in desalination. *Desalination*, vol. 141, No. 2, pp. 145-156.

Arab Union of Electricity (2015). Statistical Bulletin 2015, issue 24. Available from http://www.auptde.org/Article_Files/inside%202016.pdf.

Darwish, Mohamed A., and Rabi Mohtar (2012). Qatar water challenges, desalination & water treatment. Paper presented at the International Conference on Desalination for the Environment, Clean Water and Energy, European Desalination Society. Barcelona, April. Available from http://wefnexus.tamu.edu/files/2015/01/Qatar_water_challenge_Journal_paper.pdf.

Delucchi, Mark A., and Mark Zachary Jacobson (2011). Providing all global energy with wind, water, and solar power, Part II: Reliability, system and transmission costs, and policies. *Energy Policy*, vol. 39, No. 3, pp. 1170-1190.

Energy Information Administration (EIA) (2015). United States Energy Information Administration. Energy Units and Calculator Explained. Available from http://www.eia.gov/Energyexplained/?page=about_energy_units.

Entergy (n.d.). *A Comparison: Land Use by Energy Source - Nuclear, Wind and Solar.* Available from http://www.entergy-arkansas.com/content/news/docs/AR_Nuclear_One_Land_Use.pdf.

Electric Power Research Institute (EPRI) (2012). *Economic Evaluation of Alternative Cooling Technologies*. Report No. 1024805. Palo Alto, California, USA. January.

Feng, Kuishuang, and others (2014). The energy and water nexus in Chinese electricity production: A hybrid life cycle analysis. *Renewable and Sustainable Energy Reviews*, vol. 39, pp. 342-355.

Guerra, Katie, and others (2011). Oil and Gas Produced Water Management and Beneficial Use in the Western United States. U.S. Department of the Interior, Bureau of Reclamation. Available from https://www.usbr.gov/research/AWT/reportpdfs/report157.pdf.

International Renewable Energy Agency (IRENA) (2011). *Desalination Technologies and the Use of Alternative Energy for Desalination*. November 2011. Available from http://www.wipo.int/export/sites/www/patentscope/en/programs/patent_landscapes/documents/patent_landscapes/948-2E-WEB.pdf.

International Renewable Energy Agency (IRENA) (2015). *Renewable Energy in the Water-Energy and Food Nexus*. Available from http://www.irena.org/documentdownloads/publications/irena_water_energy_food_nexus_2015.pdf.

Kirk, Barton, and others (2005). *Methods for Comparing Wastewater Treatment Options*. Project No. WU-HT-03-33. Prepared for the National Decentralized Water Resources Capacity Development Project. Washington University, St. Louis, Missouri, USA, by Oceans Arks International Burlington, Vermont. Available from http://www.ndwrcdp.org/documents/WU-HT-03-33/WU-HT-03-33.pdf.

Knoema (2016). Oil Statistics. Available from http://knoema.com/vhzbeig/oil-statistics-production-costs-breakeven-price. Accessed 2 April 2016.

League of Arab States, Economic and Social Commission for Western Asia and Arab Countries Water Utilities Association (2015). *MDG+ Initiative First Report 2015*. Amman, Jordan. Available from http://www.acwua.org/mdg+/images/files/FINAL.pdf.

Mandi, Laila, and Naaila Ouazzani (2016). Water and wastewater management in Morocco: Biotechnologies application, Sustainable Sanitation Practice. *WaterBioTech*, (January 2013), pp. 9-16.

Mielke, Erik, and others (2010). Water Consumption of Energy

Resource Extraction, Processing, and Conversion. Energy Technology Innovation Policy Discussion Paper Series, 2010-15 (October). Cambridge Massachussets, USA: Belfer Center for Science and International Affairs Harvard Kennedy School.

Miller, James E. (2003). Review of Water Resources and Desalination Technologies. Albuquerque, New Mexico: Sandia National Laboratories. March 2003. Available from http://prod.sandia.gov/techlib/access-control.cgi/2003/030800.pdf.

Mohtar, Rabi H. and Bassel Daher (2014). A Platform for Trade-off Analysis and Resource Allocation: The Water-Energy-Food Nexus Tool and its Application to Qatar's Food Security. Chatham House: The Royal Institute of International Affairs.

Muga, Helen E., and James R. Mihelcic (2008). Sustainability of wastewater treatment technologies. *Journal of Environmental Management*, vol. 88, No. 3, pp. 437-447.

National Research Council (NRC) (2010). Hidden Costs of Energy - Unpriced Consequences of Energy Production and Use. Committee on Health, Environmental, and Other External Costs and Benefits of Energy Production and Consumption. Washington, D.C.: The National Academies Press.

Qadir, Manzoor, and others (2010). Wastewater production, treatment, and irrigation in Middle East and North Africa. *Irrigation and Drainage Systems*. June 2010, Volume 24, Issue 1, pp 37-51.

R. G. Raluy, and others (2004). Life-cycle assessment of desalination technologies integrated with energy production systems with energy production systems. *Desalination*, vol. 167, pp. 445-458.

Renewable Energy Policy Network for the 21st Century (REN21) (2014). *Renewables 2014: Global Status Report*. Available from http://www.ren21.net/Portals/0/documents/Resources/GSR/2014/GSR2014_full%20report_low%20res.pdf.

Sustainable Energy for All (SE4All) (2015). *Progress Toward Sustainable Energy: Global Tracking Framework, 2015 Summary Report*. Washington, D.C.: The World Bank. Available online from http://www.worldbank.org/content/dam/Worldbank/Event/Energy%20and%20Extractives/Progress%20Toward%20Sustainable%20Energy%20-%20Global%20Tracking%20Framework%202015%20-%20Summary%20Report.pdf.

United Nations World Water Assessment Programme (WWAP) (2014). *The United Nations World Water Development Report 2014: Water and Energy*. Paris: UNESCO. Available from http://unesdoc.unesco.org/images/0022/002257/225741E.pdf.

United Nations Development Programme (UNDP) (2013). *Water Governance in the Arab Region: Managing Scarcity and Securing the Future*. New York: UNDP, Regional Bureau for Arab States. Available from http://www.undp.org/content/dam/rbas/doc/Energy%20and%20Environment/Arab_Water_Gov_Report/Arab_Water_Gov_Report_Full_Final_Nov_27.pdf.

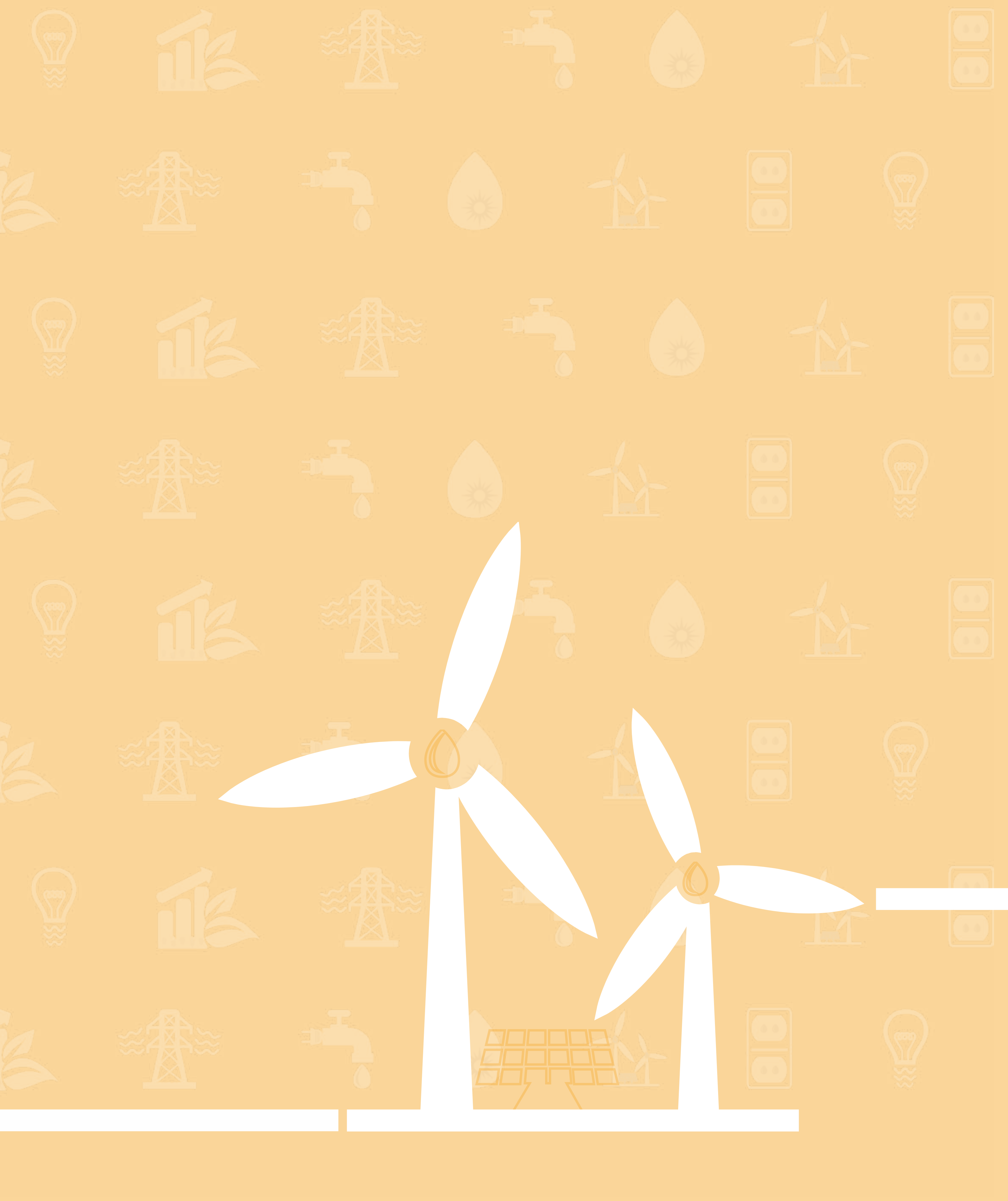
United Nations Department of Economic and Social Affairs (UNDESA) (2015). The Sustainable Development Goals. Available from https://sustainabledevelopment.un.org/sdgs. Accessed May 2016.

Water Environment Federation (WEF) (2007). Operation of Municipal Wastewater Treatment Plants. Alexandria, Virginia: WEF. Available from https://www.e-wef.org/Default.aspx?TabID=251&productId=3752.

World Bank (2014). *Transforming through infrastructure: Infrastructure Strategy Update FY2012-2015*. Washington DC: The World Bank. Available from http://siteresources.worldbank.org/INTINFRA/Resources/Transformationthroughinfrastructure.pdf.

World Bank (2016). The Activated Sludge Treatment Process. Washington, D.C. Available from http://water.worldbank.org/shw-resource-guide/infrastructure/menu-technical-options/activated-sludge. Accessed May 2016.

World Wildlife Fund (WWF) (2008). G8 Climate Scorecards. Gland, Switzerland: WWF. Available from http://assets.panda.org/downloads/2008_g8_climate_scorecards.pdf.



# Promoting Renewable Energy

6 Module

# Contents



## List of figures



## List of tables



## List of boxes

# Abbreviations and explanatory notes

| | |
|---|---|
| AFESD | Arab Fund for Economic and Social Development |
| CHP | combined heat and power |
| COP | Conference of the Parties |
| COP21 | 21st Session of the Conference of the Parties to the United Nations Framework Convention on Climate Change |
| CSP | concentrated solar power |
| EP | electric power |
| ESCWA | Economic and Social Commission for Western Asia |
| EU | European Union |
| FAO | Food and Agricultural Organization |
| GCC | Gulf Cooperation Council |
| GCR | Global Competitiveness Report |
| GCI | Global Competitiveness Index |
| GDP | gross domestic product |
| GW | gigawatt |
| GWe | gigawatt electrical |
| GWh/year | gigawatt hour per year |
| HVDC | high voltage direct current |
| IRENA | International Renewable Energy Agency |
| $KWh/m^2$ | kilowatt hour per square meter |
| MED-TVC | multi-effect thermal vapor consumption |
| MENA | Middle East and North Africa |
| MSF | Multi-stage flash distillation |
| MW | megawatt |
| MWe | megawatt electrical |
| NREAP | national renewable energy action plans |
| OECD | Organization for Economic Cooperation and Development |
| PV | photovoltaic |
| RE | renewable energy |
| RO | reverse osmosis |
| RSP | regional solar programme |
| SCP | sustainable consumption and production |
| SCPDP | self-consistent point dipole polarizability |
| SDG | Sustainable Development Goal |
| SE4All | Sustainable Energy for All |
| SSE | surface meteorology and solar energy |
| SWRO | salt water reverse osmosis |
| UNDP | United Nations Development Programme |

# Background and objectives of this module

Energy resources are of national strategic importance. Countries develop their energy portfolio to meet increasing demand from various economic sectors, keeping in mind this energy mix has a direct impact on the national and global environment. Countries worldwide are exploring the potential of renewable energy to reduce dependencies on limited, high-cost fossil fuels, the environmental impact of emissions and the rising carbon concentration in the atmosphere.

As part of the international carbon emission agreement reached in November 2015, government leaders pledged to increase the percentage of renewable energy (solar, wind, hydropower, biomass, etc.) in their national energy consumption. The commitments made at the 21st Session of the Conference of the Parties to the United Nations Framework Convention on Climate Change (COP21) in Paris will lead to a significant boost in the deployment of renewable energy and the gradual shift away from fossil fuel-driven economies. According to the International Renewable Energy Agency (IRENA), countries can deliver on the commitments they made at COP21 to keep global temperature increases below 2 degrees Celsius by rapidly scaling up wind and solar power to 36 per cent of the global energy mix by 2030. This would result in a global increase in GDP of 1.1 per cent and more than 24 million job opportunities in the renewable energy sector.[1] According to a report by Bloomberg, global clean energy investment attracted US$329 billion in 2015.[2]

Renewable energy in general and solar energy in particular will reduce the release of $CO_2$ and other emissions into the atmosphere, and also the excess heat generated from burning diminishing reserves of fossil fuels.

But augmenting the current energy portfolio with renewable energy and developing alternative energy within the existing national portfolio comes with significant prerequisites, including:

a. An understanding of how the new portfolio will interface with different energy users and other resources. This comes through quantifying energy consumption patterns across different sectors and specific practices that could be supplied by alternative energies;
b. Recognizing the impact of the new portfolio on other primary resources, such as water and land (and, therefore, agriculture);
c. Evaluating the role of this new portfolio in expanding energy access to remote rural areas where previous centralized energy production systems prevented electrification;
d. Setting up a renewable energy readiness plan that includes financial, technological, social, and policy components.

In the Arab region, which has significant water shortages, this new energy portfolio should reduce the water footprint of energy production as well as cut carbon emissions.

Addressing the prerequisites above requires a holistic approach to interactions between water, energy, land, and food within a complex external environmental and socioeconomic landscape, that includes expanding economies, climate change, international trade, governance, and global population. The Sustainable Development Goals (SDGs) bring a new momentum that allows renewable energy to be a catalyst for equity, alleviating poverty and increasing access to resources (water, energy, food), especially in previously deprived areas. A platform of nexus links and tradeoffs can help decision makers navigate this complex energy system and integrate resources planning.

This module presents a framework for achieving renewable energy targets in Arab region countries; it also presents an overview of the state of renewable energy developments in the Arab region. Challenges and opportunities presented by these projections are addressed, and case studies of renewable energy in the ESCWA region provided; these include a hydropower generation project in Lebanon and solar energy for water production in Qatar.

# Framework for achieving national renewable energy targets in the Arab region

Renewable energy is characterized by the following components: environmental (solar energy, wind current and surface water potential, energy, weather, geographical location); socioeconomic (financial capital to invest in renewable infrastructure); human resources (local capacity to develop, manufacture, deploy and maintain these energy systems), policies (subsides for traditional energy sources and incentives for new energy sources).

This section explores these elements as a guide to assess the readiness for a national and regional renewable energy portfolio. Developing the renewable energy sector to its full potential is of critical importance for the Arab region, but in parallel we must endeavour to save energy by better conservation, management and efficiency.

## Working through the barriers to achieving renewable energy targets

Each of the ESCWA countries has its own energy targets. In order to reach these, certain barriers need to be removed. These include:

### *A. Local capacity for research and development*

Renewable technologies need to be developed or adapted for the inherently specific local conditions. This requires national investment in science and technology but it is generally lacking in the Arab region. Lack of local capacity results in the added financial burden of having to import expensive technologies from OECD countries, which, in turn, limits renewable technologies being widely adopted due to high capital, maintenance and operating costs; a scarcity of local operators and know-how means causes a reliance on outside expertise to service these systems. A local capacity plan is a prerequisite for developing renewable energy.

Renewable energy has not received adequate attention in the education systems of the Arab region. A few uncoordinated programmes can be found in engineering and science, but renewable energy has not been incorporated into other relevant areas, such as social sciences, economics, policy, urban planning and management.[3] Industry training is needed to transition to a more diverse energy mix. A limited expertise is also required in the vocational capacity to support the sector's research and development efforts.

Government agencies also need to build capacity in renewable energy. These include ministries of finance, education and public works, and utility plants. Multiple stakeholders are key to integrating renewable energy at national and regional level. Such capacity should not be limited to technical expertise but should include also grid integration, energy policy and planning to better shape the national energy portfolio.

Developing civil society capacities is also important for the move to renewable energy. Awareness campaigns can promote the technology in local communities and improve the public's ability to represent its interests in any national action plan.[4] There have been some efforts to engage civil society in the region, but political and security unrest have stymied these.

### *B. Culture of innovation*

Building local capacity for new technologies requires investing in human capital and creating a culture of innovation that promotes the development and adoption of such technologies. This culture requires more than infrastructure investment; it needs to operate in a free society that values science and creativity.[5]

### *C. Manufacturing and industries*

The lack of manufacturing and industrial capacity in Arab region countries increases the cost of renewable energy technologies as they must be imported and limits the capacity to reach national targets. In addition to investment in science and technology, more vocational training is required to build a strong local workforce with the technical skills to carry innovation forward from ideas into products.[6]

## Enabling policies

Renewable energy requires sound policies for it to be a viable part of the energy portfolio. However, these policies should not conflict with holistic plans for energy conservation to regulate usage and reduce wastage. The two essential elements of public policy are:

1. Energy mix/portfolio and pricing scheme assessment.
2. Energy public awareness and education.

The energy efficiency module highlighted the strong correlation between energy price and energy use and conservation. Energy subsidies are beginning to fade in many Arab countries,

A primitive hand crafted irrigation system and damming of river water by the village people near Ait Ben Haddou, Ouarzazate in Morocco © Gail Palethorpe - Shutterstock_ 350432801

a prime example being Saudi Arabia, where energy price increases are expected to continue. Effective public awareness and conservation campaigns are most needed in the region to enhance efficiency and productivity to reduce unnecessary use of energy.

Governments must develop policies that provide incentives for local industries to produce and adopt renewable energies. Germany's government, for example, developed policies that promote grid integration and market access for solar energy. In addition to the technical capacity to enable trade across the network, policies need to provides incentives for homeowners to invest in the infrastructure – by giving them the opportunity, for example, to offset their initial investment by selling the excess electricity they produce. In addition to grid integration policies and technologies, governments must offer financial and tax incentives to develop the solar energy infrastructure and help counter the initial cost of these systems.

