OFID PAMPHLET SERIES

41

The energy–water–food nexus: **Managing key resources for sustainable development**

VIENNA 2017

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The "OFID Pamphlet Series" was begun in 1977, a year after the establishment of OFID. The series is meant to promote a better understanding of the aspirations and problems of developing countries, including OPEC Member States.

OFID is the multilateral development finance institution established by the Member States of OPEC in 1976 to promote South-South solidarity and strengthen cooperation between countries of the developing world.

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Uniting against Poverty

Unless otherwise stated “dollars” ($) refers to United States dollars.
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Foreword of the Director-General

The OPEC Fund for International Development (OFID) is widely recognized in the international development community for its pioneering Energy for the Poor initiative and its lead role in securing a prominent position for energy access in the 2030 Global Development Agenda.

OFID is driven by the conviction that access to affordable, reliable, and sustainable energy services represents one of the most powerful catalysts for both human and economic advancement. Indeed, we argue that universal energy access is a *prerequisite* to attaining the Sustainable Development Goals (SDGs) adopted by world leaders in September 2015 under the umbrella of Agenda 2030.

Energy sits at the core of OFID's strategic framework. But it does not sit in isolation. Alongside it—and just as important—are security of water and food supply, both of them essential to sustain a global population expected to grow to 9.7 billion by 2050.

Over the past four decades, OFID has co-financed countless projects in these three sectors, in a multitude of different settings in 120 countries. This broad and diverse experience has taught us that energy, water and food are intimately and complexly linked, and that uncoordinated interventions in one sector can inadvertently create risks and uncertainties in another.

Perhaps the most striking example of this kind of trade-off is the negative impact of biofuels development on food production, a danger that OFID drew attention to in its 2009 study "Biofuels and Food Security." Taking over large swathes of land previously dedicated to food crops, this practice contributed significantly to the global food crisis of 2007–2008, when shortages of basic staples and the attendant price hike sparked hunger and ugly riots across developing regions.

Extreme as it may be, this example is a perfect illustration of how essential it is to take a holistic, "nexus" approach to the challenges of energy, water and food security. Simply put: none should be pursued at the expense of one—or both—of the others, because all three are fundamental to poverty eradication and sustainable development. As well as addressing challenges in its own specific sphere, the energy–water–food (EWF) nexus reaches deep into the SDGs, impacting numerous other goals, such as those relating to climate change, health, gender equality, economic opportunity, and even education.

OFID is keenly attuned to the potential of nexus-led sustainable development. By positioning the EWF nexus at the heart of our Corporate Plan 2016–2025, we have made clear our readiness to mobilize all means at our disposal to tackle energy, water and food security in an integrated way. Over the coming decade, we are committed to channeling 70 percent of our funding to these critical sectors (plus transportation as an additional enabling component). Once again, OFID is leading by example—and with concerted action.

Guiding this strategy is our commitment to people-centered development, with poverty eradication as our bottom line. So, when it comes to the nexus, we are especially mindful of the people at the "coalface": the two billion or so small farmers and their families, who depend on the land and its ever-dwindling resources for survival. With nexus-led interventions, we can promote the development of climate- and resource-smart agriculture and potentially give these people the opportunity to escape from poverty once and for all.

We are also mindful, however, that the onus of adopting a nexus perspective in development intervention lies with our partner countries. It is not for us to impose our views on development planners, but rather to inform and support the decision-making process. At the same time, we can work to raise awareness of the advantages of nexus-led strategies—both among our partner countries and our cofinancing network—while alerting to the pitfalls of continuing with sectoral or "silo" approaches.

In this context, I hope that the discussions covered in this latest addition to the OFID pamphlet series will help build a greater understanding of the EWF nexus and offer insights as to its huge potential as an enabler of poverty eradication and sustainable development in all its critical dimensions.

Suleiman J Al-Herbish
Director-General

Introduction

The world is confronted with significant challenges in the way it manages and consumes its resources. Traditionally, energy, water and food have been treated—and intervention designed—as if the relationship between the three was only casual. Little consideration has been given, for instance, to the impact on food security and water resources of growing food crops for biofuels production. The fact is that energy security, water security and food security are closely intertwined. In its simplest form, the relationship can be characterized as follows: food production needs water and energy; water production needs energy; and energy production needs water.

Beyond these basic dependencies, the interactions among the three sectors are highly complex and dynamic. And their entanglement will only become more intimate in the coming decades, as population growth, urbanization, and economic growth combine to exert even greater pressure on resources. At the same time, the adequacy of these resources will be impacted as the effects of climate change become more significant.

In developed countries, the three resources (energy, water and food) are readily accessible. The same cannot be said, however, for the majority of developing countries, which face difficult challenges. With most of the world's population growth expected to occur in these countries, effective adaptation to climate change requires the efficient use of energy, water, land, and other vital resources, together with coordinated efforts to minimize trade-offs and maximize synergies. "Silo thinking" is no longer an option; energy, water and food need to be looked at as a "system." This means the creation of a holistic approach that explicitly defines the links between the single components of the EWF nexus and understands the effect each one has on the others. Such approach helps to eliminate the unintended consequences that are common when policy makers promote an intervention in one part of the nexus and end up damaging another.

In the wider scheme of poverty eradication and sustainable development, the EWF nexus is a key component of the 2030 Agenda for Sustainable Development, which identifies energy, water and food security as three of 17 Sustainable Development Goals (SDGs).

This publication is intended as a contribution toward raising awareness of the nature of the EWF nexus challenges in developing countries and helping the development of insightful perspectives on these challenges. The pamphlet is written as an introduction to the general public and is not meant as a highly specialized treatise on the nexus issue.

Chapter I argues that the nexus approach represents a smart strategy for the efficient use and management of natural resources. The chapter elaborates in some detail the linkages in the three areas of nexus interdependence: food and water; energy and water; and food and energy. It then maps the nexus risks at the regional level, noting that the implications and risks related to supplying these resources vary from one region to another.

Chapter II is based on the premise that future demographic prospects, including population growth and increased urbanization, are increasing the pressures on resources. It explores in detail the expected future trends in the demand for energy, water and food. In presenting these forecasts, the chapter draws upon analyses of reputable institutions.

Chapter III is dedicated to a closer inspection of the relationship between the EWF nexus and the broader sustainable development debate, including climate change adaptation. The chapter examines the definition of sustainable development as a concept that embraces three dimensions: the economic, social and environmental. Reflecting this definition, the SDGs seek to lift—and keep—people out of poverty by ensuring that development is both socially and environmentally sustainable. In achieving this, a nexus approach can help to formulate goals and targets that minimize trade-offs and maximize synergies between goals, making the SDGs more cost-effective and efficient, and ensuring sustainable resource use. As the principles, strategies and goals of the nexus approach are closely related to those employed for climate change adaptation, the chapter presents the basic elements of a nexus-based framework for sustainable adaptation. It then introduces the concept of "natural infrastructure" and addresses the need for new approaches and novel, cost-effective strategies in order to meet the challenges of developing new infrastructure while operating, maintaining, rehabilitating and ensuring the environmental compliance of aging energy, water and food systems' infrastructure in developing countries.

In Chapter IV, the challenges of ensuring the proper governance and regulatory environment to support nexus investment are discussed. The chapter argues that while the nexus approach can help realize significant economic gains, robust institutional structures are needed. It then reviews how a risk-based approach that considers the interlinkages among the nexus sectors can attract and improve returns on investment in energy, water and land-use projects.

Chapter V outlines OFID's commitment to the EWF nexus and draws on case studies of OFID-sponsored, nexus-led projects to illustrate the practical application of the nexus approach in designing, financing and implementing interventions in the energy, water and agriculture sectors.

Executive Summary

The energy–water–food (EWF) nexus approach recognizes the dynamic and complex interlinkages between energy, water and food security, all of which are key goals in the context of sustainable development. The approach is a structured planning method that aims to capture the interdependency of resource use and availability across all three major sectors. In so doing, it can lead to a more optimal allocation of resources, improved economic efficiency, lower negative environmental and health impacts, and better economic development conditions.

Agriculture is the largest consumer of the Earth's available freshwater, accounting for 70 percent of withdrawals. The challenges of the *food–water nexus* are characterized by overexploitation of groundwater together with the increased use of fertilizers and agro-chemicals, leading to water contamination and soil degradation.

The *water–energy nexus* is characterized by the extensive use of water in the production of primary energy and power generation, and the role of energy in the extraction and distribution of water, wastewater treatment and the heating of water for domestic and industrial uses. These interlinkages expose both sectors to risks.

Energy is needed along the entire value chain of food production, with end-use energy demand in the global food sector representing around one-third of total global final energy demand. Among the risks facing the *food–energy nexus* are: the diversion of food crops for the production of biofuels, and increased biofuels production leading to greater competition with the agriculture sector for water resources.

The implications and risks related to the nexus sectors vary from one region to another. Hence, putting the nexus approach into practice necessitates delivering solutions at multiple scales and in different contexts. Nexus approaches are relevant at all points on the development spectrum.

Over time, stress on the energy, water and food sectors will increase in line with population growth and urbanization. Forecasts indicate that global energy demand will grow by 30 percent between 2014 and 2030, water consumption will rise by more than 20 percent over the period to 2040, and annual global production of crops and livestock will need to be 60 percent higher in 2050. Thus, the interlinkages between the three components of the EWF nexus will become even more complex in the future. The greatest challenges will be in developing countries, where most of the demand growth will take place.

In discussing the EWF nexus, it is important to look at the challenges within the wider context of sustainable development. This means giving equal consideration to the economic, social and environmental dimensions, as reflected in the Sustainable Development Goals (SDGs). A nexus approach can make the SDGs more cost-effective and efficient by helping to formulate goals and targets that minimize trade-offs and maximize synergies between goals, while ensuring sustainable resource use.

Energy, water and food have been identified as priority areas under the SDGs, with interactions evident between most of the targets under Goal 2 (food security), Goal 6 (water & sanitation) and Goal 7 (energy access), i.e. the EWF nexus. Integration through a nexus approach could help the SDGs to manage complexity and make the goals easier to communicate and to implement.

For developing countries, the challenge of meeting the growing demands for energy, water and food is further compounded by climate change. As the principles, strategies and goals of the nexus approach are closely related to those employed for climate change adaptation, the two need to be thought about in tandem. Some adaptation measures might have positive implications for energy, water and food resources, while other measures may increase nexus-related challenges.

Understanding the role of the nexus in climate change adaptation is integral to designing effective policies and strategies. A nexus-based response strategy for sustainable adaptation can help ensure the security of resources in all three sectors while at the same time talking into consideration the three dimensions of sustainable development. Nexus perspectives should thus be integrated into adaptation plans and vice versa.

Innovative approaches and cost-effective strategies are required to help developing countries develop new infrastructure while operating, maintaining and ensuring environmental compliance of aging infrastructure. Traditionally, the private sector and governments have relied on engineered approaches, or "gray infrastructure," to secure energy, water and food systems. However, this is becoming more difficult and less appealing from a financial perspective. In planning future infrastructure systems, a useful approach is the integration of gray infrastructure with natural infrastructure, which can be utilized as a substitute or complement to the former.

When it comes to securing the necessary financing for nexus investments, it is essential to ensure proper governance and an encouraging regulatory environment conducive to fostering innovation and risk-taking. When these exist, financing from public and private sectors will be forthcoming and can be scaled up. Nexus governance must take account of many risks, and the challenges are exacerbated by the multiple conflicts of interest created by the large number of stakeholders. Governance challenges facing developing countries include institutional weaknesses, data deficits and an undeveloped culture of cooperation across the sectors.

National governments can play a key role in setting regulatory frameworks and standards, removing policy barriers, providing funding and technical assistance and facilitating coordination among sectors and different levels of government. With proper political support, a formal governance mechanism should empower all stakeholders and bring together the private sector, governments, bureaucratic structures and informal networks.

Raising finance from sources other than public funds can be challenging due to greater costs and higher risks, so policy makers should identify and create incentives for the private sector. Common approaches to scaling-up funds include using private–public partnerships and public–private and civil society platform methods. Public funds, including subsidies, are essential to compensate and incentivize the private sector. Joint nexus-related infrastructure ventures between countries can also provide good options when making investment decisions about shared resources.

Blended and innovative financing is needed to mitigate risks for large nexus investments. Blended financial solutions can channel capital from other sources and combine the skills, knowledge and resources of public and private investors to increase the scope, range and effectiveness of the investments.

International finance institutions can play a pivotal role in the financing of nexus-related projects through lending and equity participation, and by supplying risk mitigation products such as guarantees.

OFID (the OPEC Fund for International Development) is one of many development finance institutions that have adopted the EWF nexus as an important focus of its activities. OFID's involvement stems from its role as a pioneer of energy poverty eradication and its many decades of experience in development finance, which have underlined the necessity of an integrated approach to sustainable development. OFID recognizes that for energy access to take its full effect, it has to be related to the food and water dimensions.

The agriculture sector in developing countries needs to undergo significant change and modernization in order to become an expanding, income-generating and profitable business sector. This agricultural revolution will be driven by technological and commercial innovations and by the entrepreneurs that bring them to market. Some technologies are already cost effective, but enterprises that can commercialize these technologies still need help in many low-income markets.

OFID is helping to overcome these barriers through innovative EWF-nexus projects that support the agriculture sector by expanding access to modern energy services, such as solar power for irrigation and biogas systems for dairy farming.

Chapter I

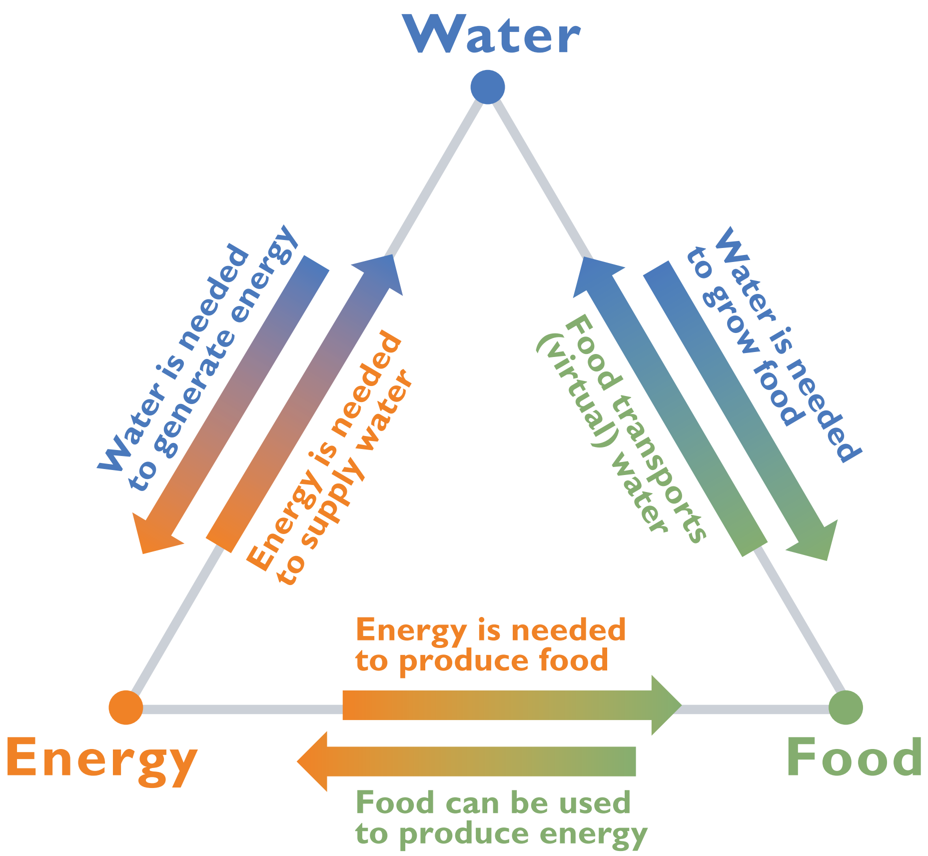
A nexus strategy for efficient resource management

Why an EWF-nexus approach? Elaborating the linkages

The EWF-nexus approach to development recognizes the dynamic and complex interlinkages between energy, water and food. At the core of this approach is the belief that, as sectoral issues, energy, water and food cannot be considered in isolation from one another. While each sector is multifaceted in its own right, the linkages among the three sectors introduce relationships, challenges and opportunities that are more complicated still. Water, for example, is necessary for fuel extraction, refining and production, as well as for electricity generation. Meanwhile, energy is needed to extract, pump and transmit water, as well as for drinking water purposes and waste treatment. Water and energy are essential inputs to food production, processing, distribution and preparation, while the production of certain biofuels uses food crops. Agriculture and food production affect the water sector through land degradation, changes in runoff, and disruption of groundwater discharge. Figure I.1 illustrates these relationships.