Carbon agreements and setting local emission targets can help promote large-scale renewable energy. These national targets cannot be reached without policies for increased renewables in the energy portfolio. After the Paris agreement, it is expected a large amount of financial aid will be available to developing countries to integrate renewable energy. But the lack of clear laws and regulation may discourage investors. Six Arab States have passed renewable energy laws: Algeria, Jordan, Morocco, the State of Palestine, the Syrian Arab Republic and Tunisia. Egypt in 2009 adopted policies that stimulate and support electricity generation from wind and solar energy to achieve a 20 per cent renewable energy contribution by 2020.[7] In 2014, the Ministry of Electricity and the Electricity Utility Regulatory and Consumer Protection

Agency launched a feed-in tariff support system for solar photovoltaic and wind projects with a capacity of less than 50 MW.[8] A new electricity law no. 87 for the year 2015 was issued, including articles that pave the way for strong private sector involvement in generating and distributing electricity from various energy resources. The Sudan and Yemen have drafted renewable energy electricity laws but these have not been approved.[9]

Most Arab countries have announced national targets for renewable energy deployment. Renewable energy targets were included in the Pan Arab Strategy for Developing Renewable Energy Utilization 2010-2030, endorsed in 2011 by the Arab Ministerial Council of Electricity under the League of Arab States (LAS). However, the format for achieving these targets, adopted by the LAS Department of Energy and used across the region, lacks cohesion and consistency. The National Renewable Energy Action Plans (NREAP) require countries to set targets for 2020 or 2030. A legal framework without tangible action plans and strategies will hinder effective change and growth in national economies. National integrative strategies should describe their objectives for adopting renewable energy (at national security, environmental, social and economic levels) and clear lines of action to follow to achieve their targets.

Jordan, which depends on oil imports to supply 96 per cent of its energy needs, has gone some way to putting in place an integrative strategy. After the 2003 invasion of Iraq, the Royal Committee on the National Energy Strategy found that a diversified national energy mix was required to safeguard against oil supply vulnerability. The Jordanian government decreed that renewable sources should meet 10 per cent of national energy needs by 2020. However, while this might represent momentum for developing renewable energy, plans for major investment to extract and process Jordan's large oil shale reserves could dilute the momentum.[10]

## Emerging technologies

Developing low-cost and locally adapted renewable technology remains a stumbling block to reaching renewable energy targets. With solar energy, two types of technology have been the focus of development, namely:

1. Solar thermal technologies.
2. Photovoltaic systems for direct electricity generation.

The choice between these depends on the environmental conditions and end-users needs. For example, while photovoltaic is useful if the end-user needs electricity, thermal technologies are appropriate for heating water for residential, domestic and industrial sectors and for steam-based energy uses, such as turbines and power plants. Other considerations when making a selection are presented in a scorecard in the module on increasing knowledge of technological choices.

The following is a brief account of both technologies to guide initial screening.

### Thermal technologies

Thermal technologies are robust, with few moving parts requiring less maintenance. Solar water heating technology for the residential sector is widespread in many Arab countries, with the biggest success stories in Jordan, Lebanon, Palestine and Tunisia. Hybrid solar thermal power technologies at the global level do not commercially scale up as quickly as photovoltaic (PV) and wind energy projects. The total installed capacity worldwide is 4.8 gigawatts (GW), compared with 177 GW for PV systems and 433 GW for wind farms in 2015.[11] There are a limited number of operational solar thermal power plants, based on parabolic trough technology, in Algeria, Egypt, Morocco and the United Arab Emirates, while Jordan has taken steps to establish its first solar thermal power plant. Only Morocco has adopted an ambitious plan to carry out 500 megawatt (MW) solar thermal power projects in stages at the Ourzazat site, starting with a 160 MW phase currently being implemented. When appraising their suitability, however, there are some cautions:

a. Materials must be resistant to the high temperatures and dust levels prevalent in Arab region countries. Temperature and dust accumulation significantly affect the efficiency of solar energy capture. Choosing the most suitable materials for local conditions requires solid local research and development, which are generally lacking in the Arab region;
b. Since solar power generation may not be economically feasible during the early investment period, co-generation of power and water production – as in Qatar, where water desalination and power generation are coupled – is the clear way to proceed to make this technology more economically feasible. Another option is tri-generation and system integration, when power and water generation is coupled with district solar cooling. Integrated systems may be the tipping point to make solar power more economically feasible for the Arab region;
c. Cleaning the mirrors of the solar field in severe desert conditions is a key consideration for a region where water is scarce. Using dry cleaning technology brings an extra cost over and above the already high upfront cost of concentrated solar power (CSP) projects, which will be reflected in the cost of the generated kilowatt-hours (KWh);
d. Molten salt is typically used to store thermal energy at night when solar generation power is down. These technologies are expensive and bulky, and require skilled maintenance and careful management for safe use to prevent the salt from crystallizing and prevent leaks and contaminations.

### Photovoltaic

Photovoltaic technologies are among the most commonly used for solar power. They are ideal for generating electricity when the end-user need is electrical power. They do, however, present challenges, due especially to the high temperatures and dust concentrations in many of the Arab countries. Besides working on improving the solar harvesting of these technologies, efforts are being focused on new materials and composites that maintain high efficiencies in high temperatures and for self-cleaning surfaces that are robust when exposed to high dust levels.

Electrical energy storage also remains a major challenge, with batteries heavy, bulky and costly. These concerns must be considered in the context of the Arab region.

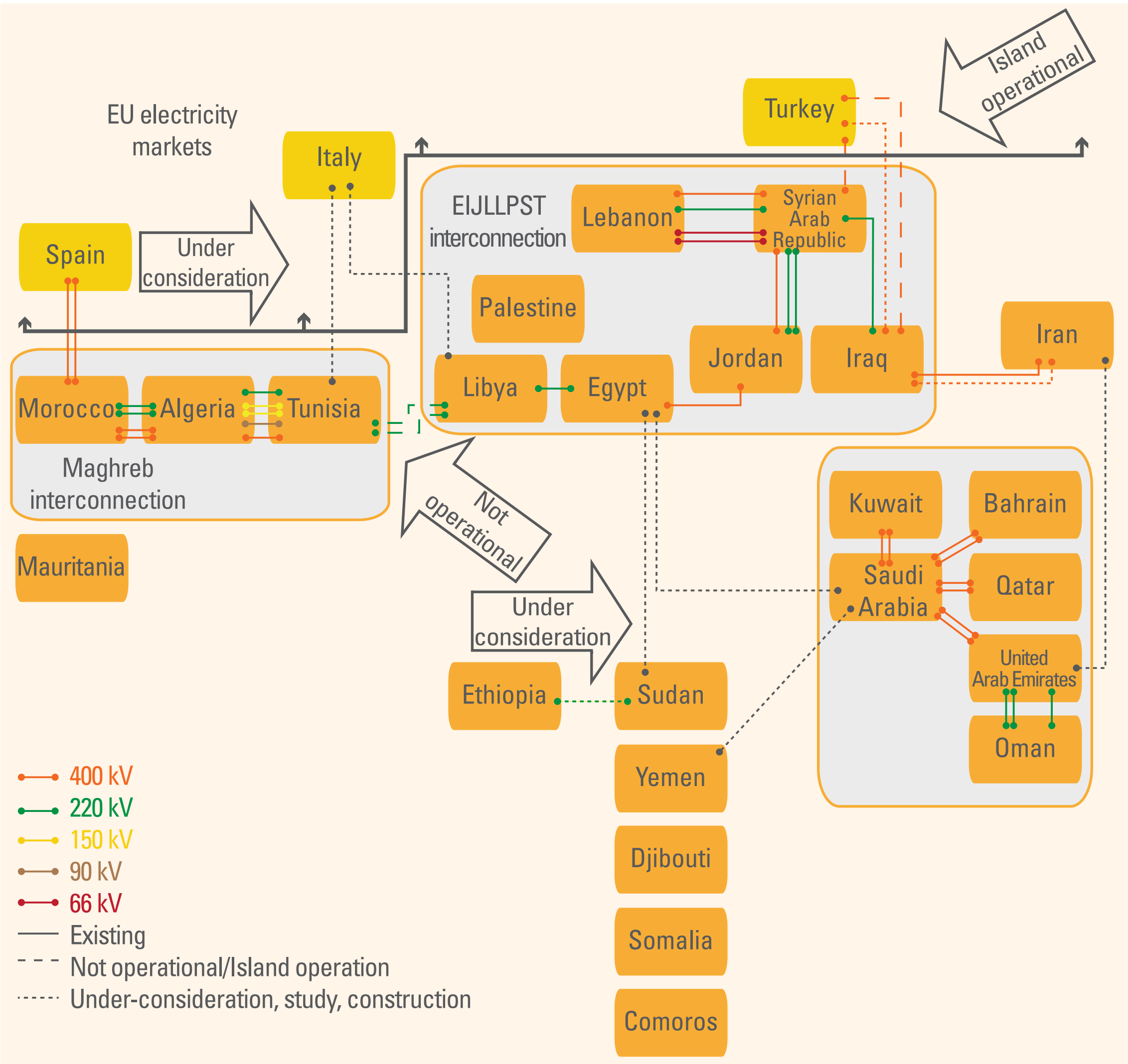
There is virtually no cooperation on technologies across and within countries in the Arab region. Stronger efforts should be made to transfer technology, data and knowledge, and to consolidate research and development efforts to adapt technologies to local conditions and supply chains.[12]

## Regional integration and infrastructure

Transitioning to solar energy requires significant investments in human capital, infrastructure, research and development, manufacturing industry, as well as policies to promote and incubate this growth in renewable energy. These resources are beyond the reach of any one country in the Arab region, but cooperation among countries to create a resources pool will benefit the entire region. While one nation might provide the human capital, for example, others might provide the natural capital or the financial capital for a regional integrated grid to provide power and meet the national renewable energy targets. Sharing knowledge and technologies makes sense in countries that share similar environmental and other conditions. The region is spread over several time and ecological zones and terrains, which potentially spreads the availability of sun and wind energy over a vast geographical area.

Integrating regional electricity markets increases energy security, promotes a more efficient use of infrastructure, allows for greater renewable energy penetration and reduces costs for consumers. Renewable energy technologies that can be scaled up to regional level, rather than

**Figure 1.** Existing and planned electrical grid interconnections




**Source:** World Bank, 2013.

just country level, will enable economies of scale to be realized.[13] Currently there are three major interconnected Arab region grids (figure 1):

1. Maghreb regional interconnection: including Algeria, Morocco, and Tunisia (since 1950). These three countries are all synchronized with the European high-voltage transmission network.
2. The EIJLLPST regional network, comprising Egypt, Iraq, Jordan, Lebanon, Libya, Palestine, the Syrian Arab Republic and Turkey.
3. The GCC power interconnection, which comprises Bahrain, Kuwait, Oman, Qatar, Saudi Arabia and the United Arab Emirates. This grid was created to share reserves and improve supply reliability.

Intermittent wind and solar energy generation has its technical challenges and is not easily integrated into existing infrastructure systems. The grid in the Arab region at present cannot absorb significant variability in quantities of renewable energy electricity coming from small-scale projects. If renewable energy is to be increased in any national energy mix, grids will need to be upgraded to advanced and smart controls, as well as combine conventional alternating current (AC) with high voltage direct current (HVDC).[14] Renewable generation technologies do not have the same voltage and frequency as traditional power sources, though special electrical interconnection norms have helped overcome these technical difficulties. Storage systems can work in tandem with renewable energy systems, enabling energy to be stored and delivered when demand is high.[15]

Wind and solar resources are sufficiently abundant to entice several investors from Europe to examine the region as a potential source of electricity for parts of Europe. The Maghreb region, for example, is already synchronized with Europe. The DESERTEC concept aims to develop 20 GW of renewable energy (mainly solar), with 5 GW to be exported to Europe. Despite the political and economic challenges surrounding regional energy integration, feasibility studies towards this goal are worthwhile. A study by the League of Arab States in cooperation with the Arab Fund for Economic and Social Development in 2014 included three scenarios for interconnecting electricity and natural gas.[16] This study can form the basis for further exploration of such integration.

Investing in regional efforts to promote renewable energy should not, however, come at the expense of local investments in the same. Governments should try to promote solar investment at the local level, including individual households. Though it represents a small contribution per house, the total sum is what matters. In Germany, grid integration and polices allow individual households to trade their excess energy to the grid during the day and buy from it at night. This policy target might face resistance from local power generators and utilities, claiming system capacity will remain the same while the demand will fluctuate during day and night. Although this policy might reduce revenues for utilities, the long-term benefits are paramount and such commercial concerns should not hinder the further expansion and integration of the electricity grid and trade.

## Renewable energy-readiness factor and competitiveness index

To achieve the targets and address the matters raised in the renewable energy (RE) framework outlined above, it is important to have a quantitative measure to assess current and projected progress towards the national renewable energy targets. The EU-GCC network has developed a RE-readiness score, which includes the following pillars:[17]

1. Infrastructure: including natural resources, country overall infrastructure, grid capacity, market infrastructure, electricity access rate and projected demand.
2. Institutions: public and private institutions related on renewable energy, key policies, access to renewable energy finance, macroeconomic environment.
3. Human capital: technical and commercial skills, technology adoption and diffusion and awareness among consumers, investors and decision makers.

Such a readiness score can be generalized for the Arab region and used as a benchmarking tool to help further develop national action plans.

The criteria and score range for readiness is aligned to the Global Competitiveness Report (GCR) developed by the World Economic Forum. The global competitiveness scores have a wider scope at a national level but these factors are relevant when evaluating the readiness of a country to adopt renewable energy technologies (EU-GCC). The table below shows the global competitiveness scores for the GCC countries; the score is out of 7 and the higher the score, the more competitive the country.

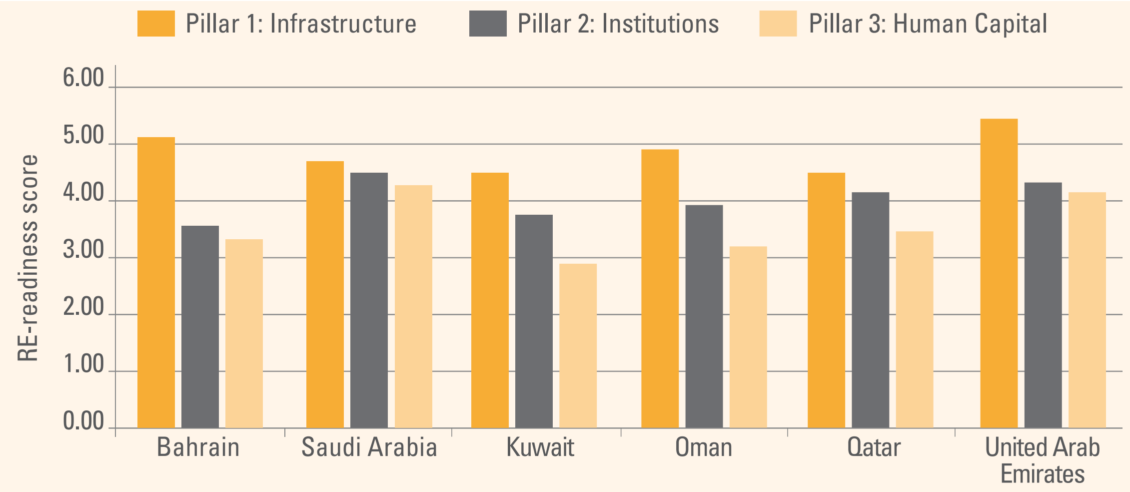
Applying the methodology and criteria described by the EU-GCC for each of the factors mentioned above, figure 2 shows the overall RE-readiness index for each of the pillars for the GCC countries. The scores shown can indicate that, in the GCC countries, human capital for renewable energy deployment is the weakest factor; the policy and institutional factor are in the middle ground; and infrastructure scores are relatively strong.

**Table.** Global competitiveness scores of the GCC countries

| Global Competitiveness Index (GCI)-pillars | Bahrain | Kuwait | Oman | Qatar | Saudi Arabia | United Arab Emirates |
|---|---|---|---|---|---|---|
| GCI 2011-2012 | 4.5 | 4.6 | 4.6 | 5.2 | 5.2 | 4.9 |
| Basic requirements | 5.4 | 5.2 | 5.6 | 5.8 | 5.7 | 5.8 |
| Institution | 5.3 | 4.4 | 5.3 | 5.4 | 5.5 | 5.2 |
| Infrastructure | 5.1 | 4.4 | 5.2 | 5.2 | 5.3 | 6.0 |
| Macroeconomic environment | 5.1 | 6.6 | 6.5 | 6.4 | 6.1 | 6.1 |
| Higher education and training | 5.0 | 3.8 | 4.2 | 4.6 | 4.8 | 4.8 |
| Goods market efficiency | 5.2 | 4.3 | 4.8 | 5 | 5.2 | 5.2 |
| Financial market development | 5.1 | 4.2 | 4.7 | 5 | 5.1 | 4.6 |
| Technology readiness | 4.5 | 3.7 | 4.1 | 4.7 | 4.3 | 4.9 |
| Innovation | 3.2 | 3.0 | 3.4 | 4.7 | 4.2 | 4.0 |

**Sources:** WEF, 2011; Khalifa, 2012.

**Figure 2.** The attractiveness index on renewable energy development pillars in GCC countries




**Source:** Masdar Institute, n.d.

A detailed analysis of the results of such a study is highly valuable to identify gaps and barriers in the adoption of renewable energy and provide a quantitative system for measuring progress in the deployment of RE.

The renewable energy technologies market is still being developed but has reached a level of maturity that is creating momentum in the world's energy mix. The solar photovoltaics systems are becoming less expensive and more efficient. It has also been reported that the cost of such systems is reduced at a rate of 19.3 per cent for every doubling of solar capacity. New investments in renewables globally rose 17 per cent in 2011.[18] Nevertheless, according to the International Renewable Energy Agency, the cost of RE technologies in the Arab region is still not competitive and they require additional support; it was found that 11 countries have not even established a designated renewable energy agency to set policy, deploy private energy projects and build capacity.[19]

Governments should establish appropriate market settings that enable competitive growth of renewable energy in the region; for example, power sector reform, where government involvement is reduced and markets are deregulated to provide space for healthy competition and higher quality services. Market deregulation should be followed by strong policies and regulations to guarantee reliable services and fair pricing. The limited involvement of the private sector in electricity production can be a barrier to deploying renewable energy[20]. On the other hand, private electricity markets that lack strong and clear regulation, as in the case of Lebanon, create a chaotic market that hinders investment in renewable energy.

In the short term, the main barriers that limit competitiveness in the region are:

a. Bureaucracy and inefficient institutional structures;
b. Lack of policy support;
c. Fossil fuel/electricity subsidies.

In general, non-producing countries of the region reinforce their dependency on oil imports due to easy access through neighboring countries, low oil prices in the market, negligible research and development in localizing renewable energy technologies and the absence of a national energy audit.

# Role of renewable energy in the socio-economic development of the Arab region

## Mapping renewable energy potential in the Arab region

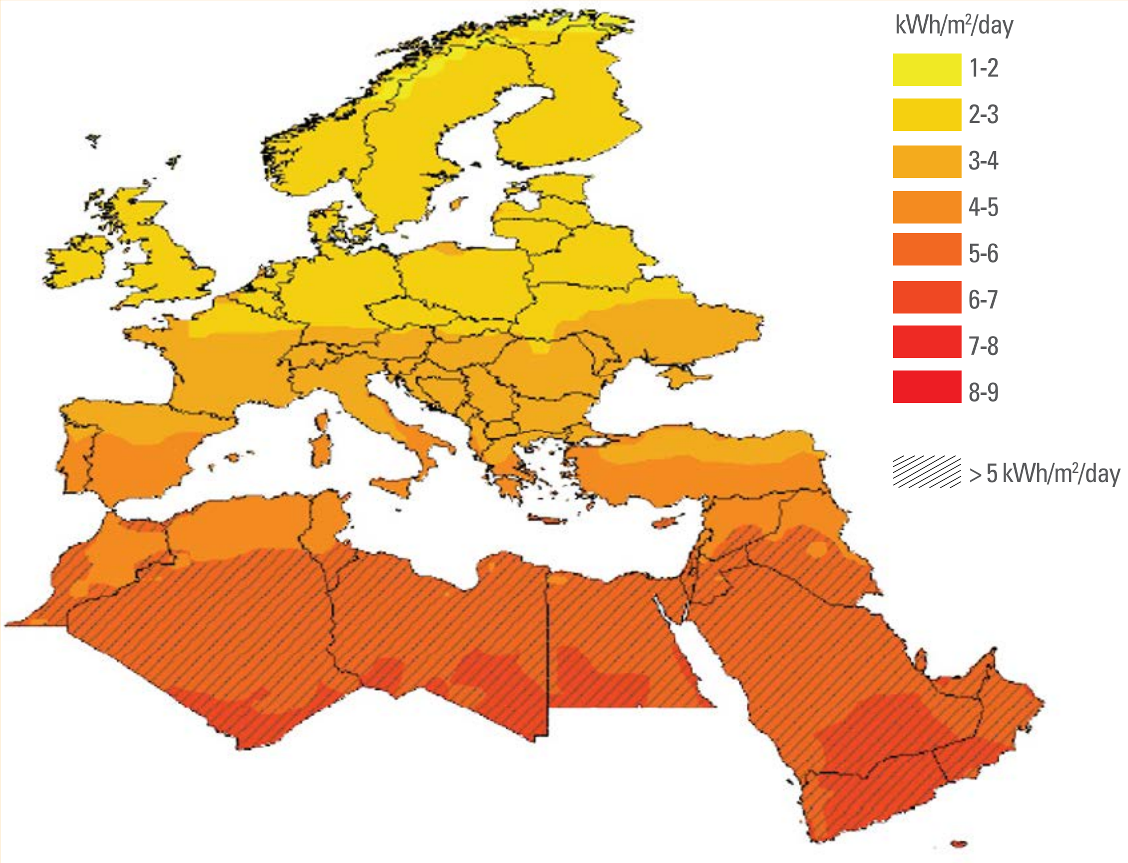
A study financed by the Arab Fund for Economic and Social Development has shown in its initial results that the installed capacity of renewable energy (RE) generation will reach 6 per cent in the Arab region by 2030 and could be higher (up to 11 per cent) if Saudi Arabia installs 23 gigawatts (GW) of RE. Interest in developing RE in the Arab region has been steadily growing and many regional and international organizations promoting RE have been created.[21]

What does all of this mean for the Arab region?

Arab countries possess some of the best renewable energy resources globally. The region is also blessed with a growing availability of locally sourced capital from banks and funds, and an expert community of developers and technical and other advisors. It has governments that understand the opportunities and are prepared to engage with the market to ensure their

Solar panels in desert near Dubai, United Arab Emirates © Kertu - Shutterstock_ 432084217

**Figure 3.** Solar Map for the Arab region



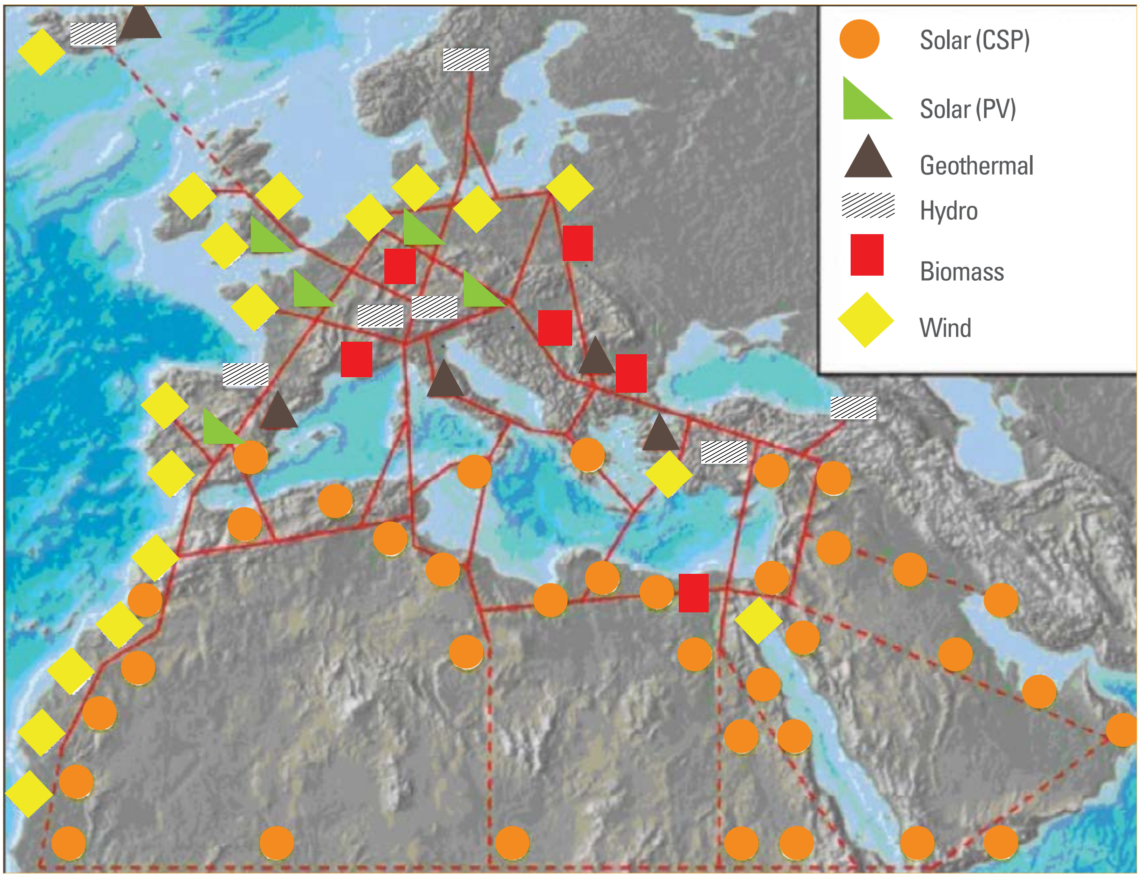

**Source:** NASA, 2014.

programmes work for all. ESCWA member countries are in a prime position to benefit from the global momentum spurred by the 2015 Paris Conference of the Parties (COP) outcome. In 2015 in the Arab region, wind and solar developments broke new low-cost records, which attracted strong international interest and resulted in new project developments and investment. Solar photovoltaic systems are now cheaper than gas for new power projects in a number of markets in the region, as is wind where resources are strong. But instead of renewables competing with conventional power, their ability to complement and neatly fit into an already established energy system is becoming more widely understood. The strong and continuing decline in oil prices impacts on renewables in several ways: as a longer-term energy security strategy, it acts as a catalyst to further strengthen a country's resolve to diversify the energy mix and the economy, and move away from price volatility and single-fuel dependency.[22]

Figure 3 shows the solar energy map for the Arab region. Data interpolated from a global dataset produced by NASA's surface meteorology and solar energy (SSE) programme shows significant solar energy availability in the Arab region.[23]

Besides solar energy, hydropower, wind, biomass and geothermal energy resources are abundant in the Arab region.  Figure 4 shows a spatial mapping of these renewable resources. Based on this map, solar and wind energy are more abundant, with wind mostly on the Atlantic side. Biomass seems to have potential only in Egypt.

**Figure 4.** Renewable energy map for the Arab region



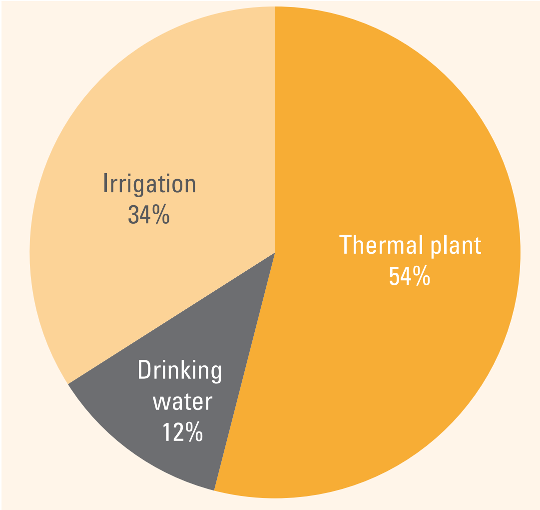

**Source:** DESERTEC, n.d.

## Hydropower potential: Lebanon case study

Renewable energy has not been a high priority for Lebanon, and 97 per cent of its energy needs are met by fossil fuel imports. The energy portfolio includes only 2 per cent of renewable energy for the production of electricity for domestic use.[24] The government has set a target of having 12 per cent of its total energy needs derive from renewable sources by 2020. Looking at the renewable resources in the country and the potential for hydropower, solar and wind, this target can be achieved mostly by upgrading existing hydropower plants, many of which were built many years ago and are in desperate need of rehabilitation. This percentage target could be doubled if the government were to consider generating hydropower from rivers and non-river streams, including thermal power plants, irrigation canals and drinking water networks. Wastewater networks were found not to have high hydropower potential.

According to a UNDP/CEDRO study on hydropower in Lebanon, non-river stream resources are estimated to be 8-15 MW.[25] The study analysed 20 non-river sites with hydropower potential, 13 of which showed that their total electrical power potential amounted to an estimated 5 MW. More than 50 per cent of this identified hydropower potential was found in established thermal power plants (figure 5) that require minimal investment to harness the potential energy production. Although drinking water networks have a theoretically high hydraulic potential in Lebanon, they have an old infrastructure with high friction due to the low flow, which decreases their potential for energy production. The significance of such a study is that other ecozones in the Arab region that may not have natural river streams, can still utilize the hydropower potential of non-river streams, a resource little explored in the Arab region. Such resources can be tapped without the environmental or socioeconomic implications of natural stream hydropower generation.

**Figure 5.** Energy potential of 20 sites in Lebanon




**Source:** UNDP, 2013a.

In Lebanon, there are 17 major rivers with high hydropower potential, and despite some existing hydropower plants operating at lower than optimal capacity, there is potential for additional plants. Hydrologic patterns in river flow in Lebanon are characterized by low flows from July to November, with minimum monthly average flows between July and October. The high water flow extends from January to May, with maximum average flows in March and April. This flow pattern is typical of rainfall distribution in the Mediterranean, where the March and April flow contribution is from rain as well as snow melt.[26] There is a total of 282 MW of installed capacity in five river stream plants with a total of 34 operational units. These plants were installed between the mid-1920s and the mid-1960s. The percentage of hydroelectric energy produced by these plants is about 8.7 per cent of the total energy share of the country. The Lebanese Ministry of Energy and Water prepared a master plan study for the hydroelectric potential of Lebanon along the main river streams, which identified 32 new sites with a capacity of 263 MW (1,271 gigawatt-hours per year) in run-of-river schemes and 368 MW (1,363 GWh/annum) in peak schemes.

However, by 2040, significant rainfall reductions are projected – more severe from coastal to inland areas – ranging from -10 per cent to -20 per cent for 2040, and reaching -25 per cent to -45 per cent for 2090. In parallel, consecutive dry days (CDD) are projected to increase by between 15-21 days, exacerbating the hydrological stress.[27] Coupled with a projected increase in cooling demand and associated electricity demand (as a result of reduced precipitation), a potential reduction in hydroelectric power plants is envisaged.

Concurrently, the forecasted 10-20 per cent decrease in precipitation by 2040 and increased evapotranspiration[28] will lead to a decrease in river flows, which will adversely affect the potential for hydropower generation. The shortening of the winter season is expected to reduce hydro potential even further. Despite the potential of hydroelectricity to alleviate energy security in the country, there are unintended ecological and agricultural consequences of utilizing these resources. Additionally, there are 30.8 MW of installed capacity, with the potential to double this figure to reach 60.3 MW, including river and non-river sources.

Despite its huge potential for meeting national renewable energy targets, hydropower comes with the following challenges and opportunities:

a. While in-stream hydropower energy resources are prevalent in some Arab region countries, non-stream resources are relevant to the entire region and should be explored;

b. The effect of climate change on hydropower production for ESCWA member countries is not quantified to a point where the economic and technical impact are fully understood. This type of mapping is worth exploring at a regional level;
c. Hydropower risks need to be taken into account as a nexus trade-off between: energy production; water allocation for agriculture; and land use changes and ecosystem and socioeconomic considerations. Nexus tools, which are described in the module on examining the water-energy nexus, are ideal to assess these trade-offs.

Consequently, to diversify the country's renewable energy sources and in addition to investing in hydropower, the Lebanese Ministry of Energy and Water has expressed a strong interest in developing solar energy. As for most Arab region countries, the Lebanese government will have to rely on international financial and technical assistance to pursue this objective.[29]

## Role of distributed renewable energy in rural economies: off-the-grid technologies for agricultural communities

While most countries in the region have electrification rates of more than 99 per cent, others, such as Mauritania, Somalia, the Sudan and Yemen, fall below 50 per cent of the population. Countries experiencing conflict have damaged infrastructure and are still recovering; Iraq, for example, is reported to have lost 25-40 per cent of its capacity since the beginning of conflict in 2003.[30]

We expect that with renewable energy expansion in the Arab region, some remote areas that did not have access to centralized electricity grid power will have another opportunity to use decentralized renewable energy units. For this to happen, these technologies must be localized so deployment is affordable.

Algeria and Jordan, for example, have provided statutory guarantees for renewable energy to be given priority access for integration into the existing electricity grid.[31]

# Renewable energy in the water-energy nexus

The links between energy and other sectors, such as water and food, make it clear that diversifying energy portfolios will have a spillover effect on all related areas. One of the targets of the United Nations Sustainable Energy for All initiative is to double the share of renewable energy in the world by 2030. Sustainable Development Goal 7 on energy includes a target to "increase substantially the share of renewable energy in the global energy mix" by 2030. Adopting renewable energy technologies that decrease fuel use reduces carbon emissions and negative environmental impacts, while water and food security are improved indirectly by an energy mix with a higher share of renewable energy.[32]

Wind and solar energy require minimal resource inputs, while producing biofuels can have a negative effect on water security due to high land and irrigation requirements. Therefore, the choice of feedstock when producing energy from biomass is critical to determine trade-offs and possible impacts on water and food security. In the case of hydropower, the impacts on water availability and its social implications have to be considered on a case-by-case basis.

## Renewable energy for water supply

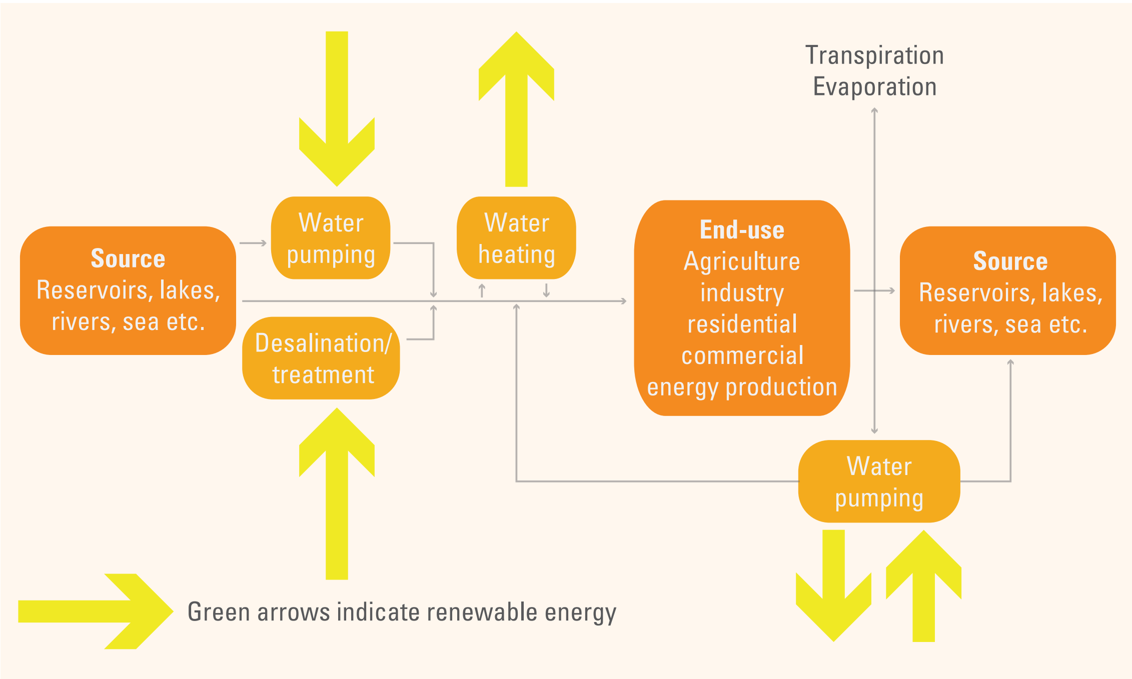
Renewable energy technologies can play an important role in the water-energy security nexus. Using decision-support tools that have a nexus approach is highly valuable when evaluating the effects of different energy mixes on water, food and land resources at a local, national and regional level.

In the water supply industry, energy inputs are spread throughout the supply chain. Renewable energy can play an important role in various operations, such as pumping, desalination, heating and wastewater treatment, as illustrated in figure 6. Although renewable energy in this sector might not reduce the energy intensity of operations, it can certainly remove the environmental footprint and can be especially useful in small-scale, off-grid applications to enhance access to water services.[33]

Solar irrigation using solar-powered pumps have been successfully used in remote agricultural areas in many countries that lack reliable access to electricity. From a nexus perspective, however, access to low-cost energy should not be pursued without considering water security (i.e. low water efficiency and productivity). These matters are discussed in the improving efficiency module.

In the water utilities sector, renewable energy has had a significant impact in reducing energy costs and increasing the reliability of services. One clear example of this is a sanitation utility in South Africa. By replacing pressure-reducing valves with mini-turbines, they have been able to use the excess pressure to generate power; the power produced has the potential to be used for wastewater treatment and for supply.[34]

**Figure 6.** Renewable energy in the water supply sector




**Source:** IRENA, 2014.

Wastewater can be considered an important source of renewable energy. It has been reported that wastewater and biosolids contain 10 times the energy needed for treatment.[35] The biogas produced from anaerobic digestion has been used to generate energy on-site, as well as for combined heat and power (CHP) production.

The recent trend in wastewater facilities in the United States, such as at the Washington, D.C. water utility company, to refer to these facilities as energy-recovery units and energy-neutral or even energy-positive systems, demonstrates the recognized value of wastewater as an energy source.

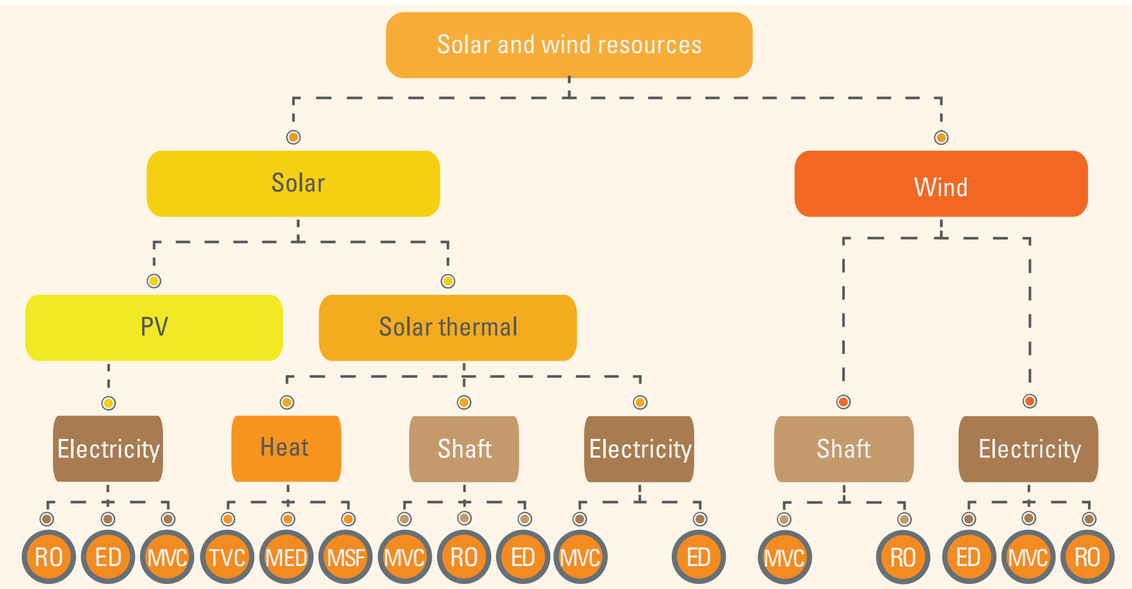
**Water desalination**

Water desalination is a technology with massive potential for growth in the region. However, growing this industry using traditional energy-intensive technologies can pose a big risk to water and food security, and have a considerable negative effect on the environment.