Food security, sound water management and universal access to modern energy services are key goals in the context of sustainable development. Risks and uncertainties arise if policies and interventions in these sectors are made without cross-sectoral coordination. Traditional development solutions that treat energy, water and food security separately are inadequate and often lead to unintended consequences. For example, the pursuit of energy security in many countries led to an unprecedented expansion in the production of first-generation biofuels in the second half of the last decade. This expansion encroached on land traditionally used for growing food crops, resulting in a drop in production and a subsequent significant rise in food prices, especially in developing countries.

The energy–water–food nexus[1] **Figure I.1**



The EWF-nexus approach defends against traditional silo thinking, since it is a structured planning method that aims to capture the interdependency of resource use and availability across all three major sectors.[2] A holistic framework focuses on system efficiency, rather than on the productivity of individual sectors. The EWF-nexus approach, therefore, can lead to a more optimal allocation of resources, improved economic efficiency, lower negative environmental and health impacts, and better economic development conditions. In short, the EWF-nexus approach can optimize people's welfare.[3]

The EWF-nexus and the wider development agenda

Box 1.1

In September 2015, the United Nations General Assembly adopted the 2030 Agenda for Sustainable Development, "a plan of action for people, planet and prosperity." Agenda 2030 recognizes that eradicating poverty is the greatest global challenge and an indispensable requirement for sustainable development.

The Agenda's 17 SDGs reflect an improved understanding of the complexity of the relationships between the different aspects of development. They are presented as separate elements but are based on an integrated, systematic approach that seeks to balance the three dimensions of sustainable development: the economic, social and environmental.

The SDGs cover a wide spectrum of topics: from food security, poverty, and gender inequality, to inclusive economic development, climate change, and health, among others. Under each of the Goals is a list of quantifiable targets to be achieved in the coming 10–15 years. Progress toward 12 of the SDGs is directly related to the sustainable use of resources such as land, food, water, energy and materials. Energy, water and food security (the nexus sectors) are recognized as priority areas and are SDGs in their own right.

As a "system," the EWF nexus not only addresses challenges in its own specific ambit, but also impacts other SDGs, including those relating to climate change, health, gender equality, economic opportunity, education, and, above all, poverty eradication. The nexus may thus be seen as a central pillar of Agenda 2030 and an enabler of sustainable development in all its dimensions.

See Chapter 3 for a more detailed analysis of the EWF nexus, the SDGs and climate change.

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1 Source: Institute of Agriculture and Natural Resources, University of Nebraska–Lincoln, http://www.unl.edu/nc-few/food-energy-water-nexus

2 Leck H. et al., *Tracing the Water–Energy–Food Nexus: Description, Theory and Practice*, Geography Compass, Vol. 9 (8), pp. 445–460, 2015

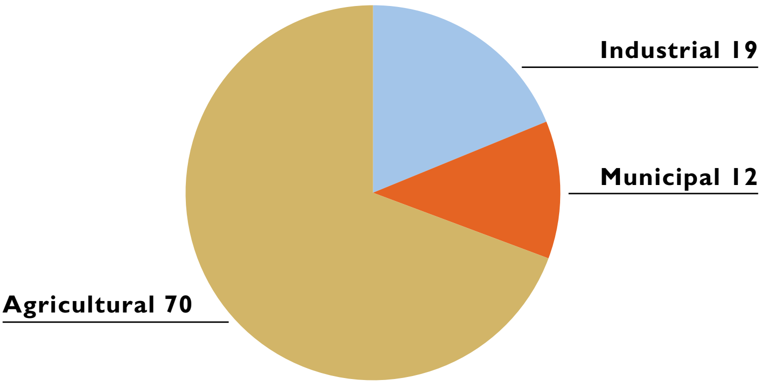
3 Id.

The food–water nexus

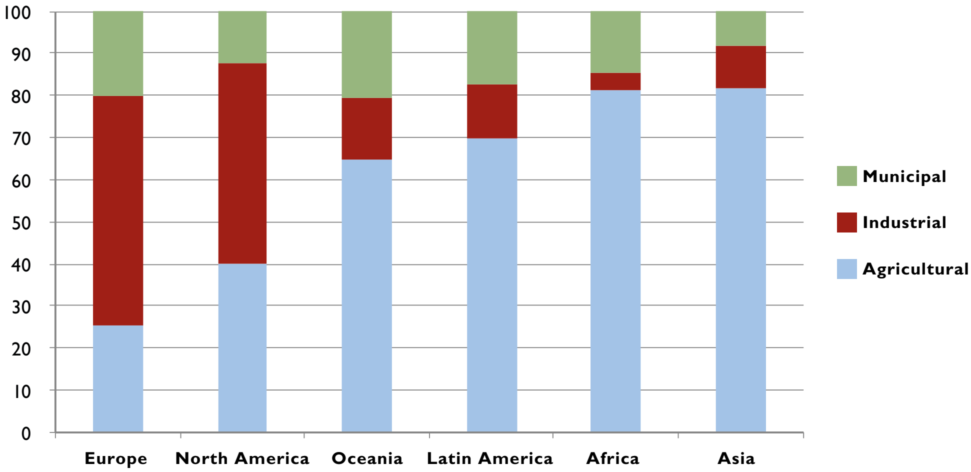
Agriculture is by far the largest consumer of the Earth's available freshwater. Globally, 70 percent of withdrawals from watercourses and groundwater are for agricultural usage, with significant variation between regions (Figures I.2 and I.3). Approximately 40 percent of the world's food is currently cultivated in artificially irrigated areas, according to the International Assessment of Agricultural Knowledge, Science and Technology for Development's Global Report, 2009.[4]

Through the 1960s to the 1980s, particularly in the densely populated regions of South East Asia, huge investments were made in additional irrigation systems in an attempt to increase yields. The availability of small, cheap diesel or electric pumps has revolutionized how farmers invest in self-managed groundwater irrigation. In India, more than 60 percent of all irrigated areas depend fully or partly on groundwater.[5] In China, more than two million pumps irrigate some nine million hectares (ha).[6] In the USA, the Ogallala aquifer extends northward from western Texas to South Dakota, underlying about 450,000 square kilometers. It provides nearly all the water for residential, industrial and agricultural use. Because of widespread irrigation, farming accounts for 94 percent of groundwater use over this area. Groundwater irrigation has increased substantially since the 1950s: from an estimated 850,000 irrigated ha in 1949, to 5.5 million ha in 1980 and 6.5 million ha in 2005, according to the latest data available from the US Geological Survey.[7]

Global water withdrawals by sector (in %)[8] **Figure I.2**



Regional water withdrawals by sector (in %)[8] **Figure I.3**



While groundwater irrigation has contributed substantially to the world's food production and provided farmers with a dependable source of water, it has also led to the massive overuse of water and falling groundwater tables (see Box I.1). In the Ogallala aquifer, studies showed a water-level drop of 4.7 meters from before 1950 to 2013, with 14 percent of the loss (0.65 meters) occurring in just two years, between 2011 and 2013.[9]

The overexploitation of groundwater makes it necessary to pump at greater depths, and consequently increases the cost of pumping. Moreover, overexploitation may cause groundwater to become contaminated, and, in coastal areas, may give rise to salinity ingress, which results in fresh water turning saline. In addition, evaporation from reservoirs, canals, and soil accounts for a large proportion of water earmarked for irrigation, as does crop

4 IAASTD Global Report, 2009

5 Sustainable Energy for All (SEforAll) and the Energy Sector Management Assistance Program (ESMAP), *Direct Delivery of Power Subsidy to Agriculture in India*, 2015

6 The World Water Council, *World Water Vision: Making Water Everybody's Business*, 2014

7 US Geological Survey, *Water-Level Changes and Change in Water in Storage in the High Plains Aquifer, Predevelopment to 2013 and 2011–13*, 2014

8 Source: AQUASTAT Main Database, Food and Agriculture Organization of the United Nations (FAO), 2016

9 Id.

Groundwater pumping for agriculture in India

Box I.2

In India, agricultural development and food productivity increased rapidly in the 1960s, with an accompanied explosive growth in groundwater irrigation. In the 1970s, with the objective of saving transaction costs, the Indian electricity utilities removed all meters from wells and stopped recording the consumption. Most states introduced low, flat electricity tariffs for farmers and these proved politically inexpedient to increase, thus providing strong incentives to over pump. Today, India is the largest groundwater user in the world, with an estimated annual withdrawal of 230 cubic kilometers.[10]

Such usage has proved problematic. According to the Indian Planning Commission, groundwater resources are already under pressure.[11] An estimate for 2004 showed that 28 percent of India's groundwater blocks were in a semi-critical, critical or over-exploited condition. Nine states, where electrical groundwater pumping dominates, account for 85 percent of India's stressed groundwater. The Expert Group report attributes the prime cause of over-exploitation in the most part to rising demand for groundwater from agriculture, although growing urbanization and industrialization is also partly to blame.

transpiration. Of the water withdrawn[12] for irrigation, the proportion of consumption[13] ranges from 40 percent for flood irrigation to 90 percent for drip irrigation,[14] meaning that between 60 percent and 10 percent flows back and reaches groundwater with higher salt concentrations and becomes contaminated with nutrients, pesticides and herbicides. With the increased use of fertilizers and agro-chemicals in modern agriculture, this risks building up salt and contamination levels that could ultimately make for infertile soil. By the late 1980s, an estimated 50 million ha of the world's irrigated lands—representing more than 20 percent of the total—had suffered a build-up of salts.

10 SEforAll & ESMAP, Direct Delivery of Power Subsidy to Agriculture in India, 2015

11 Government of India Planning Commission, Report of the Expert Group, Groundwater Management and Ownership, 2007

12 Water withdrawal: the volume of water removed from a source; by definition withdrawals are always greater than or equal to consumption.

13 Water consumption: the volume withdrawn that is not returned to the source (i.e. it is used effectively by the plant, evaporated or transported to another location) and by definition is no longer available for other use.

14 Ibid, The World Water Council,

15 FAO, *Policy Brief: Food Security*, 2006

The World Food Summit of 1996 defined food security as existing "when all people at all times have access to sufficient, safe, nutritious food to maintain a healthy and active life."[15] Food security, thus, has three facets: availability, access and appropriate use. The quality of water used in the preparation of food impacts the first two—if not all three—of these facets. In addition, the negative consequences of climate change may increasingly affect the availability of water:

- variability in rainfall may affect the physical availability of food; and
- changes in precipitation patterns and droughts at the regional level may disrupt normal food supply routes, thus denying access to food in vulnerable areas.

The energy–water nexus

Water is a key input to the value chain of energy production. Table I.1 lists the components of the production of primary energy and power generation, and notes where water is used.

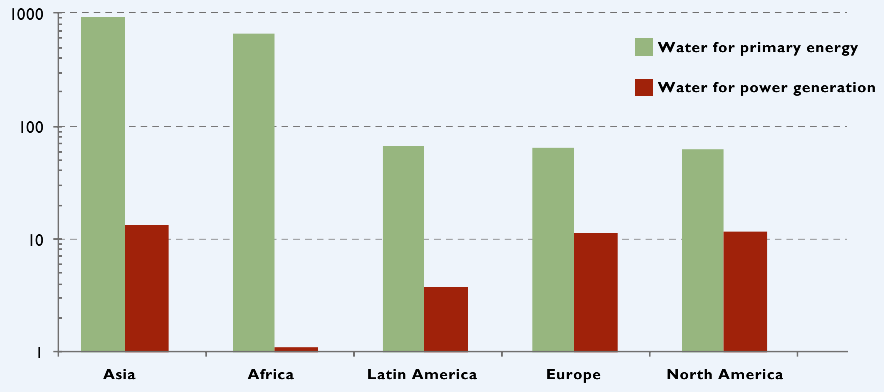
Uses of water in energy production — Table I.1

	Fuels	Description of water use
Primary energy	Oil and gas	Drilling, well completion and hydraulic fracturing; secondary and enhanced oil recovery; oil sands mining and in situ recovery; upgrading and refining.
	Coal	Cutting and dust suppression in mining and hauling; washing to improve quality; re-vegetation of surface mines; long-distance transport via coal slurry.
	Biofuels	Irrigation for feedstock crop growth, wet milling, washing and cooling in conversion processes.
Power generation	Thermal	Boiler feed; cooling for steam condensing; pollutant scrubbing for emission control.
	Solar thermal and geothermal	Boiler feed; cooling for steam condensing; cleaning of reflective surfaces.
	Hydropower	Electricity generation; reservoir storage.
	Photovoltaics	Panel cleaning.

Estimates of the water requirements for energy production vary significantly from one source to another. For example, the International Energy Agency (IEA) calculates that global energy production in 2010 accounted for 580 billion cubic meters of water, or 15 percent of global freshwater withdrawals.[16] By including traditional biomass (primarily wood fuel derived from trees and shrubs) in the consideration of primary energy, the World Energy Council (WEC) estimated that the 2005 water requirements for global primary energy production and power generation were 1,815 and 41 billion cubic meters, respectively.[17]

Figure I.4 shows the geographical variations in water requirements for energy by continent. Africa produces only 9 percent of the world's primary energy and 3 percent of electricity. However, water used to produce and generate energy in Africa accounts for more than one-third of water consumed in the energy sector worldwide. This is mainly due to the fact that traditional biomass—including cut trees, wood and agricultural waste, grown with large amounts of water—contributes a relatively high share (~ 22 percent) to Africa's energy mix, compared to a world average of 8 percent. Power generation in Latin America represents just 5 percent of the world total. Because hydropower accounts for 70 percent of the total electricity generated in Latin America, the region accounts for 10 percent of the global water requirements for power generation.

Water requirements for the production of primary energy and power generation (billion m^3)[18] **Figure I.4**



Energy uses for water Table I.2

	Process	Description of water use
Water	Extraction	Deep-well pumping; surface-source pumping.
	Sea and brackish water desalination	Feed pumping; high-pressure reverse osmosis pumping; heat for thermal processes.
	Treatment	Dosing pumps for chemical treatment; pumps, fans, agitators, blowers for physical treatment.
	Conveyance	Submersible, shaft turbine, horizontal or vertical centrifugal pumping systems to distribution network; booster pumping.
	Distribution to end consumers	Horizontal or vertical centrifugal pumping.
Waste-water	Sewage and rain water piping	Horizontal or vertical centrifugal pumping.
	Wastewater treatment	Pumps, fans, agitators, blowers.
	Distribution to end consumers	Horizontal or vertical centrifugal pumping.

Energy is needed at all stages of the supply chain for water. Wastewater is also subjected to treatment processes that use energy. Table I.2 summarizes the water and wastewater operations that use energy.

In 2014, the worldwide water sector consumed 120 million tonnes of oil equivalent (mtoe), a majority of this in the form of electricity, corresponding to 4 percent of total global electricity consumption. Of the electricity consumed for water, around 40 percent is used to extract water, 25 percent for wastewater treatment and 20 percent for water distribution. Roughly half of the thermal energy used in the water sector is to pump groundwater for agricultural purposes, with the remainder for desalination. In the developing world, the cost of energy to supply water may easily consume half of a municipality's total budget. In the USA, water services account for 13 percent of annual energy consumption.[19] Even in the municipal water systems of developed countries, energy is typically the second largest cost after labor.

16 International Energy Agency (IEA), *Water for Energy, Excerpt from the World Energy Outlook 2012*

17 World Energy Council (WEC), *Water for Energy, 2010*

18 Ibid, WEC

19 International Renewable Energy Agency (IRENA), *Renewable Energy in the Water, Energy & Food nexus*, 2015

Energy is also needed to prepare hot water for both domestic and industrial uses. In Canada, for example, the residential sector accounts for 20 percent of the total annual energy consumption while 22 percent of residential energy goes toward water heating.[20]

The interlinkages between water and energy bring to the fore a number of risks that need to be understood and properly managed in specific circumstances. Here are just four examples:

- Water shortages due to droughts can result in reduced energy production.
- Bodies of water that supply thermal power plants with cooling water may undergo a temperature increase, causing, in turn, a drop in the efficiency of the power plant.
- By interrupting the normal flow of a river, large hydropower dams may cause salt water intrusion into deltas.
- Large water bodies behind dams serve as heat sinks, and the water is hotter than the normal river water. This warm water can affect ecosystems, as well as the efficiency of thermal power plants downstream (see Box I.2).

On the other hand, restricted access to affordable energy may hamper the delivery of water to end users and / or increase its cost.