Renewable resources, such as wind, hydropower, biomass and geothermal energy, can be used in particular desalination plants known as solar cogeneration power desalting plants (SCPDP). Direct solar energy-operated desalination is not an economically viable solution. SCPDP can be used where integrating concentrated solar power with conventional natural gas-fired power plants can be a real solution for an integrated solar combined cycles system. Solar and wind energy can be integrated in desalination processes in a diverse range of unit operations, as shown in figure 7.

Shifting to more energy-efficient membrane technologies (SWRO) rather than thermal (MSF and ME-TVC) can reduce the energy demand of desalination and, therefore, solar energy becomes more feasible. When considering renewable sources, an integrative approach should be taken, one that takes account of efficiency, losses due to infrastructure and technology choices. In Qatar, for example, it has been reported that more than one third of the desalinated water is leaked before reaching homes.[36]

**Figure 7.** Renewable energy in water desalination processes




**Source:** IRENA, 2014.

The world's largest solar power plant in Morocco will eventually provide 1.1 million people with electricity © World Bank/Dana Smillie - United Nations Africa Renewal 2016 - Created by Africa Section, Strategic Communications Division, Department of Public Information, United Nations.

Most of the renewable technologies developed for desalination are typically based on membrane desalination systems (RO). Solar stills, solar PV and wind-based reverse osmosis plants are well deployed and commercially available. Figure 7 shows the different renewable energy desalination technologies and their development stages.[37]

Solar desalination is particularly valuable in small-scale remote areas where access to electricity or fuels is challenging. Further research and development for solar desalination at larger scales will radically expand the scope of its application. Despite that, most countries are in the solar belt and concentrated solar power (CSP) desalination has the potential to work in large-scale projects and can be easily integrated in membrane and thermal processes, though there are many challenges hindering its adoption. The key challenges are the high upfront cost, particularly in the case of thermal storage systems and dry clean technology; the lack of national expertise (know-how is limited to a certain number of companies in Europe and the United States); the need to develop Solar Atlas; and a monopoly in manufacturing some of the main components of the solar field. Given these challenges, photovoltaic technology could be an attractive option to CSP technologies.

## Box. An example of solar desalination in Qatar

In the city of Al Khor in Qatar, the mean monthly global solar radiation in 1987, based on the average monthly normal radiation, was 5.09 KWh/m$^2$. The mean annual global solar radiation for Al Khor was 1,858 KWh/m$^2$yr in 1987. Because of possible fluctuations in solar irradiance, a backup solution exists for electric generation, using molten salt storage units to store heat for later use. For water desalination, one can increase the capacity of the fresh water reservoirs (Mohtar, 2012).

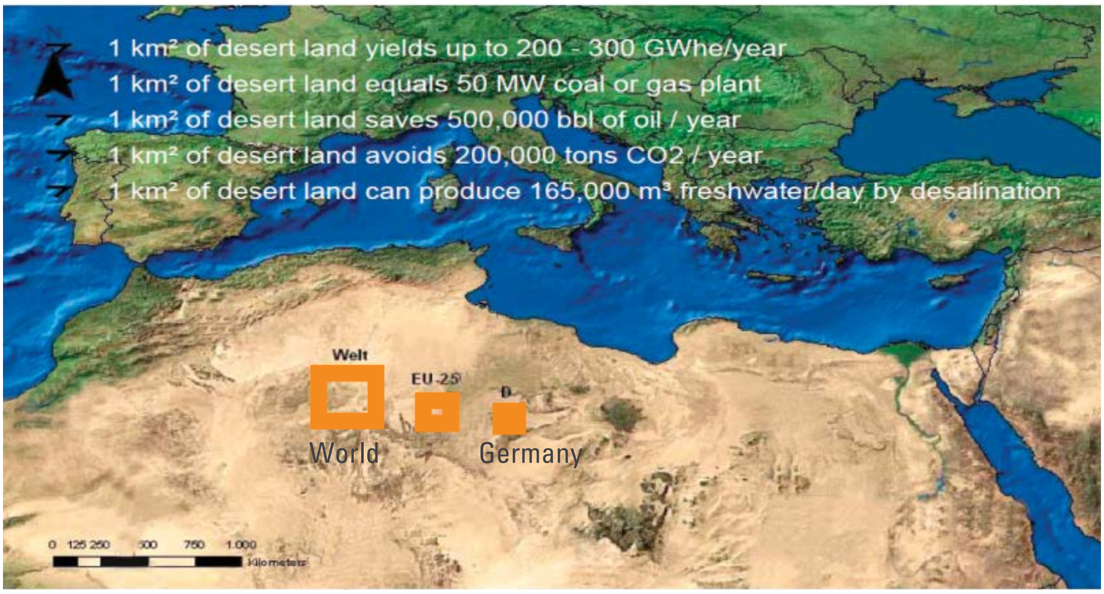
Based on data from Plataforma Solar de Almeria (Spain), parabolic trough collectors can achieve 50 MWe/120 hectares.

A 250 km$^2$ area will provide 10 GWe with zero $CO_2$ emission, an amount that would satisfy Qatar's energy needs by 2020 without any reduction in projected consumption. The figure below shows a schematic of the land requirements of solar energy systems.

The following solar technologies could be considered for Qatari conditions, the aim being to find its optimum working point and how it could be cleaned and maintained due to sand dust, in addition to obtaining an integrated system for water desalination:

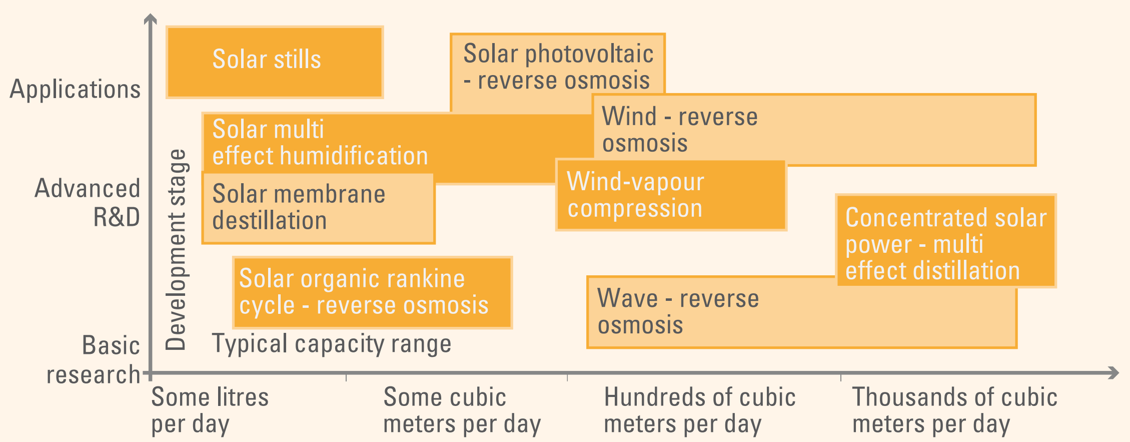
1. Fresnel solar collector.
2. Parabolic trough + molten salt storage unit for electricity production (day and night).
3. Dish collector (Sterling motor) for local electricity production.
4. Concentrated photovoltaic collector for electricity production.

### Land requirements for solar energy production




**Sources:** Calculations done by author; figure adopted from Desertec Project.
**Note:** The small to big red squares represent the area of land needed in Algeria to be covered with CSP mirrors to generate enough electricity for Germany, for EU-25 (European Union), and the world.

**Figure 8.** Renewable energy desalination technologies and their different stages of development and capacities




**Source:** IRENA, 2014.

# Key messages and recommendations

As the global environmental and economic drivers continue to emerge, renewable energy technologies are poised for substantial growth in the coming decades, particularly in the Arab region where alternative energy sources, such as solar, wind and hydropower, are abundant. The question is whether the Arab region is able to exploit these growth opportunities in this emerging sector. A combination of drivers, including energy security ambitions, climate change mitigation (as reference in the COP21 Paris Agreement), socioeconomic considerations and energy access, will propel the transformation of the energy sector away from traditional fossil fuel options. The dynamics of the emerging energy portfolio present opportunities and challenges for regional energy, water, land and food resources.

The distributed and environmentally sustainable nature of most renewable energy sources has the potential to ease the stresses and trade-offs in the water, energy and food sectors and leverage synergies to enhance sustainability across these sectors.

A shift towards less resource-intensive renewable energy sources such as solar photovoltaic and wind energy can address challenges posed by the water-energy nexus. For example, the heavy reliance of power generation on water can be relaxed by a solar or wind energy strategy that reduces the water footprint per unit of energy produced. Projections for water use by the energy sector show that, at a global, regional and national level, an energy system with substantial shares of renewable energy could be less water-intensive compared with one based on conventional fuels.

More importantly, renewable energy sources offer a low-carbon and less water-intensive path to expanding the energy sector. However, while the cumulative benefits of renewable energy are estimated to be positive, the water impacts of individual technology solutions must be assessed. For example, whereas solar photovoltaic and wind energy technologies have minimal water needs, concentrated solar power and bioenergy development could have a substantial water footprint. These assessments cannot be generalized and must be localized to each country, based on the local conditions stated above, since water availability and environmental and socioeconomic conditions vary. What remains constant is the protocols used for these assessments.

In the Arab region, where food security is a major concern and a large percentage of food is imported, renewable energy, when implemented in a sustainable manner, can stimulate the food sector with new economic opportunities and bridge energy deficits along the supply chain to reduce losses and enhance food productivity. Renewable energy can provide off-the-grid access to enable energy-intensive food production processes, such as water production, pumping and distribution, food storage and processing.

Renewable energy sources have a direct impact on water security. Renewable energy systems are increasingly being deployed to spread access to water in remote communities and simultaneously increase water availability for irrigation, with certain impacts on food security. In the same manner, renewable energy in urban settings enhances the resilience of urban water systems. Tapping into locally available energy resources is a remarkable way of reducing the costs of utilities and improving the reliability of water supply. Energy-intensive desalination has a vital role in meeting growing water demand in arid regions; the development of renewable energy-based desalination solutions is necessary and receiving more attention. Renewable energy desalination, together with renewable energy for electricity generation, provide an integrated solution to address water and energy challenges.

There is consensus, however, that the growth in renewable energy deployment has to come with adequate consideration of the broader impacts, both positive and negative, on other development sectors. Bioenergy, for instance, can play a transformative role in the transition towards a renewables-based energy system. It is a resource that is widely and locally available, with tremendous synergies in rural agro-economies. But in developing this resource, the impacts on water and land use, competition with food crops and broader sustainability issues need to be considered. Such assessments are particularly useful at an energy-system level, whereby energy sector strategies can be vetted through standard frameworks, such as the FAO's Bioenergy and Food Security Rapid Appraisal[38], which allows for such cross-sectoral assessment.

In summary, transitioning to a portfolio with a significant renewable energy mix requires an acknowledgment that renewable technology must be localized and needs more planning and investments in many areas, including research and development investment, and training and human capital building at various levels, including vocational training to develop, adapt and maintain these systems. It also requires developing the manufacturing and industrial sector and a complete supply chain to allow these technologies to be deployed at a lower cost. This transition must also be coupled with policies to provide a suitable environment for incubating this transition. These policies may include energy pricing reform as well as renewable energy incentives. Regional integration to create a common resources pool can be a worthwhile effort. From a water-energy nexus perspective, renewable energy plans must be seen as integrated solutions between water and energy, involving coordination among all stakeholders.

This module outlined a framework that can be useful for renewable energy transformation. Challenges and opportunities are also presented. However, the plan presented requires a quantitative metric to assess progress towards these goals.

# Endnotes

1. IRENA, 2016.
2. The Guardian, 2016.
3. IRENA, 2016.
4. Ibid.
5. Mohtar, 2015.
6. Ibid.
7. New and Renewable Energy Authority Egypt (n.d.).
8. EgypytERA, 2014.
9. IRENA, 2016.
10. Mason and Mor, 2009.
11. REN21, 2016.
12. IRENA, 2016.
13. World Bank, 2013.
14. IRENA, 2016.
15. World Bank, 2013.
16. AFESD, 2014.
17. Masdar Institute, n.d.
18. Ibid.
19. IRENA, 2016.
20. Masdar Institute, n.d.
21. IRENA, 2016.
22. Eversheds, 2016.
23. NASA, 2014.
24. Mason and Mor, 2009.
25. UNDP, 2013a.
26. UNDP, 2013b.
27. UNDP, 2013a.
28. The process by which water is transferred from the land to the atmosphere by evaporation from the soil and other surfaces and by transpiration from plants.
29. Mason and Mor, 2009.
30. IRENA, 2016.
31. IRENA, 2014.
32. IRENA, 2016.
33. IRENA, 2014.
34. Ibid.
35. WEF, 2011.
36. Darwish and Mohtar, 2012.
37. IRENA, 2016.
38. FAO, 2014.

# Bibliography

Arab Fund for Economic and Social Development (AFESD) (2014). Feasibility Study of the Electrical Interconnection and Energy Trade between Arab Countries: Executive Summary. Kuwait. Available from http://www.arabfund.org/Data/site1/pdf/other/execsumen.pdf.

Darwish M. A., and Rabi Mohtar (2012). Qatar water challenges, *Desalination and Water Treatment*. Presented at the International Conference on Desalination for the Environment, Clean Water and Energy, European Desalination Society, 23-26 April 2012, Barcelona, Spain. Available from http://wefnexus.tamu.edu/files/2015/01/Qatar_water_challenge_Journal_paper.pdf.

DESERTEC (n.d.). *Global "Energiewende": The DESERTEC concept for Climate Protection and Development.* Available from https://issuu.com/global_marshall_plan/docs/desertec_atlas_global_energiewende/1.

Egyptian Electric Utility for Consumer Protection and Regulatory Agency (EgyptERA) (2014). Renewable energy – Feed-in tariff projects' regulations. Cairo. Available from http://egyptera.org/Downloads/taka%20gdida/Download%20Renewable%20Energy%20Feed-in%20Tariff%20Regulations.pdf.

Eversheds (2016). *Developing renewable energy projects. A guide to achieving success in the Middle East*. Third Edition, pwc. Available from https://www.pwc.com/m1/en/publications/documents/eversheds-pwc-developing-renewable-energy-projects.pdf .

Food and Agriculture Organization (FAO) (2014). FAO Bioenergy and Food Security Approach: implementation guide. Rome: FAO. Available from http://www.fao.org/docrep/019/i3672e/i3672e.pdf.

Suzanne Goldberg, "Rapid switch to renewable energy can put Paris climate goals within reach", *Guardian*, 16 January 2016. Available from http://www.theguardian.com/environment/2016/jan/16/rapid-switch-to-renewable-energy-can-put-paris-climate-goals-within-reach.

International Renewable Energy Agency (IRENA) (2014). Pan Arab Renewable Energy Strategy 2030. Abu Dhabi, UAE. Available online at http://www.irena.org/DocumentDownloads/Publications/IRENA_Pan-Arab_Strategy_June%202014.pdf.

International Renewable Energy Agency (IRENA) (2016). *Renewable energy benefits: measuring the economics.* Abu Dhabi, UAE. Available from http://www.irena.org/DocumentDownloads/Publications/IRENA_Measuring-the-Economics_2016.pdf.

Khalifa, Ahmed (2012). Macroeconomic Competitiveness of the GCC Economies. In *The GCC Economies: Stepping up the Future Challenges,* M. A. Ramady, ed. (New York, Springer Science and Business Media).

Masdar Institute (n.d.). *Renewable Energy Readiness Assessment Report: The GCC Countries 2011-2012.* Masdar Institute of Science and Technology. Study under EU-GCC Clean Energy Network. 2013. Available from http://eugcc.epu.ntua.gr/LinkClick.aspx?fileticket=ZLVAyWw9x_8%3d&tabid=448.

Michael Mason and Amit Mor, eds. *Renewable Energy in the Middle East: Enhancing Security through Regional Cooperation.* NATO Science for Peace Security Series. The Netherlands, Springer Science and Business Media, 2009.

Mohtar, Rabi H. (2015). Opportunities and Challenges for Innovations in Qatar. *Muslim World.* vol. 105(1). pp. 46-

57. Available from http://onlinelibrary.wiley.com/doi/10.1111/muwo.12079/epdf.

National Aeronautics and Space Administration (NASA) (2014). Surface meteorology and Solar Energy*:* A renewable energy resource web site (release 6.0). Available from http://eosweb.larc.nasa.gov/sse/. Accessed May 2016.

New and Renewable Energy Authority Egypt (n.d.). Strategy and Mandate. Cairo. Available from http://www.nrea.gov.eg/english1.html.

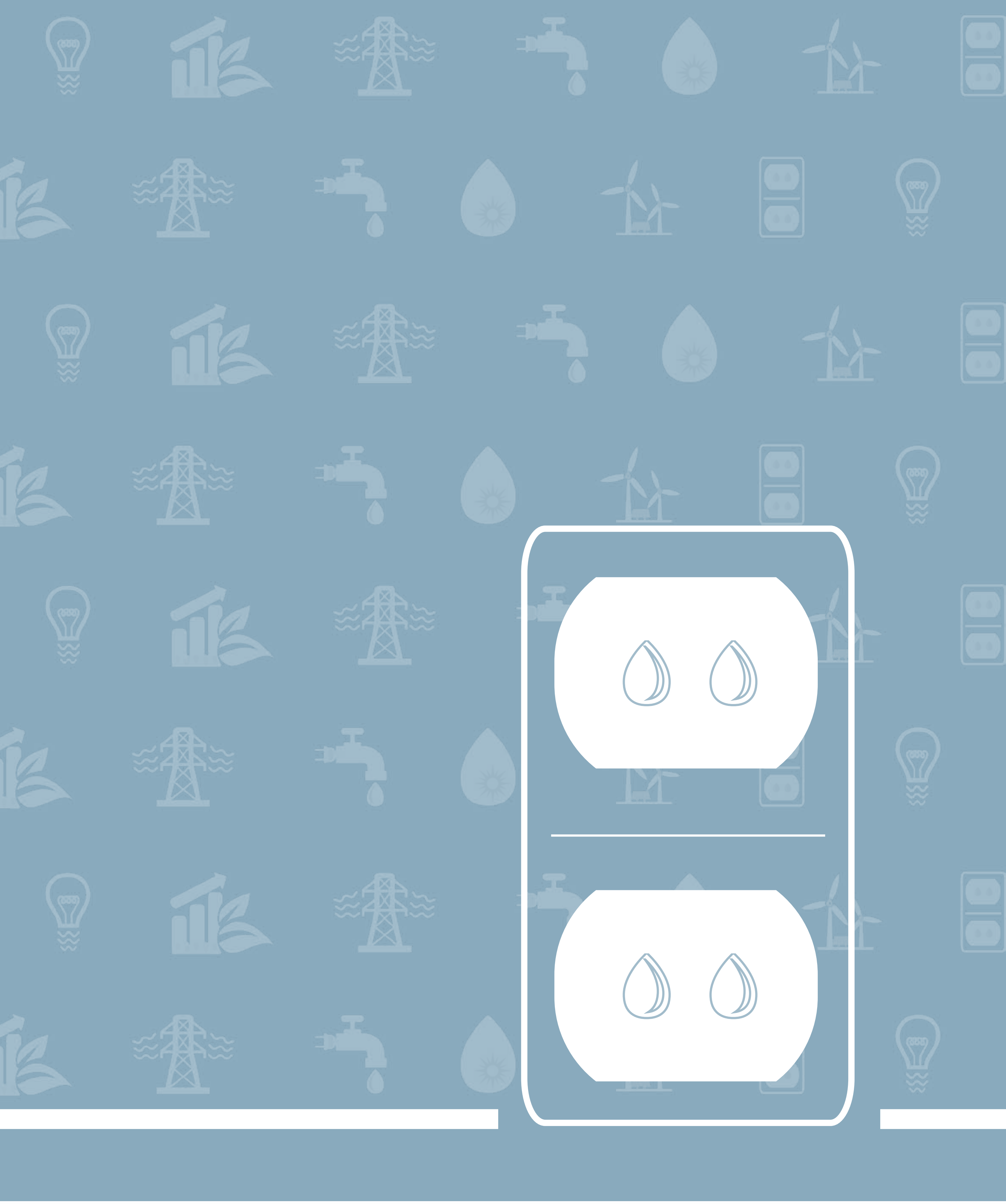
Renewable Energy Policy Network for the 21st Century (REN21) (2016). Renewables 2016 Global Status Report key findings 2016. Paris. Available from http://www.ren21.net/wp-content/uploads/2016/06/GSR_2016_Key_Findings.pdf.