Water-shortage impacts on power production — Box I.3

According to the World Bank, more than half of the world's power utilities from 2009 through 2014 experienced negative effects from water shortages, with two-thirds of power utility and energy companies indicating that water scarcity represented a substantive business risk.[21] The following are examples of how water shortages and / or changes in water properties (temperature, for example) can impact power generation:

- South Africa is one of the driest countries in the world.[22] The country also has an unusually high intensity of water usage. The problem of water scarcity is compounded by the spatial pattern of economic activity and settlement, which is out of line with the natural availability of water. Lack of sufficient water resources in South Africa means that the wet-cooling of coal-fired power stations is not possible. As early as the 1930s, the South African electricity public utility Eskom was aware of the potential impact of limited water availability on the expansion of the electricity supply and took an interest in dry-cooling methods. In the 1980s, when it became apparent that there was insufficient water for power plants situated on coalfields, Eskom committed to dry-cooling for all new power plants, despite the increased costs and decreased efficiency in comparison to water-cooled systems.

- In 2016, a severe water crisis gripped India and forced several of the country's power plants to shut down. The affected plants included five units (totaling 1.6 gigawatts (GW)) at the 2.1GW Farakka plant in West Bengal and four units (2.6GW) at the 3.3GW Tiroda plant in Maharashtra. In addition, India's hydropower generation dropped by nearly 20 percent compared with 2015, even as 1.5GW of new hydro capacity was installed. Analysts have estimated that at least $350 million in profits was lost for the coal power sector alone.[23]
- In the USA, a number of power plants were forced to shut down or reduce power generation due to low water flows or high water temperatures. During a 2006 heatwave, while electricity demand broke records across the country, high water temperatures forced four nuclear plants in the Midwest to reduce their output. At the two-unit Prairie Island nuclear plant in Minnesota, the Mississippi River water was too hot to be used for cooling and the plant reduced output by more than 50 percent.[24]
- The Hoover Dam—the largest hydro plant in the world when it came online in 1936—satisfies peak-demand electricity for Las Vegas, Los Angeles and other southwestern cities in the USA. Since 1999, the water level at Lake Mead, behind the Hoover Dam, has dropped (by 40 meters to a low of 330 meters above sea level in July 2014). Electricity output has been significantly curtailed. In July 2014, the facility was de-rated from 2,074MW to 1,592MW.[25]

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20 G. M. Thirlwell et al., *Energy–Water Nexus: Energy Use in the Municipal, Industrial, and Agricultural Water Sectors*, Canada—US Water Conference, Washington D.C., 2007

21 http://blogs.worldbank.org/water/4-ways-water-shortages-are-harming-energy-production

22 Nick Segal, *Generating Electricity in a Dry Country: Governance of Water and Energy in South Africa*, School of International Relations and Pacific Studies, University of California, San Diego, 2011

23 http://www.powermag.com/indian-water-crisis-shuts-multiple-power-plants/

24 Union of Concerned Scientists, *The Energy–Water Collision—Power and Water at Risk*, 2011

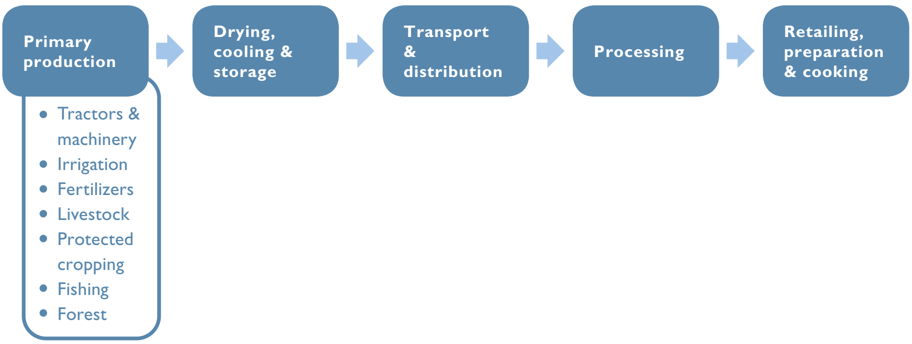
25 https://wrrc.arizona.edu/drought-diminishes-hydropower

The food–energy nexus

The modern global food sector is dependent on energy. While the technology and industrialization underpinning the agricultural green revolution has resulted in enormous improvement in crop yields, at the same time it has increased the energy needs of farming and food production. Today, the end-use energy demand of the global food sector is around 2,270 mtoe / year, or 32 percent of the total global final energy demand.[26] Energy is needed along the entire value chain of food production, from farm to table (Figure I.5).

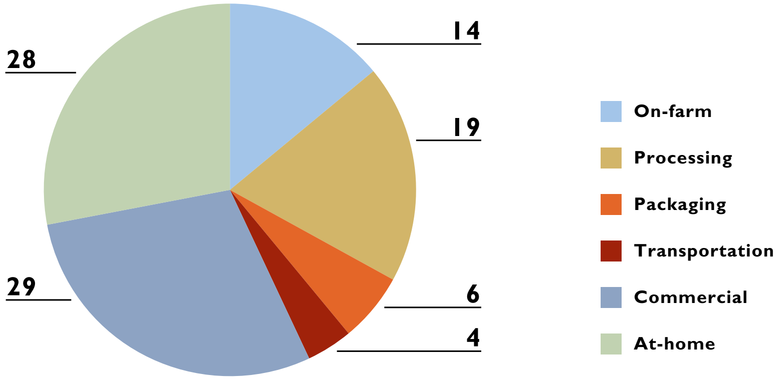
Over the first decade of the current century, the average annual US food-related energy use was about 378 mtoe, or 15 percent of the energy use in the entire US economy. Of this, at-home energy consumption (food preparation, cooking and cooling) holds a share of 28 percent (Figure I.6). In contrast, energy for cooking dominates energy inputs in the food supply chain in Africa, with a share of more than 60 percent, as most food in sub-Saharan Africa is consumed with little need for preservation, packaging or transportation.[27]

Energy uses along the food value chain Figure I.5

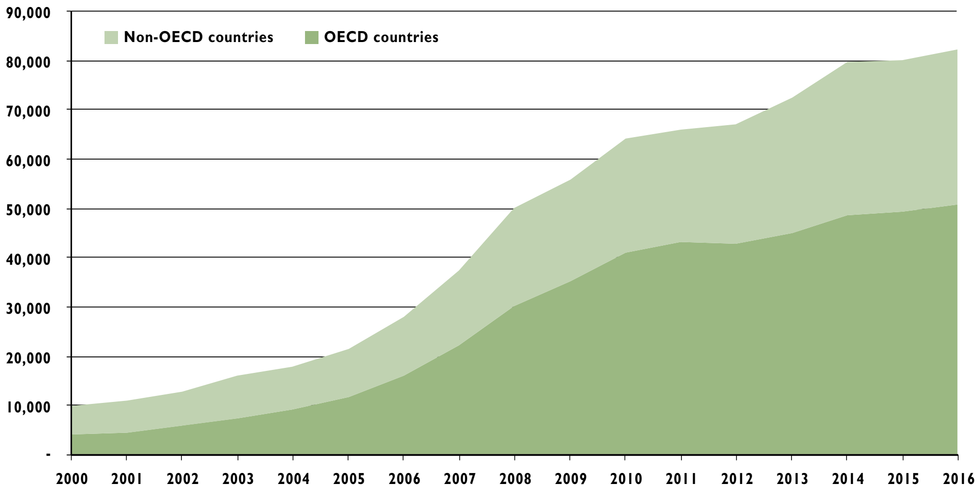


In recent years, the use of modern biomass in the global energy mix has grown significantly. In particular, the world's production of transportation biofuels has increased at an average annual rate of 15 percent (See Figure I.7). In the second half of the last decade, supply security, climate change and local development were the drivers for the expanded use of biofuels in large consuming countries. Many countries set ambitious biofuel targets that were based on the assumption that large volumes would be met by advanced biofuels, mostly

Distribution of energy requirements along the US food-supply chain (in %)[28] **Figure I.6**



World production of transportation biofuels (thousand toe)[29] **Figure I.7**



26 FAO, *Energy-smart Food for People and Climate*, Issue paper, 2011

27 Ibid, FAO

28 Source: Azzeddine Azzam, Energy Consumption in the US Food System, University of Nebraska, 2012

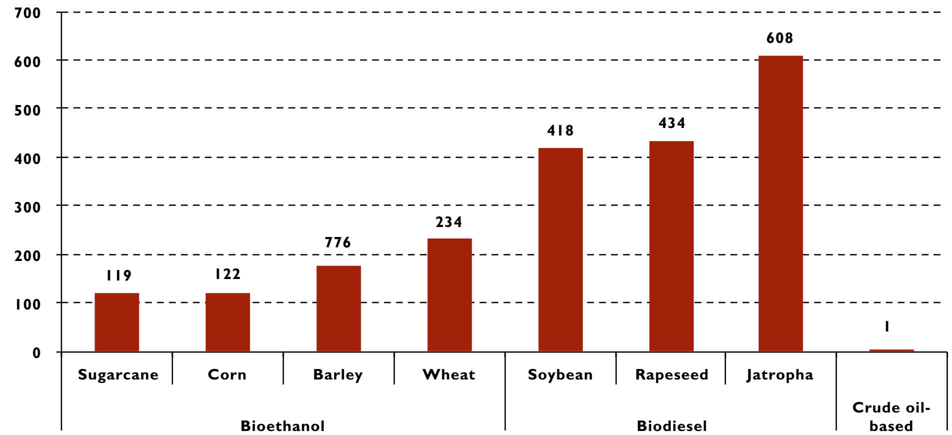
29 Source: BP Statistical Review of World Energy June 2016

those derived from cellulosic biomass. However, although considerable research is being directed at the production of these "second generation" biofuels, many questions relating to technology remain unanswered and it is unclear whether "true" second generation biofuels can be achieved at all. Today, the bulk of biofuels—such as biodiesel and bioethanol—are made from biomass crops that can also be used for food.

Clearly the food and energy markets impact each other in fundamental ways. In 2007, at the peak of biofuels growth, the International Monetary Fund (IMF) estimated that higher ethanol production in the US accounted for 60 percent of the global increase in corn consumption, and that the use of soybean and rapeseed oil in producing biofuels in the USA and the European Union accounted for the bulk of demand growth for such crops in recent years (World Economic Outlook, 'Globalization and Inequality,' IMF, October 2007). The dependence of food production on energy inputs makes it particularly sensitive to energy prices.

The increase in biofuels production, whether in terms of food crops or dedicated "energy crops," could lead to increased competition for water resources. Biofuels require large amounts of water (see Figure I.8). The result could be significant for a number of countries, and global food markets are also expected to be impacted.

Water requirements for transportation fuels production (m^3 per gigajoule)[30] — Figure I.8



Mapping the risks

Trends such as population growth, urbanization, socioeconomic development, international trade, cultural and technological changes, and climate change, are driving increased competition among energy, water and food.[31] The implications and risks related to supplying these resources, however, vary from one region to another. Putting the nexus approach into practice necessitates delivering solutions at multiple scales and in different contexts.

For low-income countries, the highest priority is to close simultaneously the large energy-, water- and food-security gaps related to low productivity. This requires investment to overcome infrastructural constraints and enable extraction, cultivation, distribution and export, while ensuring adequate consumption to sustain livelihoods.[32] Furthermore, rising inequality, underinvestment and high unemployment have exacerbated the challenges in low-income economies during recent years. Access to technologies and finance are key for integrated nexus solutions[33]—particularly in agriculture—and can help accelerate progress toward sustainable development and poverty reduction.[34]

Emerging economies are, conversely, witnessing rapid growth, a doubling of gross domestic product (GDP) over a 10 to 15 year period, and a rapidly growing population. Thus, demand per capita is also increasing; something that is driving a need for resource-efficient development to ensure adequate energy, water and food resources. The rapid growth in China, India, the Middle East, South America, sub-Saharan Africa and North Africa puts at risk local nexus solutions.[35]

Industrialized countries—with consumption-based, service-dominated economies supported by trade, manufacturing and commodities[36]—have high per capita resource demands and large external resource footprints that put pressure on resources.

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30 Sources: Ibid, WEC and Susan Bolton, The Water–Energy–Food Nexus, School of Environmental and Forest Sciences, University of Washington, Seattle, 2012

31 Stockholm Environment Institute , *Climate Change, Water and Energy in the MENA Region: Why a 'Nexus' Approach is Crucial for Mitigation and Adaptation*, 2012

32 SABMiller and the World Wildlife Fund (WWF), *The Water–Food–Energy Nexus: Insights into Resilient Development*, 2014

33 Holger H. et al., *Managing the Water–Land–Energy Nexus for Sustainable Development*, UN Chronicle, ProQuest Central, 2012

34 The Organisation for Economic Cooperation and Development (OECD), *Green Growth and Developing Countries: A Summary for Policy Makers*, 2012

35 Ibid., Holger H. et al.

36 Ibid., SABMiller & WWF

The above interlinkages demonstrate the relevance of nexus approaches to all instances of economic and development cooperation, as well as the importance of sharing innovative technologies—for example, modern renewable energies—on a global basis.[37]

Middle East and North Africa (MENA)

The MENA Region is among the driest regions on the planet, with constrained water and land resources. As a result, more than 50 percent of the region's food is imported.[38] Pressure on water is increasing rapidly, and countries are using oil and gas to power desalination plants and address the widening freshwater supply gap to meet industrial, agricultural and domestic needs.[39]

Meeting these needs has become increasingly challenging and costly.[40] Producing more of one resource (energy or water) creates risks related to the reliable, affordable supply of the other.[41] Thus, a "nexus" approach to water, energy and food could lead to more resilient development solutions[42] and should be factored into infrastructure development and planning.[43]

The challenge is to invest in boosting production while safeguarding the natural environment for future generations. With this in mind, there is significant potential for regional cooperation through knowledge and technology sharing, joint resource management and joint initiatives to promote nexus-based solutions and cross-sectoral interactions.[44]

Asia and the Pacific

Asia is one of the most dynamic regions of the world in terms of population growth, economic progress, urbanization and industrialization. Nevertheless, the region faces the challenge of sustaining water, food and energy security due to limited land resources, inadequate energy supplies and growing water stress.[45]

Two-thirds of the world's population lives in Asia, which accounts for 59 percent of the planet's water consumption. In Asia as a whole, 51 percent of the population is food–energy deficient, about 20 percent lacks access to safe drinking water and per capita energy consumption is among the lowest in the world.[46] The challenge of sustainable development is especially acute in Afghanistan, Bangladesh, Bhutan, India, Maldives, Nepal, Pakistan and Sri Lanka, where more than 40 percent of the world's poor live.

Sub-Saharan Africa

Agriculture accounts for 32 percent of Africa's GDP, 65 percent of its employment[47] and 33.6 percent of its exports.[48] Moreover, agriculture and related industries are essential to economic growth and key to poverty reduction.[49] However, challenges relating to poverty and food security are made ever more complex by an increasing population, severe land degradation and limited investment in water and rural energy.[50]

Africa faces a serious energy deficit. Sub-Saharan Africa is the only region in the world where the number of people without access to electricity is on the rise. The number is expected to reach 660 million by 2030, or 50 percent of the total population.[51]

An energy–water–food nexus, with transport as an enabling sector, can support sustainable social and economic development in sub-Saharan Africa. Water security can be bolstered by increasing supply and / or by improving demand management. For agriculture security, adequate and sustainable supplies of agricultural commodities for industrial use and energy production are needed. Infrastructural facilities that will improve energy security include hydropower dams, thermal power stations, run-of-river schemes and mini-grids.[52]

37 Ibid., Holger H. et al.

38 The World Bank (WB), *Middle East & North Africa: Agriculture & Rural Development*, 2008

39 Metzger E. et al., *Water–Energy Nexus: Business Risks and Rewards*, World Resources Institute, 2015

40 Id.

41 Id.

42 Ibid., Stockholm Environment Institute

43 Ibid., Metzger E. et al.

44 Ibid., Stockholm Environment Institute

45 Rasul G., *Food, water and energy security in South Asia: A nexus perspective from the Hindu Kush Himalayan region*, Vol., 39, pp.35–48, Environmental Science and Policy, 2014

46 Id.

47 WB, Fact Sheet: The World Bank and Agriculture in Africa

48 World Integrated Trade Solutions, Sub-Saharan Africa Trade at a Glance: Most Recent Values, 2014

49 FAO, *Water for Agriculture and Energy in Africa: The Challenges of Climate Change*, 2008

50 The Infrastructure Consortium for Africa (ICA), the International Union for Conservation of Nature (IUCN) and the International Water Association (IWA), *Nexus Trade-offs and Strategies for Addressing the Water, Agriculture and Energy Security Nexus in Africa*, 2015

51 Ibid., FAO (2008)

52 Ibid., ICA, IUCN, IWA (2015)

Latin America and the Caribbean

In Latin America and the Caribbean, water, energy and land are under increasing pressure from climate change and a growing population. Despite their abundance, much of the existing energy, water and land resources have been harnessed to fuel economic growth. While this has supported socioeconomic progress, high levels of inequality persist and millions of people still experience energy, water and food insecurity.[53]

A nexus approach can help to identify and resolve trade-offs, foster synergies and optimize outcomes across different sectors. Hydropower represents 65 percent of electricity in the region and agriculture accounts for over 70 percent of water use in the region. Thus, water is at the heart of the nexus approach since it underpins hydropower generation, agricultural production and industry.[54]

53 Bellfield H., *The Water–Energy–Food Nexus in Latin America and the Caribbean: Trade-offs, Strategic Priorities and Entry Points, Global Canopy Programme*, 2015

54 Id.

Chapter II

Global trends in energy, water and food

The world population is growing by approximately 83 million people annually. It is projected to reach 8.5 billion in 2030, and to increase further to 9.7 billion in 2050.[1] Population growth remains especially high in the group of 48 countries designated by the United Nations as the least developed countries (LDCs), of which 27 are in Africa. Of the additional 2.4 billion people projected to be added to the global population between 2015 and 2050, 1.3 billion will be in Africa. Asia is predicted to be the second largest contributor, adding 0.9 billion people between 2015 and 2050, followed by North America, Latin America and the Caribbean, and Oceania, which are expected to contribute much smaller increments.