United Nations Development Programme (UNDP) (2013a). *Hydropower from Non-River Sources: The potential in Lebanon.* New York, UNDP; Beirut, CEDRO. Available from http://climatechange.moe.gov.lb/viewfile.aspx?id=55.

United Nations Development Programme (UNDP) (2013b). Hydropower in Lebanon; History and Prospects. UNDP-CEDRO Exchange Issue Number 4, February 2013. Available from http://cedro-undp.org/content/uploads/Publication/141009092113199~Exchange%204.pdf.

World Economic Forum (WEF) (2011). *The Global Competitiveness Report 2011-2012.* World Economic Forum. Geneva, Switzerland. Available from http://www3.weforum.org/docs/WEF_GCR_Report_2011-12.pdf.

World Bank (2013). *Middle East and North Africa Integration of Electricity Networks in the Arab World: Regional Market Structure and Design.* Report No. ACS7124. Available from http://www-wds.worldbank.org/external/default/WDSContentServer/WDSP/IB/2014/07/10/000442464_20140710112306/Rendered/PDF/ACS71240ESW0WH0I0and0II000Final0PDF.pdf.



# Addressing Climate Change and Natural Disasters

Module 7

# Contents



## List of figures



## List of tables

## List of boxes



# Abbreviations and explanatory notes

| | |
|---|---|
| **AAL** | average annual losses |
| **AFED** | Arab Forum for Environment and Development |
| **BCM** | billion cubic metres |
| **COP21** | 21st Session of the Conference of the Parties to the United Nations Framework Convention on Climate Change |
| **$CO_2$** | carbon dioxide |
| **ESCWA** | Economic and Social Commission for Western Asia |
| **FAO** | Food and Agriculture Organization |
| **GCM** | global circulation models |
| **GDP** | gross domestic product |
| **GHG** | greenhouse gases |
| **GHM** | global hydrological models |
| **GRID** | Global Resource Information Database |
| **IPCC** | Intergovernmental Panel on Climate Change |
| **MENA** | Middle East and North Africa region |
| **$m^3$** | cubic metre |
| **OECD** | Organization for Economic Cooperation and Development |
| **PV** | photovoltaic |
| **RICCAR** | Regional Initiative for the Assessment of Climate Change Impacts on Water Resources and Socio-Economic Vulnerability in the Arab Region |
| **SDG** | Sustainable Development Goal |
| **SLR** | sea level rise |
| **SRES** | Special Report Emissions Scenarios |
| **UNDP** | United Nations Development Programme |
| **UNEP** | United Nations Environment Programme |
| **UNFCCC** | United Nations Framework Convention on Climate Change |
| **US CCSP** | United States Climate Change Science Program |
| **WEF** | water-energy-food |

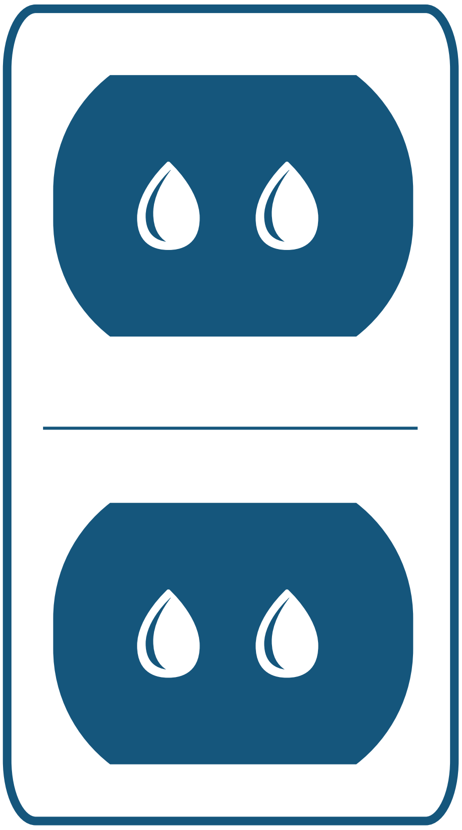
# Background and objectives of this module

The Arab region has the largest water deficit in the world.[1,2] Irrigated cereals are the biggest water consumer, and in many countries agriculture accounts for more than 85 per cent of total water withdrawn.[3] With irrigation systems heavily reliant on groundwater pumped from deep or fossil aquifers, water security will be threatened by declining aquifer levels and extracting non-renewable groundwater.[4] Unfulfilled water demand in the Arab region is expected to increase from the current 16 to 51 per cent in 2040-2050 due to climate change. The clamour for water will also be exacerbated by high population growth.

The 21st Session of the Conference of the Parties to the United Nations Framework Convention on Climate Change (COP21) in Paris in 2015 was a breakthrough moment in climate negotiations, with 195 parties of the United Nations Framework Convention on Climate Change (UNFCCC) agreeing to take targeted action towards the following objectives:[5]

a. Mitigating climate change effects, through reducing emissions fast enough to achieve temperature goal;
b. Creating a transparency system globally to account for climate action;
c. Moving towards adaptation by strengthening countries' ability to deal with climate impacts;
d. Building resilience in vulnerable areas by strengthening ability to recover from climate impacts;
e. Providing support including finance for countries to build clean, resilient futures.

In line with this is the 2030 Agenda for Sustainable Development, and its 17 Sustainable Development Goals (SDGs). Goal 13, on the need for urgent action to combat climate change, sets targets to help countries achieve this: by strengthening resilience and adaptive capacity to climate-related hazards and natural disasters (target 13.1); integrating climate issues into policymaking and national strategies (13.2); raising awareness and building capacity in institutions (13a); and promoting climate-change planning and management in vulnerable countries, focusing on gender and youth issues, poverty and local needs (13b).[6]



Given the Arab region is among the most affected by climate change, with ramifications for water, energy and food security, more work is needed to develop country - and region - specific adaptation and mitigation measures. This module describes projected climate change and its impact on water and energy resources, and provides examples of mitigation and adaptation measures to increase resilience. The need for coherent policy in water and energy planning, and for holistic nexus approaches, are also highlighted.

# Climat change regional overview

## Extreme climate indexes: temperature and precipitation projections

The Intergovernmental Panel on Climate Change (IPCC) estimates an uneven increase in surface air temperature, from 0.2 degrees Celsius (°C) to 2°C, occurred from 1970 to 2004,[7] with model projections for 2030, 2070 and 2100 indicating a steady rise in temperature in most of the Arab region under the best and worst-case scenarios.[8]

RICCAR (Regional Initiative for the Assessment of the Impact of Climate Change on Water Resources and Socio-Economic Vulnerability in the Arab Region) performed projections using assessment and vulnerability tools for two scenarios: medium, with a representative concentration pathway (RCP) of 4.5, and worst case, with an RCP of 8.5. The trends for both projected a rise in temperature of between 0°C to 2°C in the period of 2046-2065 (Figure 1); while in the longer run (2085-2100), the medium scenario projected temperature changes between 1-3°C, and 2-5°C in the worst case scenario (Figure 2).[9] These projections are consistent with the IPCC Assessment Report 5 (Table 1).

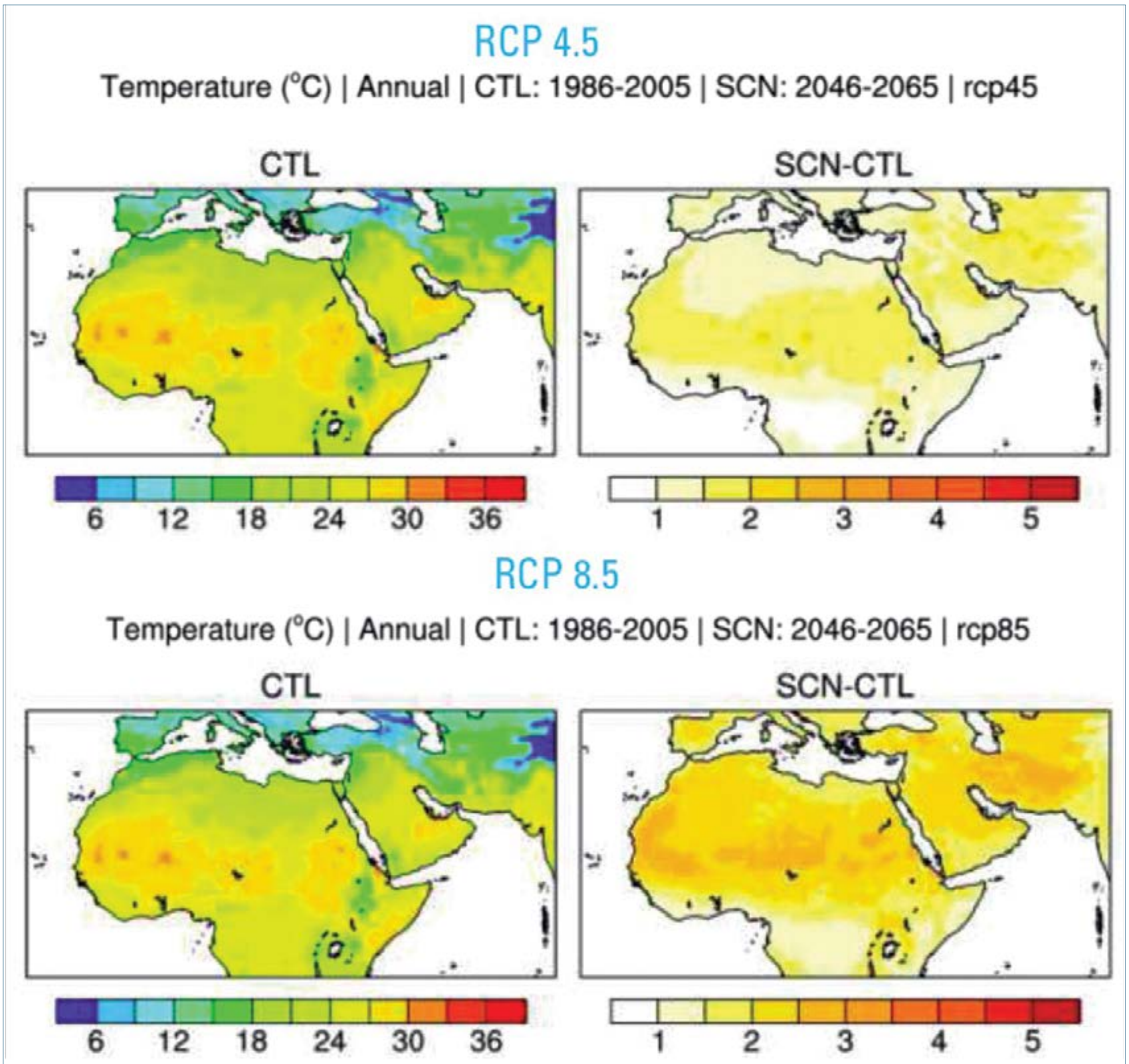
Sandstorm in Gafsa,Tunisia © Lukasz Janyst - Shutterstock_ 226006156

**Table 1.** Projected temperature range over parts of the Arab region

| | Increase in annual average temprature range in °C | |
|---|---|---|
| **Years** | Best scenario | Worst scenario |
| **2030** | 0.5 - 1.0 | 1 - 1.5 |
| **2070** | 1.0 - 1.5 | 2.0 - 2.5 |
| **2100** | 2.5 - 3.0 | 3.0 - 4.0 |

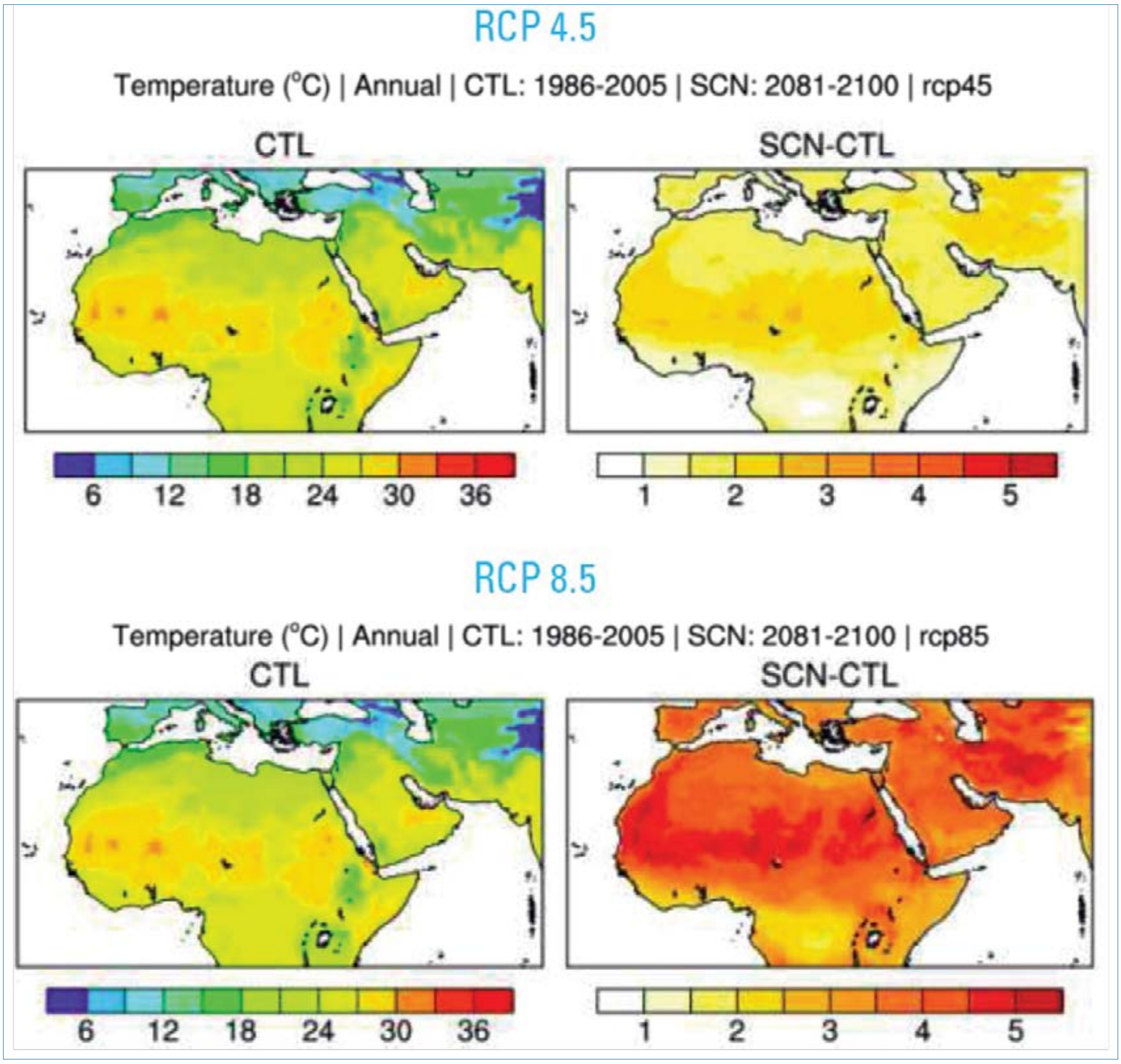
**Source:** IPCC, 2007.

**Figure 1.** Regional climate model projections of average temperature changes (°C) in the Arab region for two scenarios: medium (RCP 4.5) and worst case (RCP 8.5), time period 2046-2065 compared with the baseline 1986-2005




**Source:** ESCWA, 2015.

**Figure 2.** Regional climate model projections of average temperature changes (°C) in the Arab region for two scenarios: medium (RCP 4.5) and worst case (RCP 8.5), time period 2081-2100 compared with the baseline 1986-2005



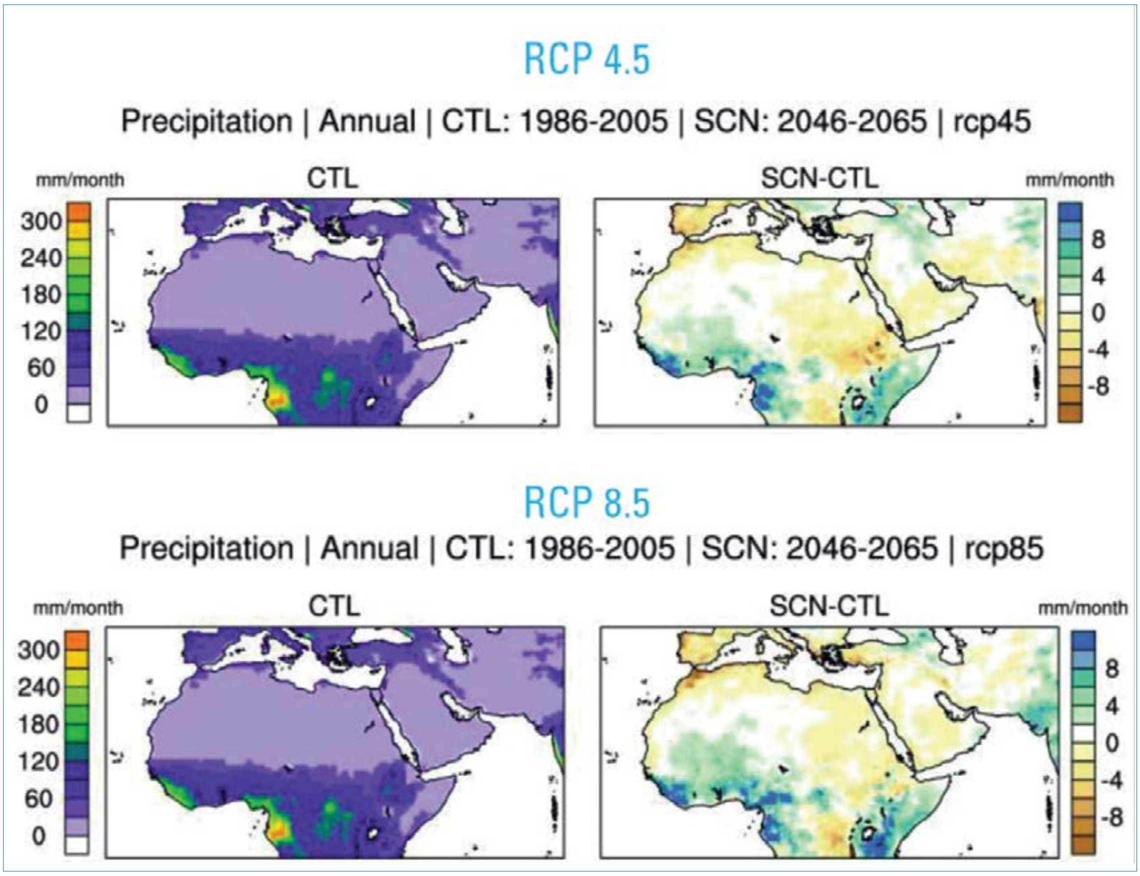

**Source:** ESCWA, 2015.

The Sahara area, including Morocco and Mauritania, is more vulnerable. By the end of the century, the effect of temperature increases is expected to be observed more strongly along the western shores of Yemen and Saudi Arabia.

Projected rainfall in the region during the summer months (figure 3 and figure 4) will have larger variability compared with temperature changes. It is expected there will be -0.5 mm to 0.5 mm less rain per day by the end of the century.[10] Drier conditions are more dominant in the northern Maghreb, and both scenarios show reduced average monthly precipitation, down to 8-10 mm, in the coastal regions, mainly around the Atlas Mountains in the west and in the upper Euphrates and Tigris river basins in the east.[11]

The RICCAR and IPCC extreme rainfall projections predict a reduction in rainy days with intensity greater than 10 mm (and greater than 20 mm), accompanied by more pronounced

**Figure 3.** Projected changes in average monthly precipitation for 2046-2065 from the baseline of 1986-2005 in the Arab region for two scenarios: medium (RCP 4.5) and worst case (RCP 8.5)




**Source:** ESCWA, 2015.

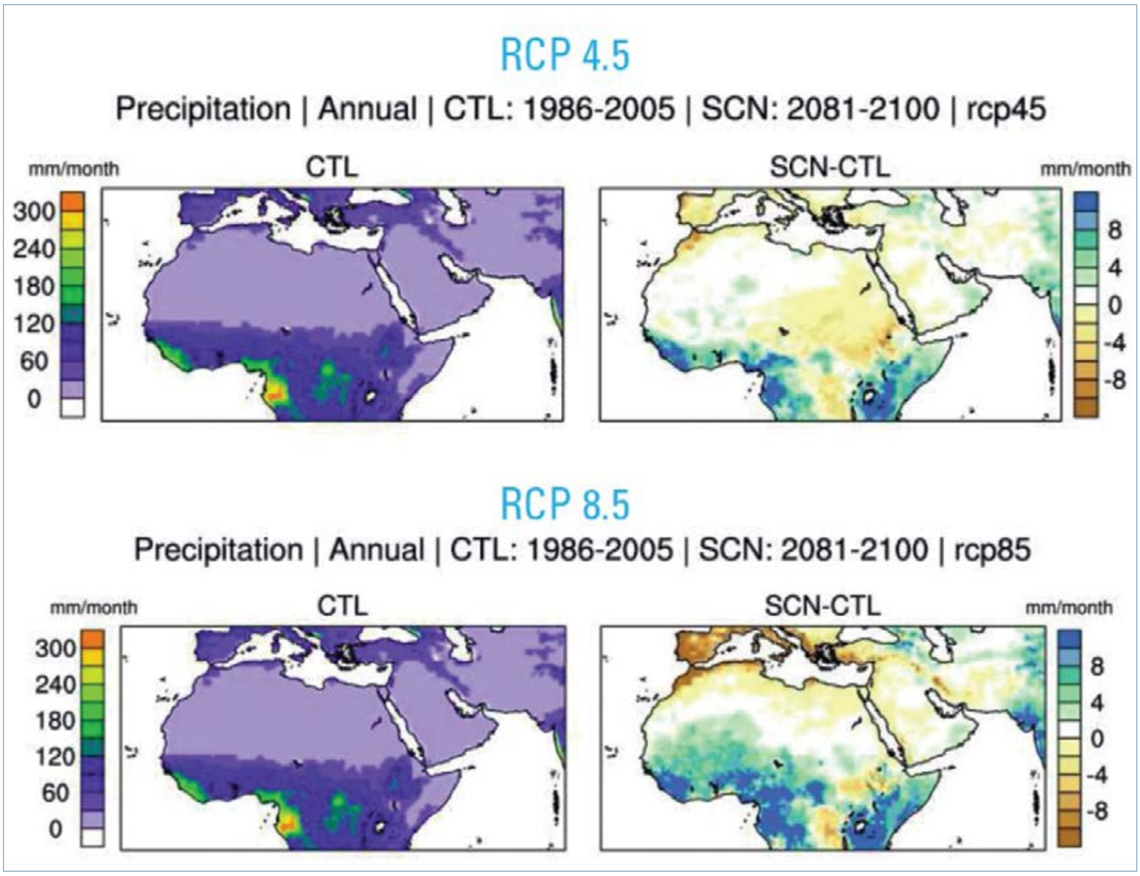
dry spells. The summer season is projected to be longer, especially in the Mediterranean and the northern parts of the Arabian Peninsula.[12]

The zone of severely reduced rainfall extends throughout the Mediterranean region and the northern Sahara,[13,14] and this, with the anticipated increase in surface temperature, will result in a 30 to 70 per cent reduction in recharge in aquifers located on the eastern and southern Mediterranean coast, affecting the quantity and quality of groundwater.[15] Milly and others (2005) identify climate change as causing a fall in run-off of 20 to 30 per cent in most of the Arab region by 2050.

Changes in extreme temperature are also projected, with increased tropical nights in central Africa and the southern Arabian Peninsula. It is expected that summer days of more than 40°C will increase in the Sahara and central Arabian Peninsula, showing that extreme temperature increases for coastal area scenarios might be lower than for central parts of the region.[16]

It is expected that by the middle of the century, the Levant region of ESCWA countries – Lebanon, Jordan, the State of Palestine and the Syrian Arab Republic – will become hotter across all seasons. Models predict an increase of between 2.5°C to 3.7°C in summer, and 2°C

**Figure 4.** Projected changes in average monthly precipitation for 2081-2100 from the baseline of 1986-2005 in the Arab region for two scenarios: medium (RCP4.5) and worst case (RCP 8.5)




**Source:** ESCWA, 2015.

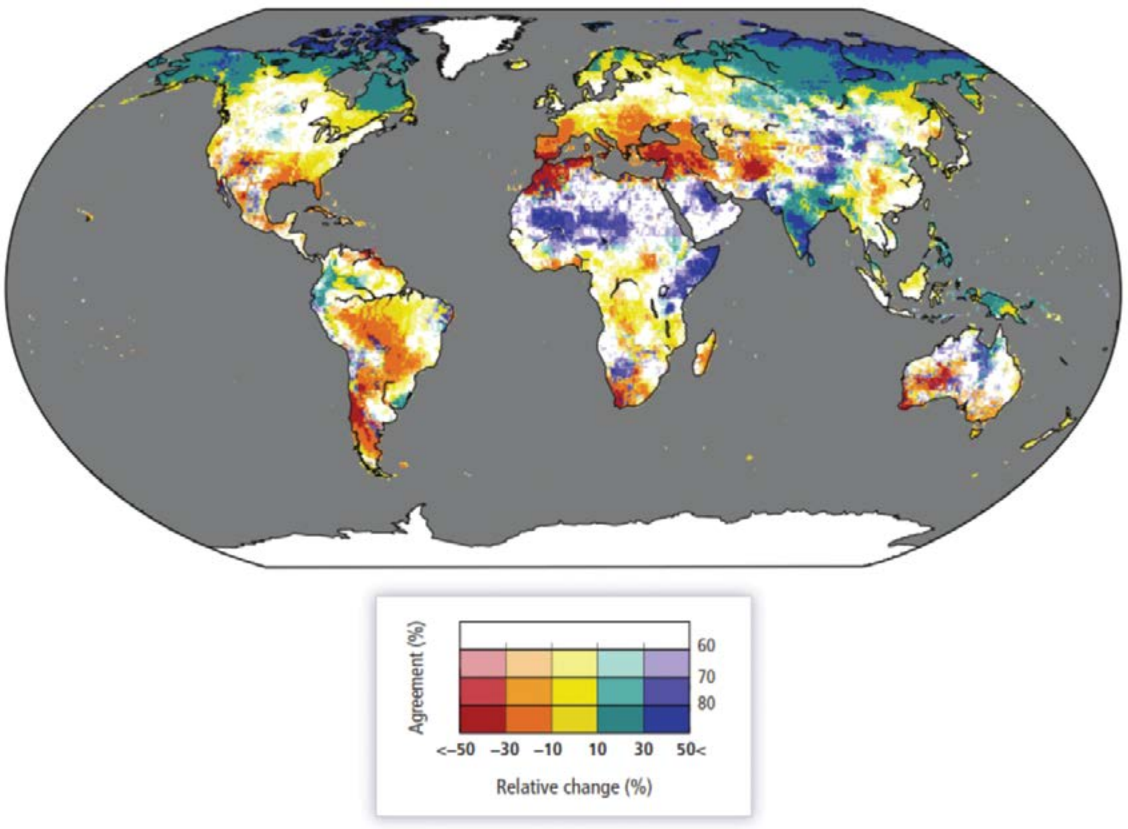
to 3.1°C in winter, as shown in figure 1. The region will get drier, with significantly declining rainfall in the wet season outweighing slight increases during the summer months.[17] The distribution of rainfall will change, moving to the north.

## Climate change and the water-energy nexus

As indicated by the 2007 and 2014 IPCC reports, climate change impact on streamflow is most dramatic in the subtropical region where ESCWA member countries are located. The 2014 report shows consistent projections of reduced groundwater recharge around the eastern Mediterranean, which affects surface and subsurface resources, as seen in Figure 5. Reduction in river flow impacts water supply in these regions, putting access at risk and threatening the recharge potential for many groundwater resources.

Reduced streamflow resulting from less rainfall also impacts on soil moisture availability, affecting food production. Globally, more than 60 per cent of food produced is rain-fed, increasing the pressure to compensate through irrigation, which will impact on water resources allocation and energy security as a result.

**Figure 5.** Predicted percentage change of mean annual streamflow for a global mean temperature rise of 2°C above 1980-2010 (2.7°C above pre-industrial)



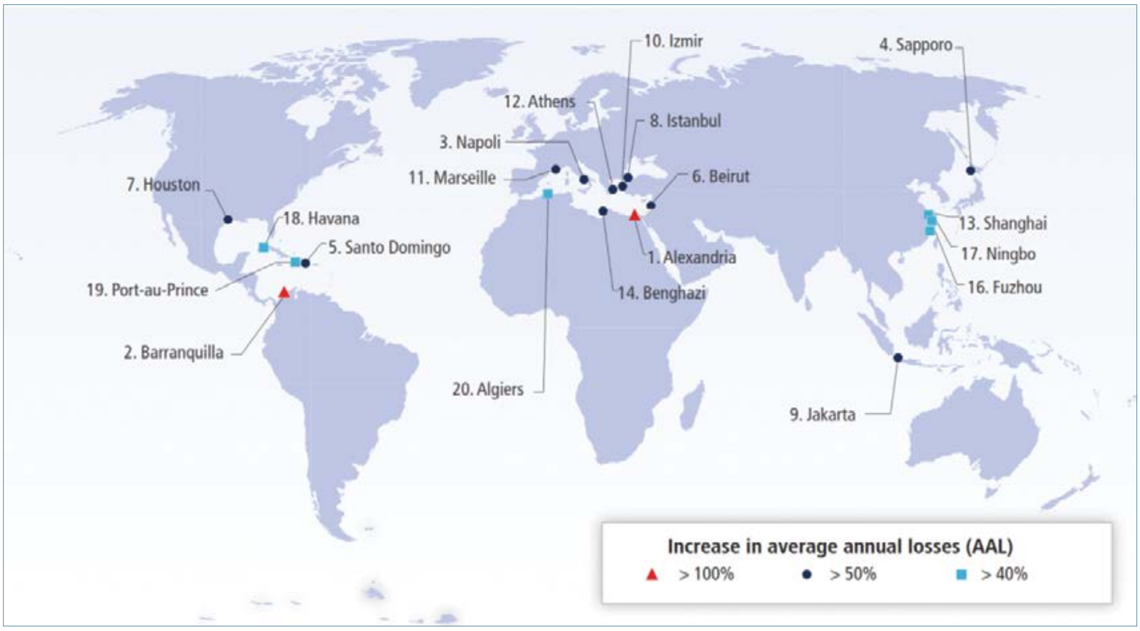

**Source:** Schewe and others, 2014.
**Note:** Colour hues show the multi-model mean change across five general circulation models (GCMs) and 11 global hydrological models (GHMs), and saturation shows the agreement on the sign of change across all 55 GHM–GCM combinations (percentage of model runs agreeing on the sign of change).

Reductions in projected streamflow also have a negative impact on potential hydropower generation in some ESCWA countries, including Egypt, Iraq, Lebanon, Morocco and the Syrian Arab Republic, where hydropower already plays a role in the energy portfolio. This must be addressed in future studies.

As for the economic impact, studies by the World Bank show the average annual cost for the water infrastructure system to restore services due to climate change by 2050 is projected at between US$13 billion and US$27.5 billion, for low and high projection, 5 per cent of this for systems in the Middle East and North Africa region.[18] This is an incredibly high cost when compared with the economies of some of the countries. Since many of the region's larger cities are coastal, they will be most affected by sea level rise. Figure 6 shows that at least four of the world's top 20 cities most affected by coastal migration due to sea level rise (SLR) are in the Arab region, namely Alexandria, Algiers, Beirut and Benghazi.

A nexus approach to climate change adaptation and mitigation needs models to explore intensification options and trade-offs with water and energy use. It also involves sustainable energy and water production technologies that consider environmental impact and availability of resources.

**Figure 6.** The 20 coastal cities where average annual losses (AALs) increase most (in relative terms in 2050 compared with 2005) in the case of optimistic sea level rise, if adaptation maintains only current defence standards or flood probability (PD)




**Source:** Hallegatte and others, 2013.

Policymaking must be done in consultation with all stakeholders through proactive cross-sector collaboration, underpinned by quantitative assessments.[19] Building partnerships through community-driven projects are important to ensuring the sustainability of natural resource management.[20]

# Impacts of climate change and natural disasters on different sectors

## On water security

Regardless of climate change, water scarcity in the Arab region will reach severe levels by 2025. A recent report has warned that what is known as the Fertile Crescent, spanning Iraq and the Syrian Arab Republic to Lebanon, Jordan and the State of Palestine, will lose all fertility traits due to deteriorating water supplies from major rivers, possibly before the end of the century.[21]

Estimates of water resources in the region indicate that total available natural water resources are 262.9 billion cubic metres (BCM), made of 226.5 BCM surface water and 36.3 BCM groundwater, and 11,874 BCM of non-renewable (fossil) groundwater, with variations between countries.[22] With future scenarios projecting further decreases in rainfall, and greater pressures on water resources, the water deficit is likely to increase from about 28.3 BCM in 2000 to 75.4 BCM in 2030 due to climatic and non-climatic factors.[23] For example, a climate change study by Abdulla and Al-Omari in 2008 showed that temperature increases of between 2°C to 4°C in Jordan would reduce the

Irrigation in the city of Dubai, United Arab Emirates © Philip Lange - Shutterstock_ 48492841

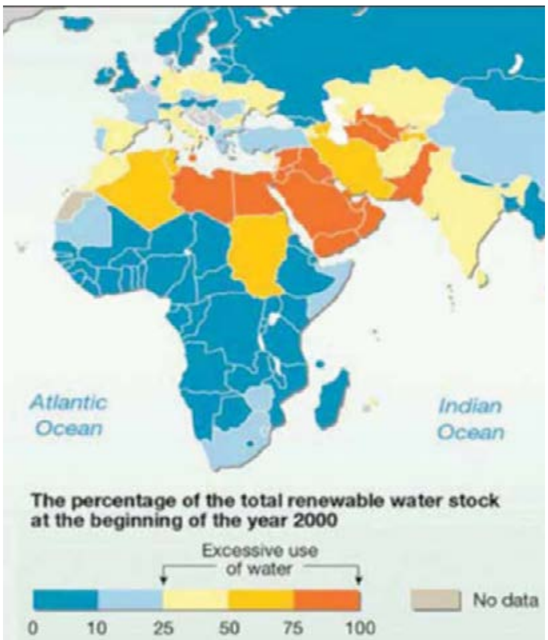
flow of the Azraq River by between 12 and 40 per cent, stressing supplies in a country already facing severe water scarcity. Figure 7 shows the total water withdrawals in the region in 2000.

Per capita renewable water resources in the region, which in 1950 were 4,000 cubic metres ($m^3$) per year, are currently 1,100 $m^3$, with a projected drop by half, to 550 $m^3$ per person per year in 2050.[24]

## On energy security

The energy sector in the Arab region plays a critical role in the region's socioeconomic development. Oil revenues, estimated at US$419 billion in 2006, have been the major source of income in many Arab countries, especially in the Gulf region. The Gulf countries also contribute directly to the Arab region economy through the employment and economic flow from expatriates working and living there.

**Figure 7.** Withdrawal of total renewable water resources in 2000




**Source:** UNEP/GRID Arendal, 2009.

**Box 1.** Climate change, vulnerability and adaptation in North Africa with focus on Morocco

Morocco depends heavily on rain-fed agriculture, which contributes to the region's vulnerability to climate change. Low per capita income and its unequal distribution in North Africa, particularly in Morocco and Tunisia, limit the adaptive capacity of populations to face droughts and natural disasters. Analysis of future conflict scenarios finds Algeria, Egypt and Morocco most prone to climate change-related instability.

Already in Morocco, social stability has been affected by droughts. Projections show climate change could cause a decrease in agricultural production of 15 to 40 per cent, with a major impact on food prices and conflict. If this development scenario continues, it is possible that the impact of drought will be aggravated by soil degradation. Lower rainfall and soil moisture, along with poor regulation, has led to over use of groundwater for agriculture, which further jeopardizes the availability of water for other sectors, such as industry and energy production.

This case study provides policy options for adaptation. One is to shift the focus of agricultural production from maximization to output stabilization. For rain-fed agriculture, shifting planting patterns and changing crop types can substantially reduce the impacts of climate change. Monitoring irrigation practices and soil conditions will also be crucial to securing future productivity.

Simulations made in the study showed expanding the use of solar power plants can greatly increase revenues of agricultural systems in rural areas of Morocco while increasing resilience to climate change. Pushing forward with development of solar power plants in arid areas, as envisioned by the Moroccan government, shows promise, combining stimulus for the domestic economy with adaptation to climate change.

**Source:** Schilling and others, 2012.

## Contributions of the energy sector in climate change

Electrical power production is one of the biggest contributors to greenhouse gas emissions (GHG). Industry is a major energy-consuming sector in Arab countries, on average accounting for about 30 per cent of consumption,[25] pushing to 60 per cent in countries such as Oman and the United Arab Emirates.[26] The transport sector consumes an average 33 per cent of the total energy consumption, and the residential sector 41 per cent. This consumption pattern determines the major sources of the GHG emissions, and in many instances defines the policy priorities and measures needed to reduce them.

On the supply side, these measures include energy efficiency in electricity generation and oil refining, the use of combined heat and power to produce electricity and water, switching from carbon fuels, electricity imports and exchange through regional electricity networks, transmission and distribution loss reduction, and power generation using renewable energy resources.

On the demand side, measures for efficient lighting systems, solar water heating, efficient cooling and refrigeration, improvements in combustion and recovery of waste heat will help to improve energy efficiency throughout the economy, diversify away from fossil fuels and promote renewable energy applications.[27]

## Climate change impacts on the energy sector

Although the energy sector is emphasized as the main source of GHG emissions, the effect of climate change on energy generation and the supply system is little understood.[28] A study by the United States Climate Change Science Program (US CCSP)[29] collated current knowledge on energy consumption, generation and supply; information from this study deemed relevant to the Arab region is summarized in the following paragraphs.

Projected higher summer temperatures will increase cooling energy requirements, already a major item on the total energy bill of most Arab countries. Despite projected warmer winters reducing heating energy requirements, any energy savings will be dwarfed by a rise in cooling energy requirements. This can be tempered by savings gained through technological advances but it will require investment, and incentives, which may be lacking at present.

A significant share of energy is used in groundwater abstraction, desalination, treatment, transfer and distribution, and projected climate change-induced declines in fresh water supplies and the rise in demand in the region will increase energy requirements for these activities. Leaks in pipes range from 30 to 45 per cent, adding to energy and water losses, but infrastructure investments to repair and upgrade these networks are absent in many countries.

Projected increases in average air and water temperatures and limited supplies of adequate cooling water are expected to effect the efficiency, operation and development of new power plants. The performance of gas turbines is particularly sensitive to ambient temperature and pressure. A 30°C increase in ambient temperature, typical of diurnal changes in desert areas, can result in a 1 to 2 per cent reduction in efficiency and a 20 to 25 per cent decrease in power output; as these results are linear, smaller increases will have considerable effects on efficiency and output.[30] Consequently, overall warming is expected to decrease total power capacity and increase production costs, while increased water temperature will also place strains on thermal plants.

Climatic change is expected to impact on renewable energy infrastructure. Changes in wind conditions will affect the performance and reliability of wind farms, and solar energy production is sensitive to cloudiness and dusty conditions. Decreased river run-off will reduce hydroelectric output, particularly significant for Egypt, Iraq and the Syrian Arab Republic with large hydroelectric capacity. Heavy reliance on hydroelectric power may increase the risk of vulnerability to drought or water shortage, so countries need to diversify their electricity production portfolios to renewable sources and regulate energy production costs.[31]

Extreme weather events are projected to increase, and could result in the downing of more electricity transmission towers and lines, and disruption in power plants and refinery operations. It could also impact on the trucking and shipping of fuel supplies, with a disproportionate effect on remote areas and small countries, such as Lebanon, with no or limited local energy resources.