For the first time in history, the global urban population exceeded the rural population in 2007. This urbanization trend is expected to continue so that by 2050, the world will be one-third rural and two-thirds urban.[2] Africa and Asia remain mostly rural, with 40 percent and 48 percent of their respective populations living in urban areas in 2014. Over the coming decades to 2050, however, the level of urbanization is expected to increase in all regions, with Africa and Asia urbanizing faster than the rest. While, in principle, services such as electrification and drinking water can be provided more efficiently in cities than in rural areas, urban living promotes more resource intensive lifestyles and concentrates consumption and waste production.

These demographic prospects are increasing the pressures on resources. The following sections explore in detail the expected future trends in the demand for energy, water and food.

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1 United Nations, Department of Economic and Social Affairs, Population Division, *World Population Prospects—The 2015 Revision*, 2015

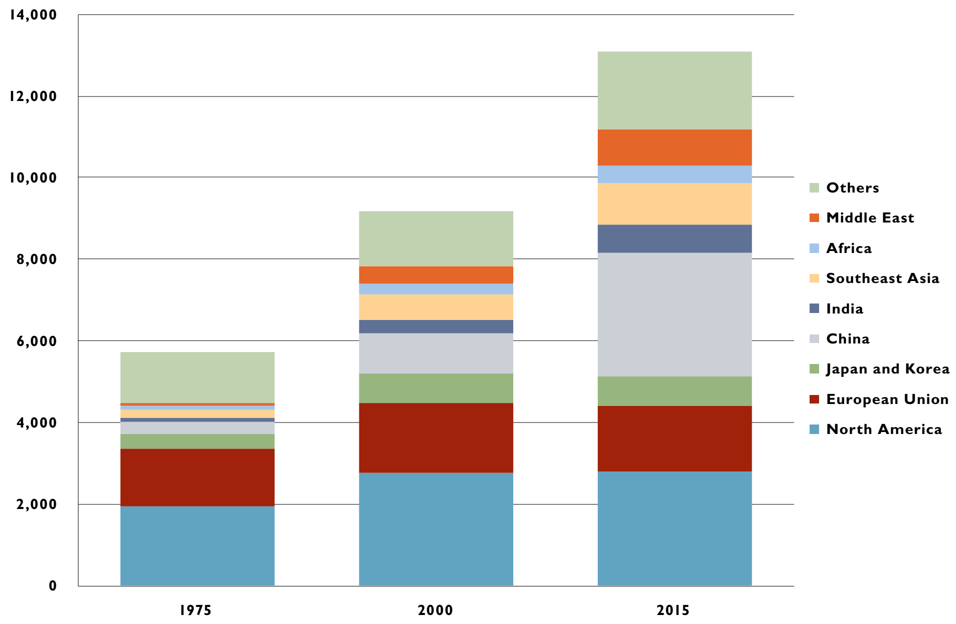
2 United Nations, Department of Economic and Social Affairs, Population Division, *World Urbanization Prospects—The 2014 Revision*, 2014

Energy outlook

World energy consumption has been on the rise, as developing nations begin to industrialize, and as consumers in developed nations buy more energy-consuming appliances to make life more comfortable (Figure II.1). Despite the success of many countries in promoting energy-saving measures and energy efficiency, global energy consumption is expected to continue to grow, with most of this increase taking place in non-OECD (Organization for Economic Cooperation and Development) countries. The continued increase is explained by economic development and population growth, primarily in developing and emerging economies, and especially in India and China.

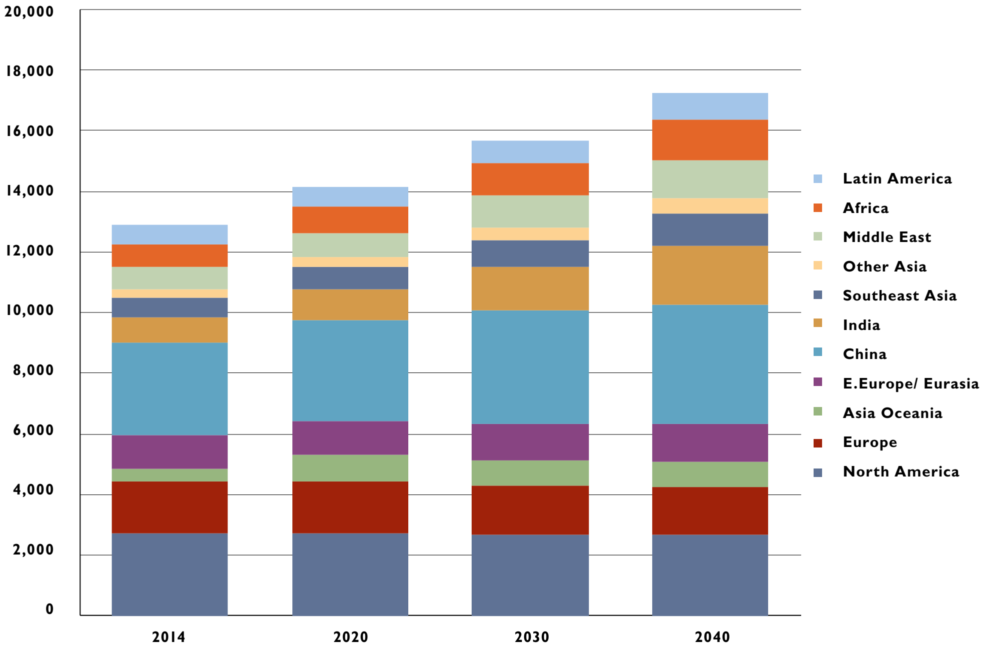
The majority of international organizations and companies recognize this trend of growing global energy consumption. For example, the IEA forecasts global energy demand will grow by 30 percent in 2040 (compared with 2014 figures), despite the decreasing energy intensity trends exhibited by developed countries. Primary energy demand in most advanced economies is

Historical energy trends by region (in mtoe)[3] **Figure II.1**



Total final energy consumption by region, forecast (in mtoe)[4]

Figure II.2



set to fall over the coming decades. Despite some areas of growth, the net trend in OECD countries points toward such countries consuming less energy in 2040 than today. But this is more than offset by increases elsewhere in the world, with rising incomes, industrialization and urbanization—and rising levels of energy access—proving to be powerful spurs for consumption.

China has had a huge influence on global energy trends since 2000 and is predicted to be the largest single source of global demand growth until the mid-2020s, according to the IEA, when it will be overtaken by India. But even as energy demand growth slows in China, other countries in South and Southeast Asia, alongside parts of Africa, the Middle East and South America—where energy demand per capita is low today—are predicted to take on a more prominent role in pushing global energy demand higher.

3 Source: BP, Statistical Review, 2017

4 Source: IEA, World Energy Outlook, 2016

The type of energy in the global energy mix into the future appears inelastic. The IEA Current Policies Scenario provides a good example of the durability of the status quo: the role of fossil fuels in global energy is essentially unchanged at 79 percent in 2040, differing only slightly from a share of 81 percent today. Oil and coal remain the most-used fuels. Natural gas demand, however, grows by nearly 50 percent over the period to 2040, overtaking coal as the second most-used fuel. The share of biofuels used for transportation may rise from 3 percent to 7 percent between 2015 and 2040, while renewable energies may reach 20 percent in the global primary energy mix by 2040, under the IEA New Policies Scenario (NPS).[5]

Energy production increases in the USA and Latin America will mainly come from non-conventional fossil fuels, whereas Asia will continue to rely on coal and further expansion of biofuels production, with considerable negative impact on water quantity and quality. Meanwhile, sub-Saharan Africa, which has the greatest untapped hydropower potential in the world, may exploit this option if regional governments find ways to tackle the associated financial challenges.

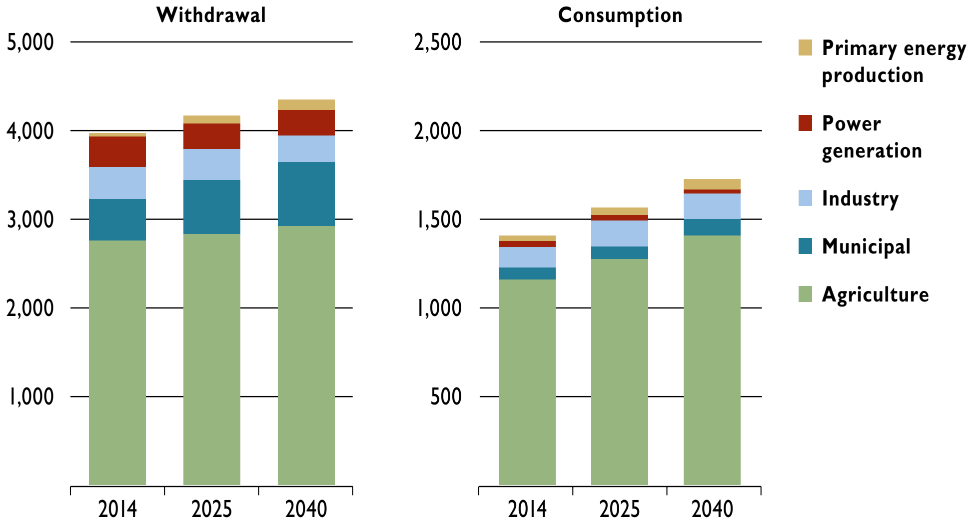
According to the IEA NPS, global energy use in the water sector more than doubles by 2040, as desalination capacity rises sharply in the Middle East and North Africa and demand for wastewater treatment grows, especially in emerging countries. Electricity consumption in the water sector rises by 80 percent (2.3 percent per year) to reach a total of 1,470 terawatt-hours in 2040, equivalent to twice the electricity consumption of the Middle East today. The largest increase is due to desalination requirements, which increase more than eight-fold and account for more than 20 percent of water-related electricity demand in 2040.

Water outlook

The rate of demand growth for water has been double the rate of population growth over the last few decades. Global freshwater withdrawals from surface water and groundwater sources have increased by roughly 1 percent per year since the 1980s, and available evidence suggests a slightly lower growth rate (0.6 percent) over the past 15 years.[6]

In much of the world's most highly developed countries, freshwater withdrawals have stabilized or slightly declined, due in part to a combination of

Global water demand by sector to 2040 (billion m^3)[8] **Figure II.3**



improved water-use efficiency and the increased importation of water intensive products, including food. It can therefore be deduced that the current increase in water use is driven mainly by developing countries.

Over the next 25 years, water withdrawals are expected to increase by almost 10 percent from 2014 levels, while consumption rises by more than 20 percent over the same period. Regional patterns of withdrawals and consumption vary widely, depending on how economies are structured. Irrigated agriculture accounts for more than 40 percent of the world's crop production and is the world's largest water user.[7] It accounts for roughly 70 percent of total global freshwater withdrawals (and up to 85 percent in some developing countries), although its share of withdrawals is projected to decrease slightly over the period to 2040 (Figure II.3). Agriculture is also responsible for the bulk of water consumption, stemming from evaporation from land surfaces during irrigation, and transpiration from plants.

5 IEA, *World Energy Outlook*, 2016

6 United Nations Educational, Scientific and Cultural Organization (UNESCO), *United Nations World Water Assessment Program*, 2016

7 UNESCO, *United Nations World Water Assessment Program*, 2012

8 Source: Ibid, IEA

Withdrawals to meet municipal water demand accounted for 13 percent of the total in 2014 and this figure is projected to rise to 17 percent in 2040. Three-fifths of the increase comes from three regions: India, Africa and other developing countries in Asia (excluding China). The levels of consumption by end-users in the municipal sector are lower, accounting for 5 percent of total global consumption in 2014. Future trends will be shaped by growing urbanization and rising standards of living, as well as changes in dietary preferences—from traditional staples such as roots and tuber vegetables to meat and milk products, refined and processed foods, as well as sugars, oils and fats—which require increasing quantities of water.[9]

Additionally, more than 650 million people, primarily in sub-Saharan Africa, lack access to an improved source of drinking water, and 2.4 billion do not have access to improved sanitation.[10] One of the SDGs (SDG 6) is to ensure the availability and sustainable management of water and sanitation for all. The pursuit of this goal—to provide improved access to drinking water for the remaining 10 percent of the global population without adequate supply and improved sanitation for the one-third of people who lack this basic right—could increase domestic demand and thereby the amount of energy and infrastructure necessary to provide such services.

Almost 10 percent of global water withdrawals in 2014 were for industry (excluding the energy sector). In advanced industrial nations, industry accounts for 12 percent of water withdrawals, whereas in many developing countries, industry accounts for less than 8 percent. Water is used in industry for processing, but also for fabricating and washing. Industry is the second-largest water-consuming sector (after agriculture). Its share is projected to stay steady at around 8–9 percent over the period to 2040.[11]

As global energy production rises, the amount of water used by the energy sector becomes higher. For instance, in the IEA NPS, water withdrawals for primary energy production and power generation rise by less than 2 percent through 2040 to reach more than 400 billion cubic meters (bcm), while the amount of water consumed (i.e. water withdrawn but not returned to a source) increases by almost 60 percent to more than 75 bcm. The power sector continues to account for the majority of water withdrawals in the energy sector, though its share declines with time. Primary energy production is responsible for almost two-thirds of energy sector water consumption today; a share that continues to rise to 2040.

According to the IEA NPS, non-OECD countries account for most of the global increase in energy-related water withdrawals and consumption, mirroring the trends in global energy demand. In OECD countries, total water withdrawals fall by almost a quarter between 2014 and 2040—the average annual rate falling faster than energy demand. In non-OECD countries, however, water withdrawals rise by 35 percent. In terms of consumption, the increase in non-OECD countries is more than 30-times greater than in OECD countries, where consumption stays relatively stagnant over the course of the projection period.[12]

The evolution of water demand for energy will depend to a great extent on the technological choices made, as well as on the application of water conservation and efficiency measures and technologies. For example, a shift toward more efficient power plants with advanced cooling systems will lower withdrawals, but consumption will increase, while a rise in nuclear power generation and in biofuels production will result in more withdrawals and consumption.

Despite improved modeling and computing capacity, quantifying potential increases in water demand and resulting water deficits is extremely challenging due to uncertainties concerning future bio-physical, climatic, economic and sociopolitical conditions.[13] This is particularly true for rapidly evolving sectors such as industry and energy, and for smaller countries that experience high levels of seasonal and year-to-year variability in water availability. A review of 13 water demand projections[14] concluded that current average per capita domestic water withdrawal already exceeds projections made by business-as-usual scenarios for 2025 developed in the early 2000s.

Regardless of the magnitude of future global—and more importantly local—water deficits, water scarcity is likely to limit opportunities for economic growth and the creation of decent jobs in the coming decades.

9 Arup and Sydney Water, *The Future of Urban Water: Scenarios for Urban Water Utilities in 2040*, 2015

10 United Nations Children's Fund / World Health Organization, *Progress on Sanitation and drinking Water*, 2015

11 Ibid, IEA

12 Ibid, IEA

13 Ibid, UNESCO, 2012

14 Amarasinghe, U. A. and Smakhtin, V., *Global water demand projections: past, present and future*, International Water Management Institute, 2014

Food outlook

The agriculture industry in the 21st century faces multiple challenges: it has to produce more to feed a growing population, but it will have a smaller rural labor force. Additionally, more feedstocks will be required for the bioenergy market. More efficient and sustainable production methods are needed, as are climate change mitigation policies and actions.

Achieving the transformation to sustainable agriculture is a major challenge. Changes will need to be made in a way that does not jeopardize the capacity of the agriculture sectors—crops, livestock, fisheries and forestry—to meet the world's food needs. Projections by the Food and Agriculture Organization of the United Nations (FAO) suggest that to feed the world population in 2050, annual world production of crops and livestock will need to be 60 percent higher.[15] This need is driven by population and income growth, as well as rapid urbanization. In the coming decades, population increases will be concentrated in regions with the highest prevalence of undernourishment and high vulnerability to the impacts of climate change.

Agricultural production in developing countries will need to almost double by 2050. This implies significant increases in the production of several key commodities: annual cereal production, for instance, would have to grow by almost 1 billion tonnes; and meat production by over 200 million tonnes to a total of 470 million tonnes in 2050. To ensure nutrition security, feeding the world population adequately would also mean producing the kind of foods that are currently lacking. The wider use of biofuels for transportation has the potential to change some of the projected trends and cause world demand for food crops to be higher, depending mainly on energy prices and government policies.

Ninety percent of the growth in crop production globally (80 percent in developing countries) is expected to come from higher yields and increased cropping intensity, with the remainder coming from land expansion. Arable land would expand by some 70 million ha—or less than 5 percent—with the expansion in developing countries of around 120m ha (or 12 percent) being offset by a decline of some 50m ha (or 8 percent) in developed countries.

Almost all of the land expansion in developing countries would take place in sub-Saharan Africa and Latin America. Land equipped for irrigation would expand by some 32m ha (11 percent), while harvested irrigated land would expand by 17 percent. Due to a slowly improving efficiency in water use and a decline in the amount of land used for rice (relatively water intensive), water withdrawals for irrigation would grow at a slower pace, but still increase by almost 11 percent (or some 286 bcm) by 2050. The pressure placed on renewable water resources by irrigation would remain severe and could even increase in several countries in the Near East, North Africa and South Asia.

15 FAO, *The State of Food Security*, 2015

Chapter III

Framing the Nexus within the broader debate on sustainable development and environment

Long-term sustainability requires acknowledging that many of the resources that support development—water, land, materials—are finite and also needed to support vital ecosystem services. Development can only be sustainable if it works within those constraints, over time, and across sectors and locations. This is where the Millennium Development Goals (MDGs) fell short: they identified sectoral goals—and targets under them—with little consideration of how efforts to attain a goal in one sector would affect (or be affected by) efforts in another sector; or whether the total demand for key resources could be met by existing supplies without degrading the resource base and underlying ecosystems.

In the field of environmental science, resource sustainability looks at the use and resulting impacts of a certain natural resource (e.g. water, energy), including issues like integration of decisions, protection of non-renewable resources, and intergenerational equity, among others. In contrast, environmental sustainability is a broader term which relates sustainability to environmental issues at large, i.e. an evaluation of the footprint societies leave on the environment or natural resources in general.

Sustainability assessments related to the energy, water and food nexus can deploy one of the two understandings described above. Depending on the perspective, nexus-specific assessments can look at sustainability from the point of view of one sector, e.g. water resource sustainability considering influence of energy and land issues. Alternatively, there are assessments that integrate all three issues (energy, water, land) into one system and that even extend the issues to the effects on ecosystems, biodiversity or climate. These approaches can be seen in the tradition of debating environmental sustainability as a whole.[1]

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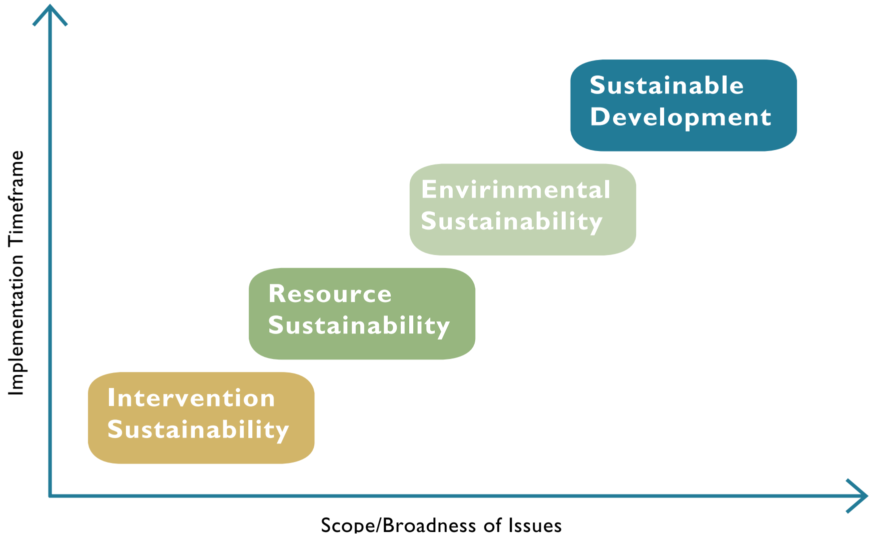
1 Al-Saidi, Mohammad, Ribbe, Lars (Eds.), *Nexus Outlook: assessing resource use challenges in the water, energy and food nexus*, Nexus Research Focus, TH-Köln, University of Applied Sciences, 2017

Sustainability understandings in environmental sciences[2] **Figure III.1**



Casting the net wider still, sustainable development is the most encompassing understanding of sustainability as it relates the concept of sustainability to the underlying growth and development model of societies. Environmental sustainability is then only one pillar of sustainable development, which commonly also includes economic efficiency and social equity. This has been the understanding of sustainable development for almost 30 years (Figure III.1).

Often, sustainability assessments about topics like nexus interactions contribute to formulating measures which enhance sustainable development at large. Further, the purpose of the assessment is its specific focus, e.g. emphasizing future or past trends, showing stakeholder perceptions or evaluating ecological thresholds, etc. It thus determines the methods of the assessment. There are a wide variety of assessment methods ranging from indicator- or index-based to perception-based when using surveys, expert knowledge or panel judgements. Developing such assessments is not always easy. It includes many other intermediate steps, like developing a conceptual model, evaluating the validity and measurability of indicators, or evaluating data quality and availability.

2 Ibid, Al-Saidi, Mohammad, Ribbe, Lars (Eds.)

The SDGs and implementing the nexus: toward an integrated framework

While the MDGs aimed to lift people out of poverty, the SDGs aim to keep them out of poverty by ensuring that development is both socially and environmentally sustainable. A framework to achieve this must consider the ways that activities in different sectors interact, including their respective pressures on natural resources. A nexus approach can help to formulate goals and targets that minimize trade-offs and maximize synergies between goals, making the SDGs more cost-effective and efficient, reducing the risk that progress toward one goal will undermine progress toward another, and ensuring sustainable resource use.

The guiding principles of the nexus approach are to promote sustainable and efficient resource use; in other words, doing more with less to ensure access to resources for the most vulnerable—especially the poor—and to maintain healthy and productive ecosystems.

A key principle of the SDGs is universality: that the goals will be relevant to all countries, and all will contribute to achieving them, but with differentiated targets and actions. The bottom-up process and nexus approach are entirely compatible with this principle.

Countries will face different trade-offs and synergies, and find different ways to improve development outcomes, emphasizing different targets. The targets may be seen as building blocks that each country will combine in its own way, balancing the needs for access to resources, efficiency, and long-term sustainability to fit the local context and capabilities. Through a bottom-up process and nexus approach, a suitable set of actions for a specific country (or region) can be identified.

For instance, the interlinkage between the energy, water and food supply systems—the EWF nexus—is a major consideration in countries' sustainable development strategies. Rapid economic growth, expanding populations and increasing prosperity are driving up demand for energy, water and food, especially in developing countries.

Given their importance, energy, water and food have been identified as priority areas for the SDGs, both in the Rio+20 outcome document and in the outcome document of the United Nations Open Working Group (on the SDGs).

Under the post-2015 agenda, the EWF-nexus suggests links between most of the targets under Goal 2 (food security), Goal 6 (water & sanitation) and Goal 7 (energy access).

Clearly there are many connections between energy, water and food targets. But, in order to be able to address them effectively, there is a need to understand the nature of those interactions as enablers of development. For example, food production requires water, land and energy.

The analysis of the Stockholm Environment Institute[3] shows three main types of interactions. Some are interdependent: one target has to be realized in order for another to be viable, usually because access to water, energy or land for food production needs to be ensured. Other targets impose conditions or constraints on one another. Yet others reinforce one another, highlighting potential synergies.

Figure III.2 shows the interactions among the energy, water and food targets of the SDGs. Achieving access to energy, for instance, often depends (red arrow) on water access, while the targets on sustainable water withdrawal levels and the ambition to increase the share of energy from renewable sources impose conditions (blue arrow) on how access to energy services can be ensured.

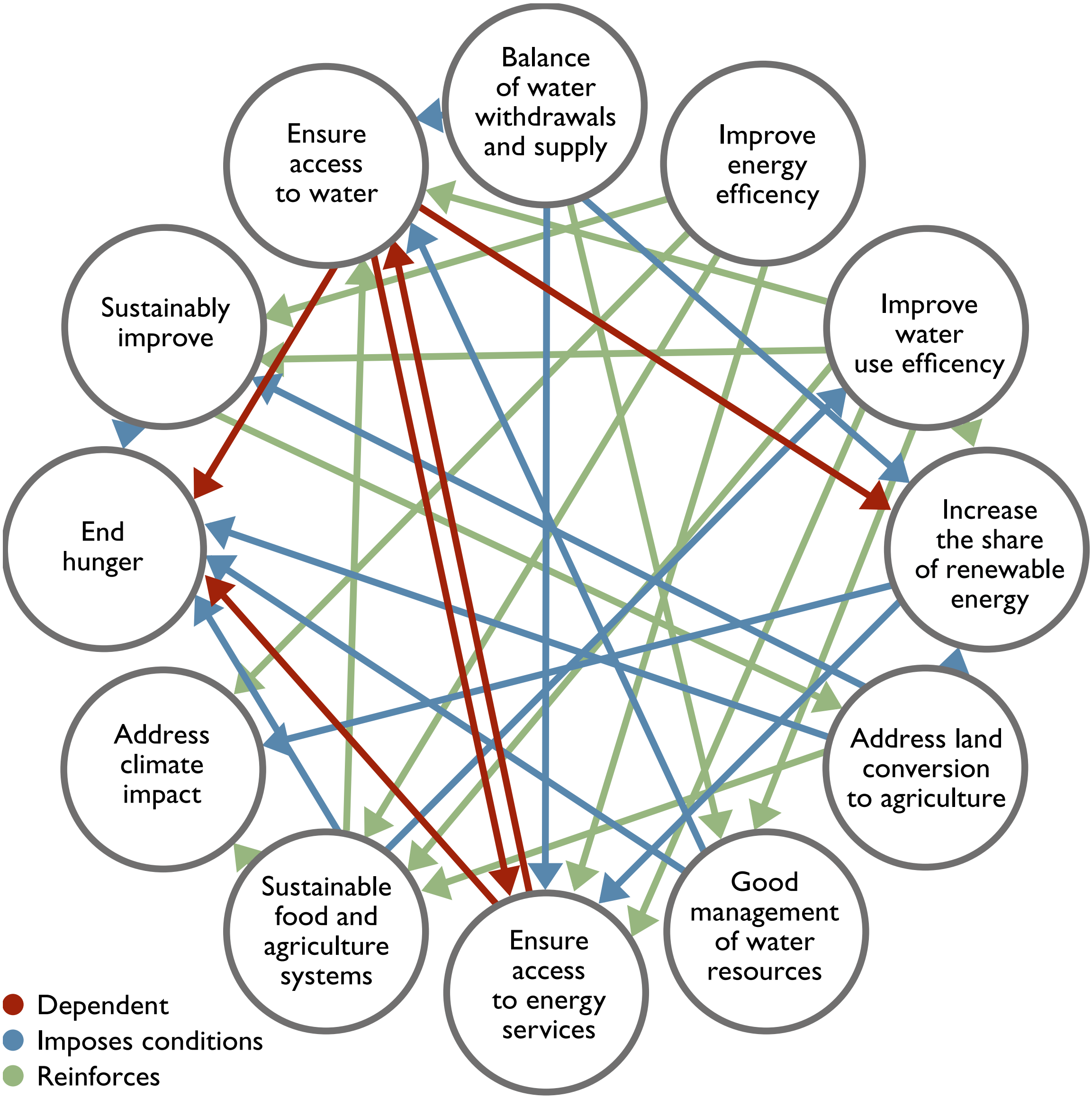
Improved water efficiency and energy efficiency reinforces (green arrow) both the energy access and the sustainable water withdrawals targets. Ending hunger, in turn, depends on access to energy services and water (as both are needed to produce food). Similarly, the targets on the sustainable improvement of yields, addressing land conversion for agriculture, and sustainable food and agricultural systems set conditions for eradicating hunger.

Integration through a nexus approach, therefore, could help the SDGs to manage complexity, and make the goals easier to communicate and to implement. The approach may also support more effective negotiations, by enabling countries to see more clearly where their interests coincide, where they diverge, and how they might reconcile their differences.

3 Stockholm Environment Institute, *Cross-sectoral integration in the Sustainable Development Goals (SDGs): a nexus approach*, 2014.

4 Id.

Interactions among energy, water and food targets.[4] **Figure III.2**



The interdependency between the nexus, climate change and the environment

For developing countries, the challenge of meeting the growing demands for energy, water and food is further compounded by climate change. Effective adaptation to climate change requires the efficient use of energy, water, land and other vital resources. As these are important resources in the fight against poverty and vulnerability, appreciating the complex interplay and the linkages among them is critical for adaptation planning. Understanding their trade-offs or synergies can provide new insight.

The nexus approach provides a framework for addressing competition for resources and using resources efficiently. The principles, strategies and goals of the nexus approach are closely related to those employed for climate change adaptation efforts. Thus, climate change mitigation and adaptation efforts and nexus-related challenges are interrelated and need to be thought about in tandem.

Some adaptation measures—such as the efficient use of water and renewable energy, and growing biofuels on arid land—might have positive implications for energy, water and food resources. However, other measures—such as extensive groundwater pumping, desalination plants, inter-basin transfers of water and the general growing of biofuels to combat fuel scarcity—may increase nexus-related challenges. For example, micro-irrigation technologies, such as drip and sprinkler irrigation, reduce water demand by increasing efficiency. At the same time, though, such practices increase energy demand. Similarly, growing biofuels on arid land can enhance the energy supply, but diverting cultivable land for biofuels can threaten food security and lead to social impacts such as higher food prices.

Promoting large-scale bioenergy production is a prime example of a policy that will give rise to opportunity costs: between supporting food security, protecting biodiversity and mitigating climate change. These costs are most obvious in developing countries, where a large proportion of the population does not have access to adequate food, nutrition, drinking water or energy. Trade-offs may also arise between efficient resource use and equity of access. Policy makers have to make choices between food and energy, and efficiency and equity. Managing trade-offs across the three sectors of energy, water and food is a daunting task and significant challenges remain.

The human face at the sharp end of the nexus and climate change

Box III.1

Behind the economic and scientific arguments of the nexus approach are some two billion people for whom the challenges of energy, water and food security are a stark, everyday reality. Wholly dependent on the land and its resources for their survival, small farmers and their families are caught in a vicious cycle of poverty that is perpetuated by an ever-dwindling resource base and the unpredictability of climate change. They are the people worst affected by inadequacies in the EWF sectors, but by the same token, they are also the ones who stand to benefit the most from nexus-led sustainable development strategies.

The FAO estimates that there are over 500 million family farms worldwide, the majority of them in developing countries. Together, they represent over 90 percent of all farms and 80 percent of global food production in value terms—and this despite accounting for just one-quarter of total land under cultivation. The fact remains, though, that the agriculture sector in developing countries is performing far below its potential, yielding just 2,400kg per ha, compared with the 4,000kg per ha produced by developed country farms. In Africa, for example, only about 6 percent of the total cultivated land is irrigated. Improving this ratio could increase output by up to 50 percent, according to some estimates.

With their specialized knowledge and collective might, smallholders have the capacity to help bolster food security and counter the food shortages that currently see some 800 million people suffering from hunger. They also have a significant role to play in sustainable natural resources management and poverty alleviation. As influential as their contribution may be, however, small-scale farmers cannot unlock their potential unaided. The obstacles standing in their way are simply too great, and most of them are outside their control.

This is where nexus-led interventions can have a transformative effect. By bringing innovative and sustainable solutions to the core problems facing small farmers, such strategies can help foster the development of climate- and resource-smart agriculture. Doing so would also help promote a transition from subsistence to commercial production and potentially provide a direct route out of poverty for billions.

Potential for synergy

Some sector-specific adaptation measures have the potential to provide synergistic "win–win" opportunities to enhance climate mitigation or adaptation objectives across one or more of the nexus sectors, while other measures may have negative impacts on mitigation or adaptation potential in other sectors. Increasing the efficiency of freshwater use, for example, increases the availability of water for energy, agriculture and industry, while contributing to climate change mitigation by minimizing energy consumption and greenhouse gas emissions per capita. In line with this, the Chinese government[5] has been able to meet the increased demand for water in industry by increasing irrigation efficiency. In northern China,[6] agricultural water use had fallen by 20 percent in 2012 compared to 1990 figures, while food production had increased by 30 percent. This freed up water for industrial and urban users, and helped to meet the increasing water demand to drive economic growth.