Many power plants in the Arab region are located only a few metres above sea level, making them particularly vulnerable to damage from sea level rise and wave surges. Enhancing the capacity of infrastructure to adapt could be achieved through an integrated approach that uses technological advances to improve efficiency and demand management, decentralize the risk over a larger area, develop storm planning for power plants and refineries, and build strategic reserves to manage disruptions to fuel supply and deliveries.[32]

## On infrastructure

Infrastructure supports all types of human activity – domestic, commercial and industrial – in urban and rural settings. Transport systems, coastal defence works, water supply and wastewater systems, electricity generation facilities and oil and gas pipelines can expect to be affected by climatic change.[33]

**Table 2.** Impact of projected climatic changes on transport

| Climate changes | Impact on structural elemants of infrastructure | Impact on operation of the infrastructure |
|---|---|---|
| **Increase in frequency and intensity of very hot days and heat waves** | • Excessive expansion in bridge joints and pavement surfaces<br>• Decrease viscosity of asphalt which may lead to traffic-related rutting and displacement of pavement<br>• Deformities in metal components including rail-tracks, bridge steel elements, etc | • Limitation on the maximum load capacity of trucks and airplanes due to weakening of pavement<br>• Harsh climatic conditions will reduce the effecttiveness and increase the cost of construction and maintance |
| **Increase in sea water level / sea surges** | • Inundation of coastal transportation elements including roads, bridges, airports, etc.<br>• Erosion and deterrioration of pavement, bridge support and its base<br>• Costly adjustment in harbour and port facilities to accomodate tidal increases and more intense sea surges | • Frequent closure of coastal roads due to sea surges<br>• Storm surges may disrupt operations and pose hazards to passengers of coastal airports (e.g. Beirut and Manama Airports) |
| **Increase in the frequency and intensity of sandstorms, thunderstorms, and windy conditions** | • Increased damages to road, rails and bridges.<br>• Increase risk of mudslide and rockslide in mountainous regions, such as in lebanon | • Intense snadstorms in desert areas across the Arab region would cause disruption of road traffic and increase frequency of closures and accidents<br>• Disruption of the operation of airports |

**Source:** Adapted from US National Research Council, 2008.

Transport infrastructure is vulnerable to projected increases in the intensity and frequency of hot days, storm activity and sea level rise. As an example, mitigation options for the transport sector outlined in the first national communication report of the United States National Research Council included:[34]

a. Improved vehicle maintenance and engine tuning;
b. Use of compressed natural gas as a vehicle fuel in transport;
c. Reintroduction of electrified railways in inter- and intra-city transport;
d. Intensified use of environmentally sound river transport systems;
e. Extending metro lines to newly developed cities, and encouraging private sector participation in financing and managing them.

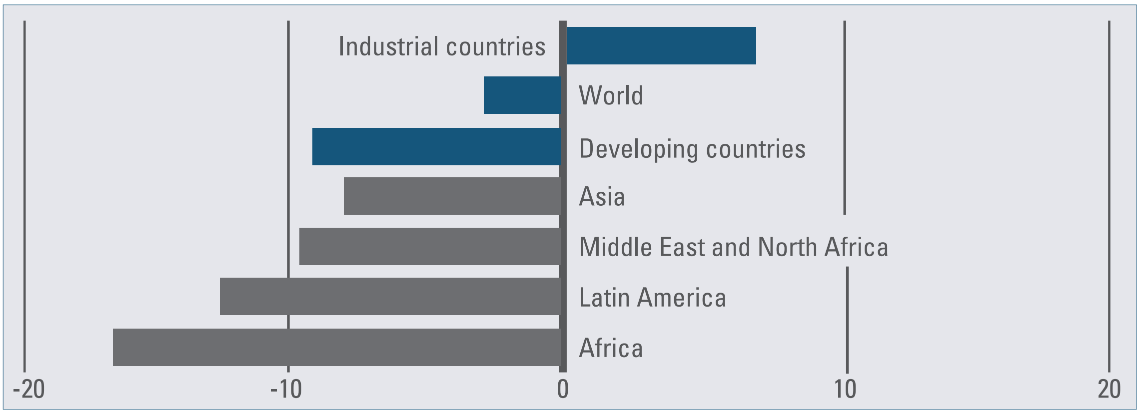
The transport sector in the Arab region is a major component of the energy portfolio, and a heavy producer of emissions. Due to the lack of other environmentally sound transport options, it is responsible for distributing food, fuel and to some extent, water resources. At the same time, this sector has been largely ignored and needs to be considered a factor in energy supply and basic infrastructure for development.

Oil - and gas - producing facilities, especially those in coastal areas and offshore facilities, are vulnerable to sea level rise and extreme weather, such as storms. Transport and distribution infrastructure, including pipelines that in the Arab region can measure thousands of kilometres, are also affected by extreme weather.

Renewable energy sources, such as solar, wind, hydropower and thermal technologies, are designed for specific climatic conditions, and climate change can have an impact on their performance. Extreme dust storms or increased air temperature can reduce the efficiency of photovoltaic (PV) cells and solar thermal collectors. Changes in wind speed and frequency also affect the optimal performance of wind turbines. In the hydropower sector, projected changes in water inflows will affect the amount of energy that can be produced. In power plants, the increased temperature of cooling can represent a big technological hurdle in electricity production.[35]

Aswan High Dam - Aswan - Egypt © Adwo - Shutterstock_ 351688475

**Figure 8.** Change in agricultural output potential (2080s as per cent of 2000 potential)




**Source:** Cline, 2007.

## On food security

Food security and agricultural production are closely related to water resources, and climate change could affect food security through its impact on agricultural production and water availability.

According to the IPCC 2007 report, by the 2080s agricultural potential could increase by as much as 8 per cent in developed countries, primarily as a result of longer growing seasons, while in the developing world it could fall by up to 9 per cent, with sub-Saharan Africa and Latin America projected to experience the greatest losses.[36] A study estimates that for the Arab region as a whole, agricultural output will decrease by 21 per cent in value terms by 2080, but up to 40 per cent in countries such as Algeria and Morocco, as shown in figure 8.[37]

**Table 3.** Agriculture and climate change impact in North Africa

| State | Percentage of water withdrawals used for agricultural purposes (2000) | Rain fed land as percentage of total agriculture area (2003) | Percentage impact of climate change on agriculture productivity by 2080 (compared to 2003), without carbon fertilization | Percentage impact of climate change on agriculture productivity by 2080 (compared to 2003), with carbon fertilization |
|---|---|---|---|---|
| **Algeria** | 65 | 98.6 | -36 | -26.4 |
| **Egypt** | 86 | 0.1 | 11.3 | 28 |
| **Libya** | 83 | 97 | NA | NA |
| **Morocco** | 87 | 95.2 | -39 | -29.9 |
| **Tunisia** | 82 | 96 | NA | NA |

**Sources:** Cline, 2007; FAO, 2010.

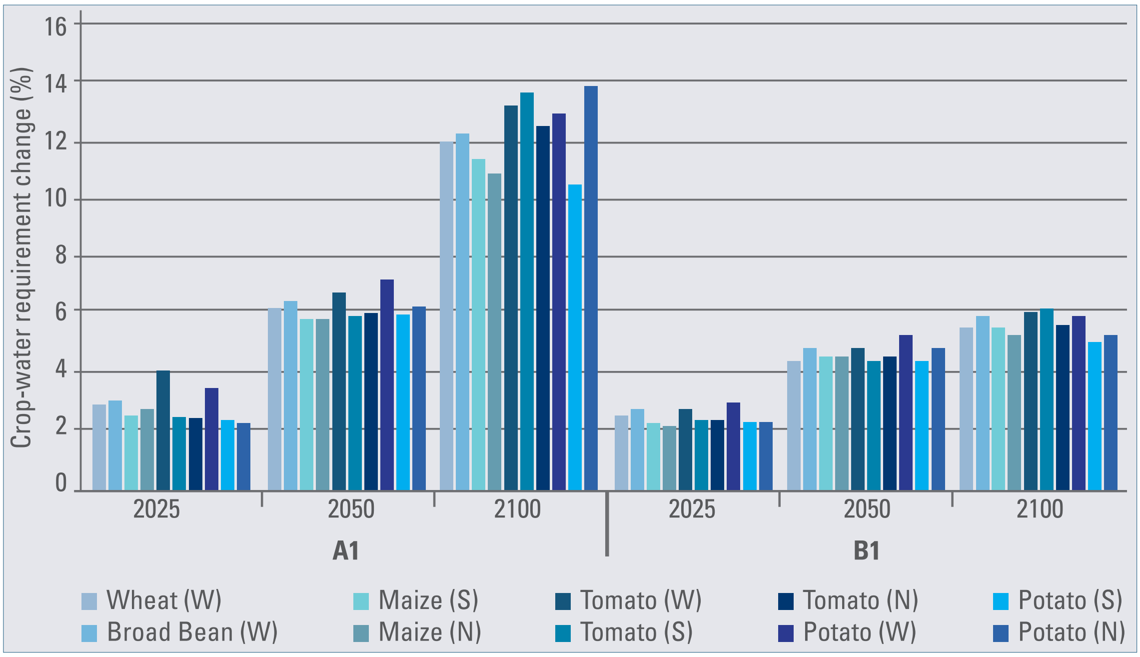
**Table 4.** Projected changes in crop production in Egypt under climate change conditions

| Crop | Change in % | |
|---|---|---|
| | **2050s** | **2010s** |
| **Wheat** | -15% [a] | -36% [b] |
| **Rice** | -11% | |
| **Maize** | -14% to -19% | -20% |
| **Soybeans** | -28% | |
| **Cotton** | +17% [a] | +31% [b] |
| **Potato** | -0.9 to -2.3 % | +0.2 to +2.3% |

**Source:** Fahim and others, 2013.
**Note:** [a] Temperature increase by 2°C; [b] temperature increase by 4°C.

For the Arab region, there is broad consensus from studies that production of most major field crops will fall.[38] El-Shaer and others (1997), for instance, concluded that climate change could severely damage agricultural productivity if no adaptation measures are taken. Table 3 shows the impact of climate change on the Egyptian cropping pattern, indicated in previous studies. By the year 2050, climate change could increase water needs by up to 16 per cent for summer crops but only reduce them by up to 2 per cent for winter crops.[39]

**Figure 9.** Change between current and future values (for years 2025, 2055 and 2100) at national level seasonal crop-water requirements of major field and vegetable crops




**Source:** Mednay, 2008.

In addition, irrigation demand will increase and the period of supplementary irrigation will be extended under projected climate change.[40] Figure 9 illustrates the change in crop-water requirements of major field and vegetable crops due to the change in temperature and $CO_2$ levels based on the IPCC special report on emissions scenarios A1 and B1 for the 2025s, 2050s and 2100s.[41]

# Towards adaptation and resilience: challenges and opportunities

## Adaptation strategies

Elaborating national development strategies without evaluating the impacts of climate change adaptation and resilience can increase vulnerability of local and regional communities. For example, building new weatherproofed roads may encourage human settlements in places that are susceptible to climate change impacts, such as coastal areas vulnerable to sea level rise. This is known as maladaptation, defined by the Organization for Economic Cooperation and Development (OECD) as a business-as-usual development that, by overlooking climate change impacts, inadvertently increases exposure and/or vulnerability to climate change. It can also include actions that fail to reduce vulnerability but increase it.[42] It is important, therefore, that countries collaborate to develop programmes and policies that include potential adaptation. Lessons are numerous in the Arab region, which includes four of the 20 cities most impacted by coastal migration due to sea level rise (Figure 6). Interestingly, these cities are experiencing an influx of migration from highland areas more resilient to future climate change impacts such as sea rise, and with more resilient food systems.

Adaptation activities can fall into the following categories:[43]

a. Human development. Activities that affect development, regardless of climate change impacts. For example, those that target poverty, literacy, gender and pollution;


Jeddah Flood 2009 - King Abdullah Street, Kingdom of Saudi Arabia © Rami Awad - wikimedia.org

b. Response capacity-building. Measures that target the strengthening and/or building of institutions, including technological approaches and tools. Examples are reforestation to combat landslides, integrated resource management systems and weather monitoring stations, which add to local community resilience in responding to catastrophes;
c. Managing climate risk. Activities that decrease the risk of certain events, such as drought-resistant crops, climate proofing and developing disaster response programmes (flooding, sand storms, etc.);
d. Climate change impacts activities. Measures aimed at alleviating the effects of climate events. This would include relocating communities and repairing damaged infrastructure.

These can be used to guide adaptation strategies in the Arab region; for example, the OECD four-step approach for assessing actions, summarized in box 2.

### **Box 2.** A four-step approach to assessing adaptation actions

**Step 1.** Identify current and future vulnerabilities. It has been discussed that there is a lack of specific local and regional climate projections for Arab countries; nevertheless, this step does not need to be too detailed, and can be carried out with simple data to form policy options and strategic plans. This is being addressed by the Regional Initiative for the Assessment of the Impact of Climate Change on Water Resources and Socio-Economic Vulnerability in the Arab Region (RICCAR), which is coordinated by ESCWA and implemented by 11 regional and international organizations.

**Step 2.** Identify adaptation measures. Begin by building a list of adaptation measures that are relevant to the local community, as well as at the national and regional levels. Next, evaluate options holistically, and not only from a financial and economic standpoint. These measures include options that are not directly related to climate change adaptation, such as pollution reduction, water conservation, public health, etc. Or they can be climate-targeted activities such as changes to infrastructure design, change in land use, promoting emergency response procedures, among others. These activities can be of two types, depending on their effect in time: a) reactive (made to respond to observed climate change effects) or b) anticipatory (to plan for future climate change risks).

**Step 3.** Evaluate and select adaptation options. In selecting adaptation actions, it is important to not use costs as the main criteria but to approach selection as a holistic process. Therefore, it is important to consider the following aspects: a) Effectiveness: compare vulnerability with or without the adaptation measure, which is actually the primary benefit of the option. b) Cost: initial, operations, maintenance, and other financial costs involved. However, it is important that non-traditional costs implied in not taking action should also be included (such as loss of biodiversity, costs to human health, etc.).

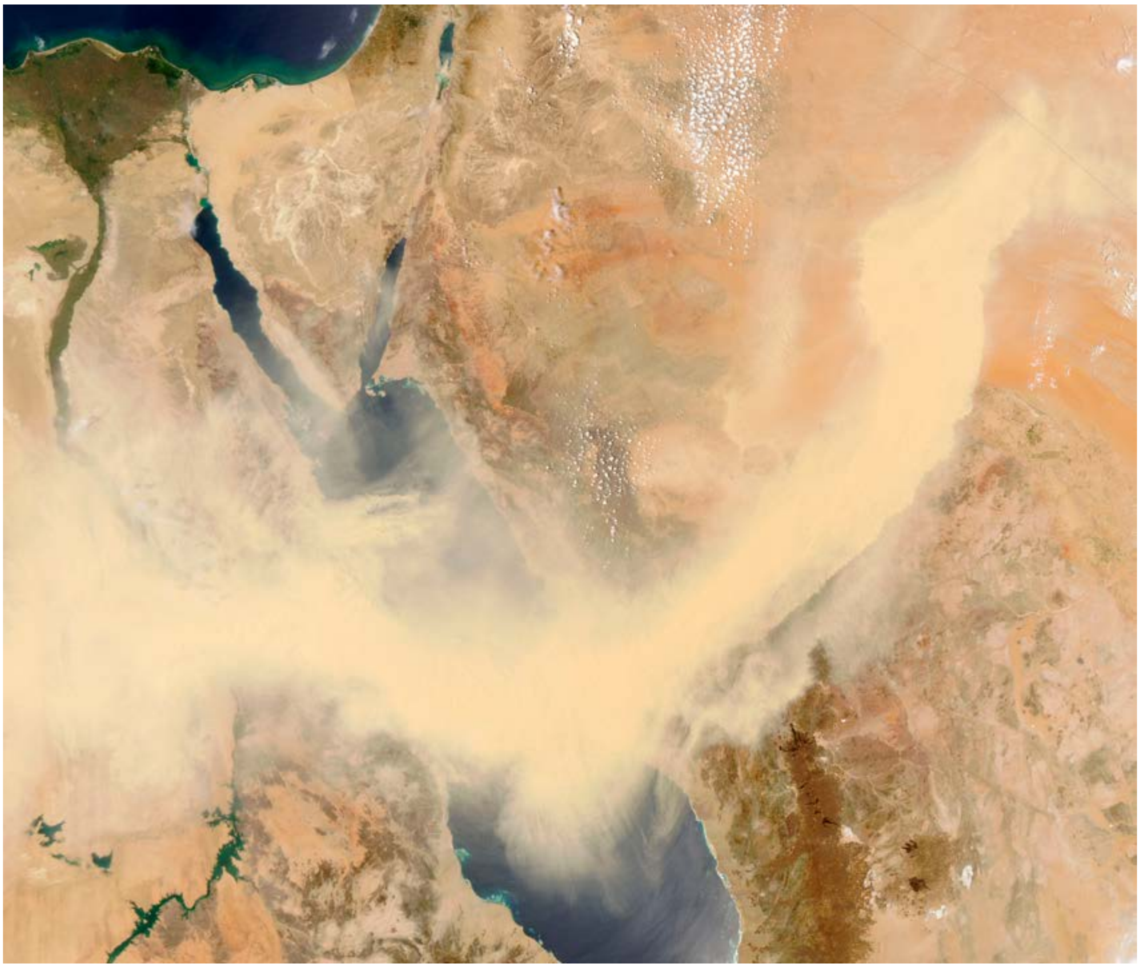
**Step 4.** Monitor and evaluate outcomes of adaptation measures. Monitoring and evaluating the success of a strategy implemented is not a trivial issue since some measures cannot be evaluated until an extreme weather event happens or until climate changes significantly. For measures that have benefits even if climate change does not change, their evaluation is more straight forward.

**Source:** OECD (2009).

## Governance of climate change adaptation and mitigation

Data and information gaps in the Arab region are major obstacles to effective adaptation measures in specific geographic and climate conditions. The most profound knowledge gaps include:

a. Resource use and availability. Lack of data on water resources, such as use and quality, groundwater, sediment transport and water-related systems, and on water use in the energy sector or energy use in the water sector. Other relevant information includes blue and green water cycle variables, updated soil information, and wastewater production, emission, treatment and reuse possibilities. The adequacy and suitability of available data should be reviewed in the context of climate change;
b. Impacts. The effect on groundwater, water quality and aquatic ecosystems is not adequately understood. For example, dust storms have a significant impact on future solar energy deployment, economic infrastructure and mobility, yet data on dust storms, their frequency, intensity and impact on the economy can be gathered only through local monitoring and observation;
c. Scaling/modelling. Data are collected at different spatio-temporal scales. Better integrated climate change and impact modelling is needed, but this requires trouble-shooting to scale mismatched data; for instance, between large-grid cells in climate



A thick band of dust snaking across the Red Sea between Egypt and Saudi Arabia on May 13, 2005 © NASA - wikimedia.org models and smaller-grid cells in hydrological models. Consequently, quantitative projections of changes in streamflow at the basin scale, relevant to water management, remain uncertain in the Arab region, where local downscaling of data, models and know-how is lacking;

d. Scientific. Inadequate and uncertain quantitative projections of changes in water (green and blue) cycles affect water management. Even state-of-the-art research on climate change impacts includes uncertainties about processes in their complex and interconnected forms. More data on the water-soil-waste nexus is needed;[44]
e. Awareness. Science communication and outreach does have a measurable effect on people's adaptive capacity and can lead to a greater willingness to act on climate change.