In the 1990s in Costa Rica, intensive farming to meet the growing demand for food accelerated soil erosion and led to increased sedimentation in hydropower reservoirs, which reduced reservoir capacity and power generation. To address this problem, the government established a National Fund for Forest Financing. Hydropower companies contributed to the Fund, which paid upstream communities for tree plantation and other conservation programs, thus reducing soil erosion and helping minimize the trade-offs between food and energy.[7] Similarly, in China, downstream industries on the Yellow River invested in agricultural water efficiency technologies in upstream Inner Mongolia to relieve the pressure on water resources and help meet the downstream demand.[8]

The engagement of the business community has contributed to minimizing trade-offs between sustainable water and food management. For example, faced by a shortage of water due to drought in Australia, the Coca-Cola Company invested

5 Doczi, J., Calow, R., & d'Alançon, V., *Growing more with less: China's progress in agricultural water management and reallocation (Case Study Report)*, Overseas Development Institute, 2014

6 Shen, D., *The agricultural water management in northern China*, Overseas Development Institute, 2014

7 Blackman, A., & Woodward, R. T., *User financing in a national payments for environmental services program: Costa Rican hydropower*, Resources for the Future, 2010

8 Ibid, Doczi, J., Calow, R., & d'Alançon

9 Gerholdt, J., & Pandya, S., *Resources: The energy–water–food nexus*, Business & Sustainability Council, Conservation International

10 Golam Rasul & Bikash Sharma, *The nexus approach to water–energy–food security: an option for adaptation to climate change*, Climate Policy, 2016

in water-use efficiency both in their operation and in the management of watershed and springs. This has considerably reduced the water required per unit of beverage production, improved the quality of watershed and springs, and ensured a sustainable flow of water.[9] Promoting strong public–private partnerships thus has the potential to offer innovative solutions for managing nexus challenges.

Toward a nexus-based framework for sustainable adaptation

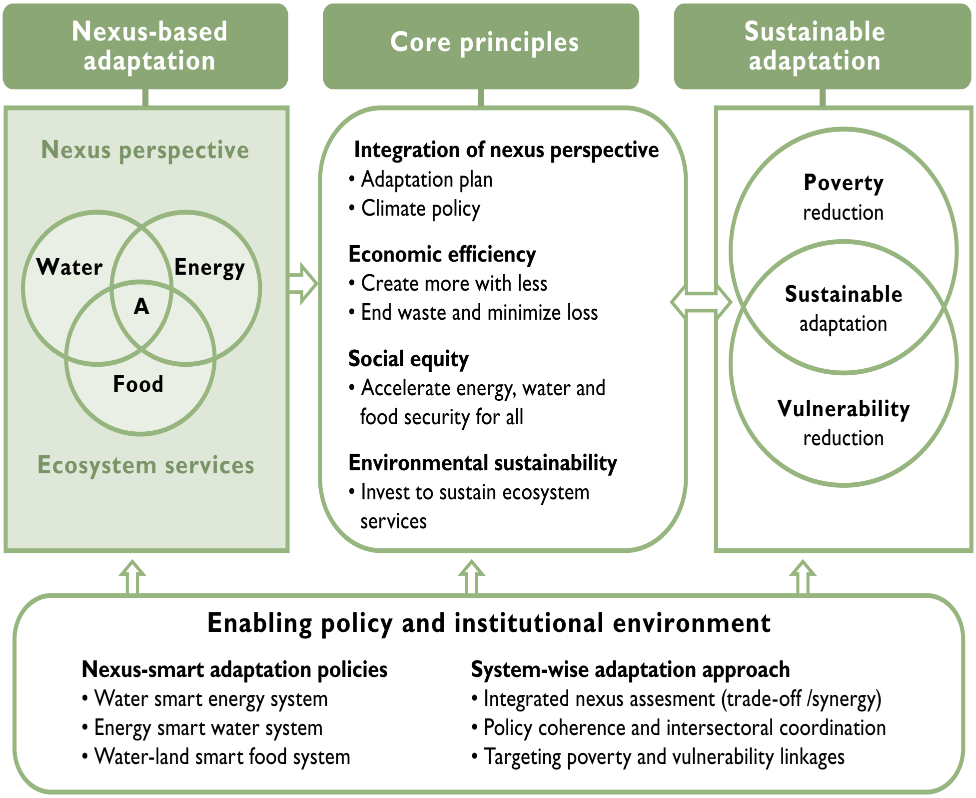
Understanding the role of the nexus in climate change adaptation is integral to designing effective policies and strategies. The nexus approach is "system-wide" and recognizes the inherent interdependencies of the energy, water and food sectors. It seeks to optimize the trade-offs and synergies, supporting more effective and sustainable adaptation responses. The nexus approach is more holistic in nature and thereby more easily aligned to Agenda 2030 and the SDGs. In reality, insufficient attention has been given to cross-sectoral issues, particularly the harmonization of sectoral goals and systemization of decision making.

A generic framework[10] for the move from a sectoral approach to a holistic nexus-based approach to sustainable adaptation is outlined in Figure III.3 (overleaf). The framework is intended to stimulate critical thinking rather than provide definitive answers. In the first section of the figure, area A in the Venn diagram represents the situation of an integrated nexus-based response strategy for sustainable adaptation to ensure the security of resources in all three sectors.

The central section represents the core principles of a nexus-smart policy and the associated outcomes that underpin the three sustainability dimensions: economic (increasing resource efficiency), social (accelerating access for all) and environmental (investing to sustain ecosystem services). A climate-smart adaptation policy should not only improve the efficiency of resource use among the nexus sectors, but also takes a broader view of the impact of resource use on the overall environment and wellbeing of society. The third section highlights vulnerability–poverty linkages and the importance of reducing poverty and vulnerability concurrently to ensure adaptation solutions are sustainable.

To be achievable, all three components of the framework (nexus-based adaptation, core principles, and sustainable adaptation) must be underpinned by an enabling policy, legal, regulatory, institutional, and macroeconomic environment.

A nexus-based adaptation framework[11] Figure III.3



Since the adaptive capacity of those affected by climate change ultimately depends on their access to poverty reducing opportunities and resources, adaptation plans can only be effective if they are built into the wider development agenda. This is necessary to ensure that adaptation policies do not work counter to development efforts—so-called "maladaptation." The framework shows that it is important to understand the context of vulnerability with regard to climate and non-climate influences, poverty and adaptation strategies, before devising a nexus-based response strategy. It stresses the need for improved cross-sector and cross-border cooperation and a coordinated effort.

11 Source: Golam Rasul & Bikash Sharma, *The nexus approach to water–energy–food security: an option for adaptation to climate change*, Climate Policy, 2016

Recommendations for nexus-based and sustainable adaptation

- Integrate nexus perspectives into adaptation plans, and climate change adaptation perspectives into development plans, for better policy integration. It is also critical to increase stakeholder collaboration in sustainable adaptation and development planning and decision making.
- Expand the nexus knowledge base. Understanding of the interlinkages between the nexus perspective and adaptation plans and responses is limited, so deepening the nexus knowledge base is critical.
- Promote a system-wide adaptation approach. Move from a sectoral to a trans-sectoral approach to encourage: different adaptation responses and measures that are mutually supportive; and enhanced synergies and minimized trade-offs.
- Promote win-win options for nexus security and adaptation to climate change. Enhance the efficiency and productivity of resource use and increase multiple uses of resources through economic incentives and good governance, institutional and policy coherence. Also promote public–private partnerships to increase benefits from productive ecosystems. For example, successful public–private partnerships in the agriculture sector can improve the efficiency of developing locally adapted innovation, enable the distribution of technology, make the most of sustainable agricultural practices, promote the responsible application of new technologies, and provide social and economic value to farmers and communities.
- Create and support an enabling environment: strengthen policy integration between nexus and adaptation mechanisms across sectors at different scales and among major actors (public / private / civil society partnerships); and strengthen institutional capacity for the holistic coordination of the energy, water and food nexus.
- Invest in nexus-smart infrastructure, multifunctional ecosystems and innovative technologies and institutions. Provide policy and institutional support for attracting investment in modern energy infrastructure and design mechanisms. Introduce appropriate incentives, regulations and payments in recognition of the environmental and social costs affecting decision making.

Natural resources, climate change and infrastructure

Many developing countries face the concurrent challenges of developing new infrastructure while operating, maintaining, rehabilitating and ensuring the environmental compliance of aging infrastructure for energy, water and food systems. New approaches and novel, cost-effective strategies are required in order to help.

Traditionally, the private sector and governments have relied on engineered approaches, or "gray infrastructure," to secure energy, water and food systems. These solutions have included treating polluted water, dredging sediments from hydropower and irrigation reservoirs to increase capacity, and lining rivers with levees and flood control dams to increase arable land. Although these engineered solutions have significantly improved the quality of life for many, it is becoming more difficult and less appealing from a financial perspective to initiate, complete and maintain such large projects.

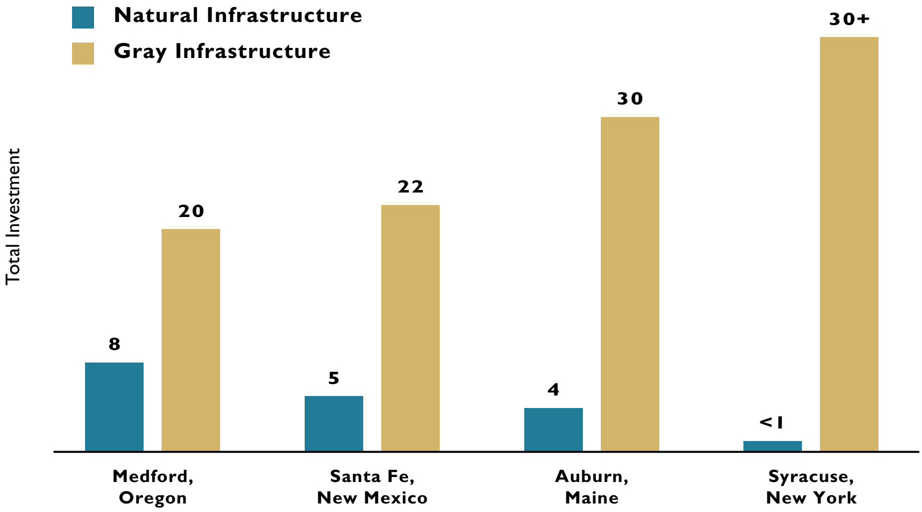
At current investment levels, the global community needs to invest $10 trillion in water infrastructure between 2013 and 2030, according to an estimate by McKinsey & Co.[12] On top of this massive investment challenge is the uncertainty associated with how land-use change, climate change and population growth will impact energy, water and food security. These questions pose an unprecedented challenge to planning future infrastructure systems. Long-lived infrastructure investments (typically 50 to 200 years) will be exposed to shifting climatic conditions, which, according to most models, will vary greatly from current conditions.[13] Yet the magnitude and even the direction of change remain unknown for crucial variables such as precipitation, temperature and storm intensity and frequency. Addressing these uncertainties in infrastructure planning necessitates new decision-making processes and management strategies.

Natural infrastructure as part of the solution

In light of these daunting challenges, integrating natural infrastructure with engineered solutions offers an approach that can help to reduce costs, protect and restore ecosystem services, enhance resilience to climate change, and provide a suite of additional social and economic benefits. Natural infrastructure is defined as a "strategically planned and managed network of natural lands, such as forests and wetlands, working landscapes, and other open spaces that conserves or enhances ecosystem values and functions and provides associated

Comparison of natural versus gray infrastructure costs (in $ million)[17]

Figure III.4



benefits to human populations."[14] Natural infrastructure can be utilized as a substitute or complement to traditional gray infrastructure, and in both cases, it has the potential to offer reduced costs while enhancing environmental benefits.

Recent work by The Nature Conservancy indicates that water utilities could save up to $890 million each year in water treatment costs if they invested in all possible watershed conservation actions.[15] Figure III.4 compares the costs of gray infrastructure investments (such as new water filtration facilities) with alternative natural infrastructure investments (such as forest protection, wetland restoration or low-impact development programs) across four US cities.[16]

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12 Dobbs, R., H. Pohl, D. Lin, J. Mischke, N. Garemo, J. Hexter, S. Matzinger, R. Palter, and R. Nanavatty, *Infrastructure Productivity: How to Save $1 Trillion a Year*, McKinsey Global Institute, 2013

13 Stocker, T., Q. Dahe, and G. Plattner,Climate Change 2013: The Physical Science Basis." Working Group I Contribution to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change (IPCC), 2013

14 Benedict, M. and E. McMahon, *Green Infrastructure: Linking Landscapes and Communities*, the Conservation Fund, Island Press, 2nd edition, 2006

15 McDonald, R.I. and D. Shemie,, *Urban Water Blueprint: Mapping conservation solutions to the global water challenge*, The Nature Conservancy, 2014.

16 Gartner, T., J. Mulligan, R. Schmidt, and J. Gunn (Editors), *Natural Infrastructure Investing in Forested Landscapes for Source Water Protection in the United States*, World Resources Institute, 2013

17 Id.

The graph shows that in each city, natural infrastructure investments had lower up-front costs than gray infrastructure investments. The outcome, however, in terms of water security goals, was the same.

Unlike gray infrastructure, which is generally designed to assist in a limited set of circumstances, natural infrastructure tends to perform well across a wide range of conditions and offers a variety of benefits across food, water and energy systems, as well as providing other benefits to ecosystems and society. A floodplain, for example, may hold larger flood volumes than can be held within a levee-lined river channel. The floodplain may also be used to grow food, sustain bird and fish species, and provide recreational benefits.

In general, natural infrastructure plays four important nexus roles in helping to secure energy, water and food resources:

- Natural infrastructure links together the nexus elements and plays overlapping roles in the management of energy, water and food systems. As such, it can provide cross-sector benefits, potentially multiplying economic returns on investments.
- Natural infrastructure for water helps reduce floods and droughts, providing a buffer against inter-annual variability as well as the added variability associated with climate change, thereby improving the resilience of energy, water and food systems.
- Natural infrastructure can help maintain the function and extend the lifespan of the grey infrastructure that supports energy, water and food systems. For example, dams play an essential role in the production of hydroelectric power. As a river flows into a reservoir and slows, sediments carried by the river sink to the bottom of the reservoir. Over time, sediments accumulate, resulting in a gradual loss of the dam's ability to store water, thus reducing its generating capacity. Deforestation and other land-use change can accelerate the sedimentation process and also alter rainfall patterns, affecting power generation. However, reforesting watersheds above dams helps prevent erosion, naturally slowing the reservoir sedimentation process, as well as increasing power-generation efficiency and the longevity of hydropower facilities.
- Natural infrastructure can mitigate negative impacts resulting from the operation of grey infrastructure to meet energy, water and food demands. For example, natural infrastructure can enhance agricultural systems

and help mitigate the negative impacts of intensive food production. As the largest global consumer of water, the agricultural sector can deplete waterways or even cause rivers to run dry, and cause land to subside due to groundwater depletion. However, managing the natural storage provided by aquifers alongside constructed reservoirs can help ensure that sufficient water remains in streams to support aquatic ecosystems throughout the year. For example, during times of abundance, water can be stored in underground aquifers and recovered for agriculture only during low-flow years, rather than constantly depleting surface water sources and riverine ecosystems.

Chapter IV

Governance, finance and investment

Previous chapters have explained the necessity of investing in affordable energy, irrigation technology and agricultural projects in order to improve energy, water and food security. Planners must consider the trade-offs between competing uses for energy, water and land, and how demand and supply patterns will evolve. This requires devising and implementing "nexus investments" that integrate approaches to policy, planning and implementation. But securing the necessary financing presupposes the existence of mechanisms conducive to fostering innovation and risk taking.

This chapter details the challenges to ensuring that proper governance—and an encouraging regulatory environment—exists to support nexus investment. The nexus approach can help realize significant economic gains. But for the approach to secure financing, robust institutional structures are needed.

Benefits of nexus investments

The nexus approach to energy, water and food security has positive implications for economic growth. In periods of increased resource scarcity, when a nexus approach is ignored, food costs rise, electricity prices increase and economic growth suffers. In Brazil, for example, water and energy rationing led to an estimated reduction in economic growth of between 1 and 2 percent in 2015.[1]

Currently, 20 percent of water consumption in China is utilized for power generation and other industrial purposes. Agricultural irrigation consumes 60 percent of water. A plan exists that aims to triple the country's hydropower capacity by 2020. Adopting a nexus approach would help reduce the water consumption while providing more benefits in the energy, water and food sectors.[2]

1 Will Sarni, *Deflecting the scarcity trajectory: Innovation at the water, energy, and food nexus*, Deloitte Review Issue 17, 20159

2 Id.

In the USA, the state of California has also demonstrated that ignoring the nexus approach poses economic risks. Between October 2011 and October 2014, California's consumers spent $1.4 billion more for electricity than in average years because of a drought-induced shift from hydropower to natural gas. Include the state's dry years from 2007 to 2009 into the equation and the total additional energy cost borne by California's electricity users during six recent years of drought is $2.4 billion. In 2015, it is estimated that drought caused about $3 billion in economic losses compared with $2.2 billion in 2014. The agriculture sector was adversely impacted, seeing an 11 percent decline in planted acreage in 2014 compared with the previous year. Job losses and declines in the production of corn, rice and cotton followed, underscoring the inextricable linkages between energy, water and food.[3]

Nexus complexity

Comprehensive integrated resource planning at regional and national levels will help manage the trade-offs that the nexus approach recognizes. Such planning will also maximize benefits among multiple sectors while contributing to diminishing costs—all of which supports the sustainable use of natural resources. The nexus approach tries to counteract sectoral policy silos by adopting connected approaches that make use of appropriate governance mechanisms. If proper governance exists and an enabling environment is achieved at both domestic and international levels, financing from public and private sectors will be forthcoming and can be scaled up.

Governance challenges

Thus, a prerequisite to the successful adoption of the nexus approach is the establishment of a supportive governance environment / mechanism and the ability to build capacity across sectors and scales.

Nexus governance must take account of many risks, including market failure (where the market rules and price signals fail to support the nexus approach), information asymmetries (where the amount of useful data for one sector, e.g. energy, is more than for the two others), cooperation breakdown, and competition for limited resources. Large numbers of stakeholders exacerbate the challenges by creating a complex web of conflicts of interest. With this in mind, it is difficult to provide a general governance blueprint for a nexus approach.

Developing countries face significant governance challenges due to institutional weaknesses, data deficits and an undeveloped culture of cooperation across the sectors. In Bolivia,[4] for example, although the legal conditions for cross-sector planning have been established through the country's Economic and Social Development Plan, such initiatives have not yet given rise to joint planning among the three core nexus sectors. Institutions lack the mechanisms and internal capacity to efficiently plan and implement overarching approaches.[5]

A study by the World Bank Group[6] shows that despite substantial progress toward recognizing water and energy links in the legislation and initiatives of many southern African countries, significant barriers still exist in implementing a cross-sectoral approach to planning across the region. These barriers appear to result from capacity constraints at many levels, including a lack of data, a limited institutional capacity to facilitate data sharing and an absence of multidisciplinary coordination to implement plans and strategies.

Governance mechanisms

The role of national governments is essential when addressing energy, water and food security issues, even though action is often required at local levels. The government should set regulatory frameworks and standards, remove policy barriers, provide funding and technical assistance and facilitate coordination among sectors and different levels of government. Combining inter-ministerial committees and policy instruments (including standards and taxation) could promote a governance mechanism to facilitate nexus-related pricing policy, cooperation agreements, permits, environmental assessment, local treaties and more.

A governance mechanism for a nexus approach would require "multi-level" dimensions. Even once such a mechanism is established, power imbalances (between the ministries of environment, agriculture and energy, for example), decision-making stagnation and resilient policy silos may make achieving synergies difficult.

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3 Id.

4 Deutsche Gesellschaft für Internationale Zusammenarbeit GmbH (GIZ) *Working together to develop the water, energy and food security sectors*

5 Ibid, Will Sarni

6 WB, *Energy–Water Nexus in Southern Africa Southern Africa—Background Paper to Support Dialogue in the Region*, 2016

For a governance mechanism to succeed, it is important to consider transaction costs, social effects and political feasibility. While market mechanisms may be the most efficient means of promoting and implementing new nexus and multi-sectoral projects, in practice such mechanisms may meet with resistance. For example, removing subsidies on natural resources like water and energy, or using pricing schemes to make efficient use of nexus-friendly resources, might not be socially acceptable to local populations. A lack of efficient and competitive markets could make governance mechanisms unfeasible.

Governance mechanisms to support a nexus approach may be accompanied by sustainable—and constantly monitored and adjusted—instruments, incentives and tools. The establishment of these monitoring and data management systems will ensure the effectiveness of new processes and cooperation activities. Inefficient monitoring can come in a variety of forms and must be guarded against. For example, a deficient hydrological dataset, a non-existent water register or a lack of information about nitrate values in water bodies can result in poor water resource management.

The challenges of nexus-promoting policy coordination should be addressed in both vertical and horizontal dimensions within hierarchical government structures. But many countries lack this framework. For instance, among sub-Saharan African countries, only South Africa appears to be actively incorporating water resource availability into its energy planning.[7]

Optimal nexus governance decentralizes some decision-making powers while other decisions are coordinated at a higher level. Energy, water and food are topics of great importance to every rural community. The work of a central government's many different departments on intersecting objectives often results in fragmented government initiatives. Achieving effective governance requires consolidation and coordination among these various initiatives. Local governments should be seen as coordinators of rural development. Social infrastructure needs to be integrated and local policies established so that projects pertaining to the EWF nexus are supported.

A fair and transparent approach will promote the interests of different stakeholders. With proper political support, a formal governance mechanism should empower all stakeholders and bring together the private sector, governments, bureaucratic structures and informal networks.

7 Id.

Policy alignments

To encourage investment in "nexus-friendly" multi-purpose infrastructure, misaligned policies and other obstacles should be superseded or removed. One major obstacle to be overcome is the existence of distorted prices in different nexus sectors. In some countries, for example, subsidizing biofuels development is justified by the quest for energy independence and climate change mitigation efforts. Biofuels, however, are water intensive and a price distortion in this sector may give rise to an incentive to grow more, resulting in the replacement of forests and pastures in order to grow feedstock. This highlights the need for appropriate economic instruments and policies—which are able to recognize price and other distortions—to support balanced and sustainable development. Similarly, energy subsidies are sometimes provided to a country's agriculture sector without considering their impacts on groundwater depletion or degradation. Balancing price signals, removing harmful subsidies and aligning incentives across the three nexus sectors are vital to encouraging the appropriate level of investment, innovation and resources.

Policy makers should identify and create incentives for the private sector to invest in nexus projects. This is not always easy. As described in Chapter 1, Box I.2, India has supported agriculture growth through power subsidies. However, these subsidies resulted in the unsustainable consumption of electricity and water resources. To counteract the situation, different states have adopted different policy approaches (see Box IV.1). Policies are made at the state level, rather than at the central government level. This makes it easier to formulate guidelines that consider the trade-offs and synergies within the nexus sectors.

Energy pricing policies for agricultural growth in Indian states

Box IV.1

Comparing electricity policy (pricing / rationing) in the agriculture sector in three different states in India underlines the importance of politics in managing the nexus.

In West Bengal, farmers pay for electricity consumption at the cost of supply. This has encouraged farmers to become more efficient users of both electricity and water.

In the Punjab, the government provides electricity to farmers for groundwater pumping via a strict rationing system. In other words, electricity rationing is the main policy lever for controlling groundwater. Farmers can increase their water supply only by using more energy efficient pumps. Such policies not only provide an environment for economical pumping systems, but can lead to more effective water conservation practices as well.

In the southern state of Karnataka, agriculture is dependent on aquifers with limited storage capacity that are nearly depleted. In providing power, the government separates agricultural and non-agricultural supply lines and rations electricity to agriculture, offering both single-phase and three-phase supply. Although the latter is stronger, it is available for only six hours / day. As single-phase power is available for an additional 10–12 hours, farmers can opt for this to exploit more water.

In south-eastern France, *Electricité de France* provided financial incentives to farmers. The incentives encouraged technology to be used for irrigation purposes, thereby optimizing water consumption *(see Box IV.2)*.

Financial incentives in a nexus approach: Case of *Electricité de France* (EDF)[8]

Box IV.2

The Serre-Ponçon dam and reservoir project is operated by EDF in southeastern France and includes 21 hydropower plants that generate up to 6.5 billion kilowatt-hours of electricity per year. The project also supplies drinking water, water for industrial purposes and irrigates more than 150,000 ha of farmland. The risk of water scarcity affecting the production of electricity, especially during the peak load, encouraged EDF to enter into an agreement with agricultural irrigators. The agreement stipulates that irrigators must consume water efficiently to receive remuneration in return.

Accordingly, irrigators adopted more innovative and efficient methods of working. Through better management and the use of water efficient technologies, 325 million cubic meters of water were saved each year. The payment from EDF is an affordable investment that reduces disruption risks to electricity production at peak load.

Finance and investment

Companies, investors and other stakeholders can use a risk-based approach to analyze energy, water and land-use scarcity and uncertainties in supply chains, project pipelines and investment portfolios. Considering the interlinkages between sectors by using such an approach can improve returns.

Relevant risk-assessment tools, reporting frameworks and disclosures are important in order to appraise nexus projects. Recently, a sharp increase in the development and use of water stewardship tools, water footprinting practices and water accounting tools has improved the success rate of nexus projects. The FAO, for example, has developed an approach to assess and manage the nexus that informs decision-making processes and guides the development of nexus-sensitive policies.

The "Nexus Assessment" consists of an easily applicable methodology that allows for a quick appraisal of possible interventions with a view to achieving overarching development goals.[9] It represents a structured way to carry out an EWF nexus evaluation, with a focus on food/agriculture, to raise awareness on nexus trade-offs and synergies, as well as increase understanding of the key interactions between EWF systems in a specific context (e.g. a country). It also evaluates the nexus sustainability (bio-economic pressure) of a context and evaluates the performance of a technical or policy intervention. Finally, it compares interventions and derives informed response options. The "Nexus Rapid Appraisal Tool" is an easier and rougher way to do the analysis *(see page 85 for more on the Rapid Appraisal Tool)*.

Given the surge in the development and use of nexus-related applications and tools, project financiers can now more easily incorporate energy, water and food sustainability into their projects. Development banks are increasing their focus on and analysis of water-related issues. The International Finance Corporation, for instance, has revised its environmental performance standards to improve the way it monitors the effects its loans have on water resources.[10] The World Bank's Thirsty Energy Initiative[11] is working to highlight the growing water needs for energy *(see Box IV.3)*.

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8 Will Sarni, Deflecting the scarcity trajectory: Innovation at the water, energy, and food nexus, Deloitte Review Issue 17, 2015

9 FAO, *Water–Energy–Food Nexus Rapid Appraisal Tool*, 2015

10 International Finance Corporation (IFC), *Understanding IFC's Environmental and Social Due Diligence Process*

11 WB, *Thirsty Energy: Securing Energy in a Water-Constrained World*, 2013

The World Bank's Thirsty Energy Initiative Box IV.3

To address challenges faced by energy and water resource planning, the World Bank launched the Thirsty Energy Initiative in January 2014. This program aims to help countries integrate water constraints into energy sector planning and better address water and energy scarcity risks. It prepares countries to better understand the benefits of a nexus approach by:

- Identifying synergies and quantifying trade-offs between energy development plans and water use.
- Piloting cross-sectoral planning to ensure the sustainability of water and energy investments.
- Designing assessment tools and resource management frameworks to help governments coordinate decision making.
- Providing capacity building and supporting knowledge transfer.

In collaboration with other organizations including the UN SEforALL, GIZ, and the Stockholm International Water Institute, the initiative has increased the awareness of water and energy challenges and promoted a dialogue among governments, international organizations and the private sector. Due to the vital role of the private sector in energy and water management, the initiative also features a Private Sector Reference Group that shares experiences and knowledge. The Group has been active in several countries including South Africa, Morocco and China. In South Africa, by incorporating water supply and infrastructure costs into an energy system model, the cost of the water supply has, for the first time, been assessed successfully.

The Austrian Development Cooperation (ADC)[12] has adopted a specific vision of a nexus approach. ADC development strategies, projects and programs must now focus on the interactions, synergies and possible trade-offs among sectors caused by interventions designed to improve energy, water and food security. ADC considers energy, water and food security as core nexus themes, which depend on renewable (such as soil, water and biomass) or non-renewable natural resources (such as fossil fuel and mineral deposits).

The Inter-American Development Bank[13] is currently investing in the production of decision-support tools to inform lending and investment in relation to the EWF nexus.

OFID, meanwhile, has adopted the nexus as the central theme of its Corporate Plan 2016–2025. Based on this plan, 70 percent of OFID's activities in the coming decade will be dedicated to the critical sectors of energy, water and food, with transportation as an additional enabling sector.

Nexus projects, like all other multisectoral projects, often require higher levels of financing than single-sector projects. Raising finance from sources other than public funds can be challenging due to greater costs and higher risks.

Common approaches to scaling-up funds include using private–public partnerships and public–private and civil society platform methods. Public funds encourage the private sector's involvement. For such partnerships to work, initial financing—such as seed funding—is often provided by the public sector. The role of government subsidies is essential to compensate and incentivize the private sector—particularly in the water and energy sectors. The government may also, or alternatively, decide to provide direct support for nexus projects through grants, equity investments and / or debt. This is particularly useful where the nexus project is not financially viable in its own right or is otherwise subject to specific risks that private investors or lenders are not well placed to manage.

Joint nexus-related infrastructure ventures between countries can also provide good options when making investment decisions about shared resources. For example, in the case of upstream and downstream countries building infrastructure together, water used to produce energy in winter in the upstream country could be stored in a nearby dam until summer for irrigation and energy production in the downstream country. This would require joint investments in the infrastructure and its management. Transboundary and multisectoral projects such as this call for special initiatives and innovative financing.

Cross-stakeholder and cross-sector tools are important to help scale up nexus projects. Payments for Ecosystem Services (PES) is a method of directing private and public investment into improving or protecting ecosystems and watersheds that support drinking water provision, as well as energy and food production. These tools promote synergies by removing the negative impacts

12 Austrian Development Agency (ADA), *Focus: Water–Energy–Food Security Nexus, From Nexus Thinking to Nexus Action*, 2015

13 Bellfield H., *The Water–Energy–Food Nexus in Latin America and the Caribbean: Trade-offs, Strategic Priorities and Entry Points*, Global Canopy Programme, 2015

and trade-offs between natural resource users. PES involves trade between suppliers and buyers of the ecosystem services. Essentially, the system monetizes negative impacts and trade-offs, which are settled through financial payments.

The PES approach is demonstrated by the Sogamoso hydropower plant (Hidrosogamoso) in Colombia.[14] The power plant is based on the Sogamoso River and has an 820MW installed capacity. From 2015, the plant has paid land users to protect the forests in the catchment area to ensure water is continually discharged into the reservoir. Forests—which capture and store water—represent an essential component of the water cycle. The payment rate has been set at $65 / month for families with up to three ha, and $195 / month for families with more than three ha.

Similarly, Costa Rica has a long history of using the PES approach and has established a formal, countrywide program of payments. PES was authorized in the fourth national forestry law in 1996.[15] The privately-owned La Esperanza Hydroelectric Power Company (LEHP) entered into a 99-year PES contract with Monteverde Conservation League (MCL), a not-for-profit, nongovernmental organization. The contract established payments from the downstream water user (LEHP) to the forest owner (MCL) for the hydrological services of the forest for a period of 99 years. LEHP is a peaking plant designed to accumulate water throughout the day in order to produce electricity during the peak hours. This helps to avoid unintentional drops in voltage and at the same time generates more income from the higher electricity prices during the peak hours.

The Global Environment Facility (GEF)—an international partnership of 183 countries, international institutions, civil society organizations and the private sector that addresses global environmental issues—has funded 42 projects where PES has been a core element of the project design. GEF has invested $70 million in 14 projects, where PES is central to the project's design, and leveraged an additional $395 million in co-financing. This type of approach can be combined with PPP schemes to scale-up more funds through private sources. Additionally, the World Bank has supported PES mechanisms in many countries, including Costa Rica, Ecuador and Mexico.[16]

Finance is about pricing and managing risks, and blended and innovative financing is needed to mitigate risks for large nexus investments. Different types of financing can address different types of risks; hence there is benefit in combining types and sources of finance, such as debt, equity, concessional finance, etc. The main concern for investors is obtaining market-rate returns.

Innovative financing, including blended facilities (which combine low-interest and commercial facilities), can improve the return of a nexus project so that it can compete with market rates. Blended facilities can also help scale up commercial financing for nexus investments with developmental impacts and ecological resource conservation aims. This is particularly important in a context where public resources are under pressure. Blended financial solutions can channel capital from other sources and combine the skills, knowledge and resources of public and private investors to increase the scope, range and effectiveness of the investments.