Climate change is not an isolated problem; it is linked to profligacy in richer societies, poverty in the developing world, and widespread destruction of natural ecosystems.[45] Immediate actions to alleviate impacts in vulnerable regions include: curbing emissions and increasing natural carbon-storing ecosystems; replacing GDP with an index that accounts for the natural and human costs of exploitative economic activity, thereby discouraging environmental damage; and reforming taxation systems to recover the cost of environmental damage.[46]

Most aspects of climate change will persist for centuries, even if emissions of $CO_2$ are stopped. It is crucial, therefore, to implement adaptive measures across multiple levels. Effective risk-reduction strategies consider the dynamics of vulnerability and exposure, and their links to development and climate change.[47]

Knowledge gaps require a platform to monitor climate change impact on economic triggers and securities, namely water, energy and food. Such a governing platform is worryingly absent. The community of practice can be a non-threatening entity that disseminates and shares knowledge to better manage these primary resources and strengthens resilience to climate change and other risks.

# Key messages and recommendations

The scientific data projected for the Arab region anticipates intense, more frequent and longer heatwaves, along with a decrease in annual rainfall, an increase in its intensity and longer periods between rain events. This is likely to induce a series of floods and droughts that disrupt water and energy services. The summer months are projected to become drier, with the hyperarid areas of the Arab region set to experience increases in wind intensities and in the number of the high-intensity storms. This, coupled with the drying, will increase the frequency and intensity of dust storms, bringing significant economic, health and environmental consequences. Stormy weather will severely limit the efficiencies of projected solar-power generation.

Of particular concern in the region is the impact on food and water security. This can be summarized by greater crop water needs as a result of temperature increases and rising municipal water demands. Climatic changes will increase pests and crop-related diseases, and with reduced crop and vegetative cover, the risk of erosion will also increase. This will have huge negative implications for soil and water quality, and land productivity. A cropping system shift will be expected, which will change food production and trade patterns, and lead to higher prices for energy and food.

Disaster-risk management increases climate resilience. According to a World Bank report, approximately 1.3 billion people and US$158 trillion in assets will be at risk from natural disasters by 2050 due to a combination of climate change, growing populations and expanding cities. Estimated annual loss and deaths from disasters increased tenfold between 1976-1985 and 2005-2014, from US$14 billion to more than US$140 billion. If risk management and natural disasters are not accounted for in policymaking and city management, future losses could increase drastically.[48]

The predicted impacts of climate change on water, energy and food security are significant. Adaptation measures need to be bold, and new paradigms are required. Nexus approaches based on the holistic systems theory will help identify hotspots, so no one sector dominates sustainability. Localizing water and food security – regional integrations – is essential for increased resilience, and again, a nexus approach to managing water resources is key.

This nexus approach to climate change adaptation and mitigation requires tools and models to explore options for intensification and trade-offs with water and energy use. This involves sustainable energy and water production technologies that consider environmental impacts and the availability of resources.[49] These tools can be shared among ESCWA member countries to assess the economic, social and environmental sustainability of solutions towards climate adaptation.

Addressing climate change and its impact on water and energy requires multi-stakeholder and multi-scale policymaking. This can be achieved through proactive cross-sector interaction, underpinned by quantitative assessments.[50] Building partnerships through projects that are community-driven is important to sustainable natural resource management.[51] While nexus tools can help provide an analytical framework, the outcomes need to be deliberated to implement solutions. Stakeholders must establish clear ownership of these discussions and potential solutions early on. Governance of deliberations, and financing responsibilities and incentives for all stakeholders, must be clearly shared among all parties involved.

Such an integrated approach can be best achieved through a regional community of practice that works towards developing local climate change benchmarks and sharing knowledge, data and best practices. It can be a platform to develop regional know-how on how climate change impacts on local resources, such as water, energy, infrastructure and agriculture, reducing the dependency on less relevant global data and models.

# Endnotes

1. Gleick, 2009.
2. World Bank, 2009.
3. FAO, 2014.
4. Antonelli and Tamea, 2015.
5. UNFCCC, 2015.
6. UNDESA, 2015.
7. IPCC, 2007.
8. Elasha, 2010.
9. ESCWA, 2015.
10. UNEP/ROWA, 2015.
11. ESCWA, 2015.
12. Ibid.
13. IPCC, 2007.
14. Elasha, 2010.
15. Döll and Flörke, 2005.
16. ESCWA, 2015.
17. Cruz and others, 2007.
18. World Bank, 2010.
19. Karlberg, 2015.
20. Olorunfemi and others, 2016.
21. Tolba and Saab, eds., 2009.
22. Abahussain and (others.,) 2002.
23. Tolba and Saab, eds., 2009.
24. World Bank, 2007a.
25. Abdel Gelil, 2015.
26. Almulla, 2014.
27. Tolba and Saab, eds., 2009.
28. Ibid.
29. US CCSP, 2007.
30. Davcock and others, 2004.
31. Guta and Borner, 2015.
32. Neumann and Price, 2009.
33. Tolba and Saab, eds., 2009.
34. US National Research Council, 2007.
35. Verner, 2012.
36. UNDP, 2007.
37. World Bank, 2007b.
38. Tolba and Saab, eds., 2009.
39. Eid and others, n.d.
40. Nagano and others, 2007.
41. Medany, 2008.
42. OECD, 2015.
43. McGray and others, 2007.
44. Lawford, 2015.
45. Moss, 2015.
46. Ibid.
47. Kundzewicz, 2015.
48. GFDRR, 2016.
49. Karlberg, 2015.
50. Ibid.
51. Olorunfemi and others, 2016.

# Bibliography


Abahussain, Ali. AAbahussain and others (2002). Desertification in the Arab region: analysis of current status and trends. *Journal of Arid Environments*, vol. 51 No. 4, pp. 521-545. Available from http://www.yemenwater.org/wp-content/uploads/2013/04/D2.-Desertification-in-the-Arab-Region-Analysis-of-current-status-and-trends.pdf.

Abdel Gelil, Ibrahim (2015). Energy Demand Profile in Arab Countries. In *Arab Environment: Sustainable Consumption. Annual Report of Arab Forum for Environment and Development,* Ibrahim Abdel Gelil and Najib Saab, eds. Beirut: AFED. Available from http://www.afedonline.org/Report2015/English/p84-107%20Energy%20English%20today.pdf.

Abdulla, Fayez A., and Abbas S. Al-Omari, A. (2008). Impact of climate change on the monthly runoff of a semi-arid catchment: Case study Zarqa River Basin (Jordan). *Journal of applied biological sciences*, vol. 2 No. 1, pp. 43-50. Available from http://www.nobel.gen.tr/yayindetay.aspx?yayin_id=1655.

Almulla, Yousef (2014). Gulf Cooperation Council (GCC) countries 2040 energy scenario for electricity generation and water desalination. Master of Science thesis EGI 2014: Mar-Sep 2014. KTH Industrial Engineering and Management. Available online at https://www.diva-portal.org/smash/get/diva2: 839740/FULLTEXT01.pdf.

Antonelli, Marta, and Stefania Tamea. (2015). Food-water security and virtual water trade in the Middle East and North Africa. *International Journal of Water Resources Development*, vol. 31, No. 3 (May), pp. 326-342.

Cline, William R. (2007). Global warming and agriculture: impact estimates by country. Center for Global Development and the Peterson Institute for International Economics. ISBN-13: 978-0-88132-403-7.

Cruz, R.V. and others (2007). *Climate Change 2007: Impacts, Adaptation and Vulnerability*, Parry Martin L., Osvaldo, F. Canziani, Jean P. Palutikof, Paul J. van der Linden and Clair E. Hanson, eds. Cambridge, UK: Cambridge University Press. Available from https://www.ipcc.ch/pdf/assessment-report/ar4/wg2/ar4_wg2_full_report.pdf.

Davcock, C., and others (2004). Generation cost forecasting using on-line thermodynamic models. Presented at the Electric Power Conference, April 1, 2004. Baltimore, MD, USA.

Döll, Petra and Martina Flörke (2005). *Global-scale estimation of diffuse groundwater recharge.* Frankfurt Hydrology Paper 03. Frankfurt am Main, Germany: Institute of Physical Geography, Frankfurt University. Available from https://www.uni-frankfurt.de/45217767/FHP_03_Doell_Floerke_2005.pdf.

Eid, Helmy. M, and others (n.d.). Assessing the impact of climate on crop water needs in Egypt: the cropwat analysis of three districts in Egypt. Available from http://www.ceepa.co.za/uploads/files/CDP29.pdf.

El-Shaer, H. M. and others (1997). Impact of climate change on possible scenarios for Egyptian agriculture in the future. *Mitigation and Adaptation*

*Strategies for Global Change*, vol. 1, No. 3, pp. 233-250.

Elasha, Balgis O. (2010). *Mapping of climate change threats and human development impacts in the Arab region.* UNDP Arab Development Report-Research Paper Series. New York: UNDP Regional Bureau for the Arab States. Available from http://www.arab-hdr.org/publications/other/ahdrps/paper02-en.pdf.

Economic and Social Commission for Western Asia (ESCWA) (2015). *Climate Projections and Extreme Climate Indices for the Arab Region.* Regional Initiative for the Assessment of the Impact of Climate Change on Water Resources and Socio-Economic Vulnerability in the Arab Region (RICAAR). Beirut. E/ESCWA/SDPD/2015/Booklet.2. Available from https://www.unescwa.org/sites/www.unescwa.org/files/publications/files/l1500436.pdf.

Fahim M. A., and others (2013). Climate Change Adaptation Needs for Food Security in Egypt. *Nature and Science*, 2013;11(12). Available from http://www.sciencepub.net/nature/ns1112/010_21338ns1112_68_74.pdf.

Food and Agriculture Organization of the United Nations (FAO) (2010). “Climate-Smart” Agriculture: Policies, Practices and Financing for Food Security, Adaptation and Mitigation. Rome. Available at http://www.fao.org/docrep/013/i1881e/i1881e00.pdf.

Food and Agriculture Organization of the United Nations (FAO) (2014). On-line database. Available from http://www.fao.org/nr/water/aquastat/main/index.stm. Accessed May 2016.

Global Facility for Disaster Reduction and Recovery (GFDRR) (2016). *The making of a riskier future: how our decisions are shaping future disaster risk.* Washington D.C. Available from https://www.gfdrr.org/sites/default/files/publication/Riskier%20Future.pdf.

Gleick, Peter H. (2009). *The world's water 2008-2009: the biennial report on freshwater resources.* Pacific Institute for Studies in Development, Environment, and Security. Washington, D.C.: Island Press.

Guta, Dawit D., and Jan Borner (2015). Energy Security, Uncertainty and Energy Resource Use option in Ethiopia: A Sector Modelling Approach. Presented at IEW/IRENA June 2015, Abu Dhabi, United Arab Emirates.

Hallegatte, S, and others (2013). Future flood losses in major coastal cities. *Nature climate change* 3 (9), 802-806.

Immerzeel, Walter and others (2011). Middle East and Northern Africa water outlook. World Bank Study. FutureWater Report, p. 98. Available from http://www.futurewater.eu/wp-content/uploads/2011/04/Final_Report_v11.pdf.

International Panel on Climate Change (IPCC) (2007). Climate Change 2007: Impacts, Adaptation and Vulnerability. Contribution of Working Group II to the *Fourth Assessment Report of the Intergovernmental Panel on Climate Change.* Parry Martin L., Osvaldo, F. Canziani, Jean P. Palutikof, Paul J. van der Linden and Clair E. Hanson, eds., Cambridge: Cambridge University Press. Available from https://www.ipcc.ch/pdf/assessment-report/ar4/wg2/ar4_wg2_full_report.pdf.

Karlberg, Louise (2015). Tackling Complexity in a Changing Climate: the Water-Energy-Food Nexus in Low Income Countries. Dresden Nexus Conference 2015: Keynotes and Publications. Dresden.

Kundzewicz, Zbigniew W. (2015). Climate Change Impacts and Adaptation in Water and Land Context. Dresden Nexus Conference 2015: Keynotes and Publications. Dresden. Available from http://www.dresden-nexus-conference.org/wp-content/uploads/2016/03/D-1-Kundzewicz-Extended-Summary-Bio.pdf.

Lawford, Richard (2015). Adapting to climate change: the role of science and data in responding to opportunities and challenges in the water-soil-waste nexus. Working paper. UNU-FLORES. Available from http://collections.unu.edu/eserv/UNU:3181/WorkingPapers_No3_All_v2_WEB.pdf.

McGray, Heather, and others (2007). *Weathering the Storm: Options for Framing, Adaptation and Development.* Washington: World Resources Institute. Available from http://www.wri.org/sites/default/files/pdf/weathering_the_storm.pdf.

Medany, Mahmoud (2008). Impact of climate change on Arab countries. In *Arab environment future challenges*, Mostafa K. Tolba and Najib W. Saab, eds. Beirut: Arab Forum for Environment and Development. Available from http://www.afedonline.org/afedreport/full%20english%20report.pdf.

Milly, Paul C., and others (2005). Global pattern of trends in streamflow and water availability in a changing climate. *Nature*, vol. 438, No. 7066 (November), pp. 347-350.

Moss, Brian (2015). Climate Change, Profligacy, Poverty and Destruction: All things are connected. Dresden Nexus Conference 2015: Keynotes and Publications. Dresden. Available from http://www.dresden-nexus-conference.org/wp-content/uploads/2016/03/D-1-Moss-Extended-Summary-Bio.pdf.

Nagano, Takanori, and others (2007). Assessing adaptive capacity of large irrigation districts towards climate change and social change with irrigation management performance model. Paper presented at the International Congress of River Basin Management. Available from http://www2.dsi.gov.tr/english/congress2007/chapter_2/52.pdf.

Neumann, James E., and Jason C. Price (2009). *Adapting to Climate Change: The Public Policy Response-Public Infrastructure.* Resources for the Future. Available from http://www.rff.org/files/sharepoint/WorkImages/Download/RFF-Rpt-Adaptation-NeumannPrice.pdf.

Olorunfemi, Felix, and others (2016). Natural resource use and adaptation to climate change in the Nigerian Savanna. DNC policy briefs. UNU-FLORES. Presented at the Dresden Nexus Conference, 2015. Available from http://collections.unu.edu/eserv/UNU:5734/DNC2015_PolicyBrief_No2_v03_WEB.pdf.

Organization for Economic Cooperation and Development (OECD) (2009). Integrating Climate Change Adaptation into Development Co-operation: Policy Guidance. Available from https://www.oecd.org/dac/43652123.pdf.

Organization for Economic Cooperation and Development (OECD) (2015). Adapting to the impacts of climate change: Policy Perspectives. Available from https://www.oecd.

org/env/cc/Adapting-to-the-impacts-of-climate-change-2015-Policy-Perspectives-27.10.15%20WEB.pdf.

Schewe, Jacob, and others (2014). Multimodel assessment of water scarcity under climate change. Proceedings of the National Academy of Sciences, vol. 111 No. 9 (March) pp. 3245-3250. Available from http://www.pnas.org/content/111/9/3245.full.pdf.

Schilling, Janpeter, and others (2012). Climate Change, Vulnerability and Adaptation in North Africa with focus on Morocco. *Agriculture Ecosystems and Environment,* 156:12–26 July 2012.

Tolba, Mostafa K. and Najib W. Saab, eds. (2009). *Arab environment: climate change: Impact of climate change on Arab countries.* Beirut: Arab Forum for Environment and Development. Available from http://www.afedonline.org/afedreport09/Full%20English%20Report.pdf.

United Nations Development Programme (UNDP) (2007). *Human Development Report 2007/2008, Fighting climate change: human solidarity in a divided world.* Oxford University Press for UNDP. Available from http://hdr.undp.org/sites/default/files/reports/268/hdr_20072008_en_complete.pdf.

United Nations Environment Programme, Regional Office for West Asia (UNEP/ROWA) (2015). Issue brief for the Arab Sustainable Development Report: Climate change in the Arab Region. Regional Coordination Mechanism (RCM). Available from http://css.escwa.org.lb/SDPD/3572/Goal13.pdf.

United Nations Department of Economic and Social Affairs (UNDESA), (2015). The Sustainable Development Goals (SDGs). Available from https://sustainabledevelopment.un.org/sdgs.

United Nations Environment Programme/Global Resource Information Database Arendal (UNEP/GRID-Arendal) (2009). Excessive withdrawal of Renewable Water Resources. Map drawn from data in UNEP Grid-Arendal using data from FAO and Aquastat, Philippe Rekacewicz. Available from http://www.grida.no/graphicslib/detail/excessive-withdrawal-of-renewable-water-resources_f365#.

United Nations Framework Convention on Climate Change (UNFCC) (2015). Historic Paris Agreement on Climate Change: 195 Nations Set Path to Keep Temperature Rise Well Below 2 Degrees Celsius. UN Climate Change Newsroom. December 2015. Available from http://newsroom.unfccc.int/unfccc-newsroom/finale-cop21/.

U.S. Climate Change Science Program (US CCSP) (2007). Evaluating Progress of the U.S. Climate Change Science Program: Methods and Preliminary Results. Washington, D.C.: The National Academies Press. Available from http://www.nap.edu/catalog/11934/evaluating-progress-of-the-us-climate-change-science-program-methods.

United States National Research Council (of the National Academies) (2007). *Minerals, critical minerals, and the U.S. economy.* Washington, D.C. Available from http://www.nma.org/pdf/101606_nrc_study.pdf.

United States National Research Council (of the National Academies) (2008). Potential Impacts of Climate Change on U.S. Transportation. Committee on Climate Change and U.S. Transportation. Transportation Research Board Division on Earth and Life Studies. Washington, D.C. Available from http://onlinepubs.trb.org/onlinepubs/sr/sr290.pdf.

Verner, Dorte, ed. (2012). Adaptation to a Changing Climate in the Arab Countries: A Case for Adaptation Governance and Leadership in Building Climate Resilience. MENA development report. Washington, D.C.: World Bank. Available from https://openknowledge.worldbank.org/bitstream/handle/10986/12216/734820PUB0REVI000PUBDATE01101602012.pdf?sequence=7&isAllowed=y.

World Bank (2007a). *Making the Most of Scarcity Accountability for Better Water Management in the Middle East and North Africa.* Washington, D.C. Available from https://openknowledge.worldbank.org/bitstream/handle/10986/6845/411130was390400Englishoptmzd.pdf.

World Bank (2007b). Middle East and North Africa Region (MENA) Sustainable Development Sector Department Regional Business Strategy to Address Climate Change (Preliminary draft for consultation and feedback). Washington, D.C. Available from http://siteresources.worldbank.org/INTCLIMATECHANGE/Resources/MENA_CC_Business_Strategy_Nov_2007_Revised.pdf.

World Bank (2009). *West Bank and Gaza, Assessment of Restrictions on Palestinian Water Sector Development, MENA Region.* Report No. 47657-GZ. Washington, D.C. Available from http://siteresources.worldbank.org/INTWESTBANKGAZA/Resources/WaterRestrictionsReport18Apr2009.pdf.

World Bank (2010). *The Cost to Developing Countries of Adapting to Climate Change: New Methods and Estimates.* Washington D.C. Available from http://siteresources.worldbank.org/EXTCC/Resources/EACC-june2010.pdf.

The water and energy nexus regional policy toolkit has been prepared as part of the United Nations Development Account (UNDA) project for developing the capacity of ESCWA member countries to address the water and energy nexus for achieving Sustainable Development Goals. This project aims to build the capacity of ministries and public service providers responsible for water and energy in the Arab region to examine and address the water and energy nexus in an integrated manner.

ESCWA member countries recognize the importance of integrating water and energy resources management. Endorsed by the twenty-seventh ESCWA ministerial session in May 2012, the ESCWA Committee on Water Resources issued a recommendation that was welcomed by the ESCWA Energy Committee to examine the water-energy nexus. In response, ESCWA organized an "Intergovernmental Consultative Meeting on the Water and Energy Nexus in the ESCWA Region" (Beirut, 27-28 June 2012) for members of both ESCWA intergovernmental committees to discuss their views and perceptions regarding the water and energy nexus within the regional context. The meeting resulted in the identification of seven priority areas. Capacity-building was put forward as the way to foster integrated policy analysis, formulation and action on these priority issues at the interministerial and intraregional levels.

This water and energy nexus regional policy toolkit contains the following seven modules, each addressing one of the identified priority areas:

- Knowledge and Awareness-Raising
- Increasing Policy Coherence
- Examining the Water-Energy Security Nexus
- Increasing Efficiency
- Informing Technology Choices
- Promoting Renewable Energy
- Addressing Climate Change and Natural Disasters

16-00155