The most important role of blended financing is aligning returns with market expectations via risk management. To promote blended financing, funders should use supporting mechanisms; by providing technical assistance, to lower transaction costs and risk, for example. Transaction costs may include I) search costs (costs of identifying appropriate projects or programs to fund); II) bargaining and decision costs (costs of negotiating and agreeing financing agreements for projects); and III) policing enforcement costs (costs of fulfilling requirements for project execution and monitoring tools). Establishing a joint supporting system platform for instance could minimize those transaction costs.

There are many cases in which government funds, supported by other means—for instance, finance from the World Bank—have improved access to commercial finance in the water, sanitation and energy sectors. One such case saw loan financing provided for utilities in Kenya that was a combination of a commercial loan, a community up-front payment and an output-based grant after implementation. The blended facility enabled the utility company to maintain and expand its operations.

Many financial frameworks and instruments are used for infrastructure and water management systems. Such frameworks and instruments may be modified for nexus use. Examples include municipal, provincial or national bonds. Institutional investors such as pension funds and sovereign wealth funds also display an appetite for solid infrastructure securities that meet

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14 Jean Carlo Rodríguez de Francisco, *Payments for Ecosystem Services and the Water–Energy–Food Nexus*, Deutsche Institut für Entwicklungspolitik (DIE), Nexus Brief No. 4, 2016

15 Ina Porras, Nanete Neves and Miriam Miranda, *PES as a strategy to minimize risk: The Case of La Esperanza Hydroelectric Power Company, Costa Rica*, Green Indian States Trust (GIST), 2010

16 Stefano Pagiola, Paola Agostini, José Gobbi Cees de Haan, Muhammad Ibrahim, Enrique Murgueitio, Elías Ramírez *Mauricio Rosales and Juan Pablo Ruíz, Paying for Biodiversity Conservation Services in Agricultural Landscapes*, Environment Department working papers; no. 96. Environmental Economics series, World Bank, 2004

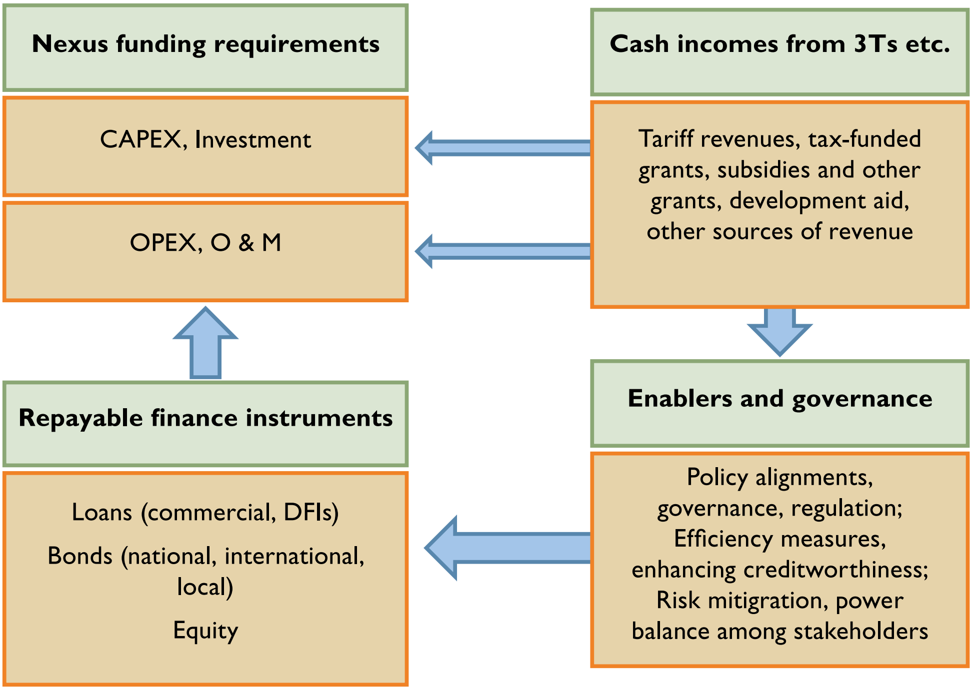
their investment criteria. Municipal bonds, for instance, have been a traditional means of financing urban water services in large cities in Europe and North America, and elsewhere.

An alternative form of funding may be achieved by forming national or regional "revolving funds" for nexus investments. Such funds involve allocating finance from central governments to stimulate borrowing by municipalities or utilities, creating revenues from loan repayments which can be further on-lent.

Basket funding may also be used to scale-up large nexus projects. This normally involves a basket of funding comprising public equity, government grants and loans, commercial loans from local or foreign banks, plus donor support (for specific elements).

The concept of the "3Ts" may also be employed. In such cases, financing is based on a cash-flow made up of tariffs, taxes (subsidies) and transfers (from aid / public grants, etc.). This cash-flow covers the recurrent costs of nexus invest-

A framework for financing nexus investments[17] **Figure IV.1**



Sources of finance for nexus investment

Table IV.1

3Ts	Loan and bond finance	Equity finance
Tariffs & user charges	Commercial banks	Individual shareholders
Taxes/subsides	Institutional investors	Institutional investors
Transfers (grants etc.)	Sovereign wealth funds	Sovereign wealth funds
Final user's contributions	Public bond issues	Private equity funds
	DFIs	Public–private partnerships
	Project bond	

ments and helps to finance the part of its capital investment that is funded by repayable sources such as loans, bonds and equity. The use of future cash-flows to leverage repayable funding for investment is already widely employed.

Figure IV.1 illustrates how revenue-earning nexus projects can use their expected cash flows to attract repayable funds, enhanced through various "enablers" and levers. The framework comprises a combination of fund providers and finance instruments, something that has been made possible by a well-designed governance system. It also aligns local policies and balances the power between the nexus sectors. In this case, it is the ecosystem users, i.e. the consumers of energy, water and food, who pay for the services and products, thus providing the cash required to pay back the debt of the project.

Table IV.1 summarizes the sources and categories of finance for nexus-related projects. Sovereign wealth funds alone have more than $7.3 trillion of assets under management.[18] This amount rises to $29 trillion[19] when other global public investors including central banks and public pension funds are added to the pot. These are funds that potentially could be channeled into

17 Adopted from: *Water: FIT to Finance? Catalysing National Growth through Investment in Water Security*, World Water Council & OECD, 2015

18 Sovereign wealth Fund Institute, http://www.swfinstitute.org/sovereign-wealth-fund-rankings/

19 Official Monetary and Financial Institutions Forum, *Global Public Investor—Concept & Synopsis*, 2017

nexus investments if the right platform is provided. The main focus then should be on establishing a supportive and enabling environment, together with frameworks that allow funds from all available sources to be utilized.

Many international finance institutions, including the World Bank, ADC, OFID and the German Agency for International Cooperation (GIZ), have adopted or supported the energy–water–food nexus approach. They can therefore play a pivotal role in the financing of nexus-related projects through lending and equity participation, and by supplying risk mitigation products such as guarantees.

Chapter V

OFID and the energy–water–food nexus

The year 2017 marks the 10th anniversary of the special mandate that OFID received from the Third OPEC Summit in November 2007 in Saudi Arabia. The Summit emphasized that eradicating poverty should be the first and overriding global priority guiding local, regional and international efforts. The Riyadh Declaration called upon OFID to continue to align its programs with the objective of achieving sustainable development, and to step up efforts to eradicate energy poverty in the developing world. OFID responded by launching its pioneering Energy for the Poor initiative, which continues to form the central theme of its work. Further impetus came in June 2012, with a Ministerial Declaration on Energy Poverty, which pledged a revolving $1 billion to bolster OFID's energy access activities. OFID Director-General Suleiman J Al-Herbish announced this pledge at the Rio+20 Summit later that same month to underline the sincerity of OFID's intent.

The value of OFID's commitments to energy projects is steadily increasing, as is the ratio of energy commitments to total commitments. The funds that OFID makes available to governments, private companies, small- and medium-size enterprises, non-governmental organizations, and entrepreneurs, are helping to finance energy projects in over 90 partner countries. These operations support all sources of energy, whether fossil or renewable, in response to specific local circumstances. They also span the whole spectrum of energy provision, from large centralized power plants and grid-extensions, to community-level mini-grids, small home systems and cook stoves.

OFID's many decades of experience in the energy sector has underlined the necessity of an integrated approach to sustainable development. For energy access to take its full effect, it has to be related to the food and water dimensions. Solutions that treat energy, water and food security separately are inadequate. A case in point was demonstrated in the special study "Biofuels and Food Security," commissioned by OFID and published in 2010. The study showed that the expanded production of first-generation biofuels—which involved diverting food crops such as corn—would push an additional 40 million people annually into hunger. In the second half of the last decade, this practice caused food scarcity and a huge rise in the price of dietary staples, especially in the developing countries.

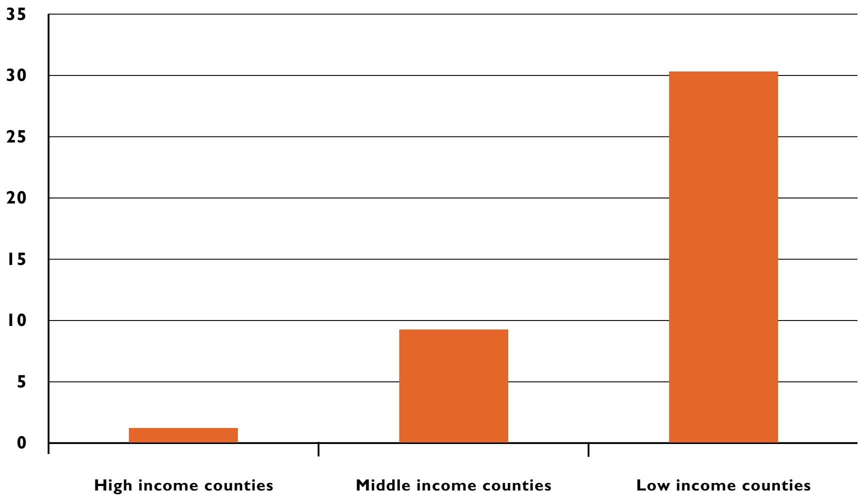
The interdependencies of the EWF nexus are clear. Strengthening the supply chain—including through coordinated investments in energy and transport infrastructure—enables efficient food processing and faster access to markets. Improved transport, storage, refrigeration and port facilities enable trade in food and non-food products and reduces the cost of fertilizers. This, in turn, lays the foundations for agriculture as an expanding, income-generating and profitable business sector. In low-income countries, agriculture is among the most dominant economic sectors (see Figure V.1), forming the basis of human sustenance, livelihood and economic growth. However, the sector needs to undergo significant change and modernization to increase efficiency and yields, enhance variety and meet the changing dietary requirements of a rising global middle class.

This new agricultural revolution will be driven by technological and commercial innovations and by the entrepreneurs that bring them to market. Technologies such as efficient solar powered irrigation systems are already cost effective, but enterprises that can commercialize these technologies still need help in many low-income markets. Governments and financial institutions need to pave the way for sustainable innovation by lowering barriers to entrepreneurship and finance.

OFID's commitment to the EWF nexus is unequivocal and embedded in its strategic direction for the next decade. Its Corporate Plan (2016–2025) identifies the multiple linkages between energy, water and agriculture and emphasizes interventions that incorporate the nexus planning approach. The Plan envisages that the three nexus strands (energy, water and food), together with transportation as an additional enabling sector, will command 70 percent of OFID's commitments in the coming decade.

Success, however, will depend on partner countries recognizing and understanding the nature of the nexus challenge and planning their development strategies accordingly. OFID stands ready to facilitate such insight. The following two case studies—drawn from OFID's project portfolio—highlight the importance of adopting a nexus perspective when planning and implementing development interventions in developing countries.

Agriculture value added (as % of GDP, 2015)[1] **Figure V.1**



OFID/REEEP EWF-nexus project in sub-Saharan Africa

Energy companies offering solutions in the agro-food value chain are mostly early-phase enterprises with one common problem: access to adequate finance. In order to encourage such companies to adopt the nexus approach, OFID cooperated with the Renewable Energy and Energy Efficiency Partnership (REEEP) to establish the "OFID–REEEP Revolving Capital Pool." The pool offers repayable grants at zero interest to start-up businesses to help them provide affordable, modern energy services and unlock their potential for scale up. In its first round in 2014, the pool partially funded two energy access projects that positively impacted the water and food sectors in Kenya and Tanzania.

As in many developing countries, agriculture is the lifeblood of Kenya's economy, directly responsible for over a quarter of GDP and a fifth of formal employment (and over 70 percent of informal jobs in rural areas). A key element to improving agricultural production is irrigation. However, only 4 percent of irrigable land is currently under irrigation. To advance productivity

1 Source: WB national accounts data, https://data.worldbank.org/indicator/NV.AGR.TOTL.ZS?end=2016&start=1960&view=chart

and wealth generation in the agriculture sector, irrigation will need to expand to cover the full potential of irrigable land, a trend already well underway. Kenya's solar potential makes solar-powered irrigation pumps, combined with low-pressure drip systems, an attractive technology that can significantly improve crop yields, productivity and farmer income, while avoiding massive amounts of greenhouse gas emissions.

This project sought to reach very low-income farmers with less than one acre of land, a group that makes up the majority of Kenya's agriculture sector. In total, 825 solar irrigation pumps were installed on smallholder farms and three alternative microfinance products tested, with the proven business model to be developed for consumer financing of solar irrigation. By addressing a key barrier in up-front cost, and by targeting the market segment accounting for the majority of agricultural production, the project holds great potential for transforming Kenya's irrigation sector from a product (i.e. conventional pumps sales) model to a service (i.e. affordable irrigation water) model with flexible payment. The objective is to prepare for private sector investment with a view to unlocking scale and increasing uptake of solar irrigation, potentially reaching 20,000 smallholder farmers.

Solar pumps in the field in Kenya

PHOTO: JEFFREYMWALCOTT.COM

PHOTO: REDAVIA

Solar farms powering food processing in Tanzania

Agriculture is also the backbone of Tanzania's economy, contributing around a quarter of GDP and employing three-quarters of the labor force in this country of 44 million people. Tanzania's staple crop is maize, in which it is largely self-sufficient. However, increasing drought and harvest losses are endangering this, placing further stress on the 34 percent of the population below the income poverty line.

Tanzania's rapid GDP growth of some 6–7 percent annually over the past decade has come in large part from the agriculture sector, including fibers (e.g. cotton), coffee, tea, sugar, fruits, nuts (particularly cashews) and oils. Much of this growth has come from advancements in farming and harvesting. For Tanzania to maintain its economic growth and generate prosperity, it must concentrate on the potential in post-harvest value-added (i.e. processed goods), which has received less attention from government programs.

Tanzania is currently struggling to expand modern energy access, which is still not available to some two-thirds of the population. At the same time, only 9 percent of Tanzania's population has access to formal financial services, and only 4 percent has ever received a loan from a bank—a situation that has stifled investment in the agriculture sector.

The OFID–REEEP project installed two pilot 87.5 kilowatt peak "pay-as-you-go" solar farms for renting to the agro-food sector. The concerned start-up has developed a fully operational food processing-focused marketing and sales channel and is working to attract sufficient private sector investment to finance the scale-up of the service, potentially to 5.2 megawatt peak. The project is also demonstrating the use of food-processing plants as minigrid-anchor customers, by dedicating about 10 percent of the solar farms' output to a minigrid providing power to adjacent residential users.

A biogas-based EWF-nexus project

Also in Kenya and Tanzania, OFID has co-financed a two-component project that aims to improve access to modern energy services by promoting the use of biogas systems. Executed by the Netherlands Development Organization (SNV), the project demonstrates OFID's strategic emphasis on the EWF nexus.

The first component of the project—"Milk Chilling for Smallholder Dairy Farmers"—sought to develop and implement a milk-chilling machine for small-scale farmers who have no or unreliable access to electricity.

The demand for dairy products increases in tandem with GDP and strong population growth. In most developing countries, the majority of the milk comes from small- and medium-scale farmers. The sector is constrained, however, by the lack of practical skills, quality animal feed and support services, all of which results in low-quality milk. In East African countries, the dairy industry not only provides a significant contribution to GDP, but also supports the livelihoods of over two million smallholder farmers. With many farmers living too far away from the market to deliver their (evening) milk before it spoils, the absence of cooling facilities places a firm brake on the development of the industry. The FAO estimates the resulting milk losses at farm level to be between 30 and 50 percent for Tanzania and Kenya.

Using biogas as a renewable energy source for on-farm milk chilling provides a viable solution to this problem for three reasons. First, the per-head production of cattle dung produces sufficient biogas energy to cool down the per-head milk production. Second, biogas is becoming an increasingly accepted and available energy source in the dairy sector. Over the past decade, domestic biogas dissemination in Africa has taken off, resulting in over 47,000 installed systems by mid-2014 and showing an accelerating trend in many countries.


PHOTO: SNV

Field testing of biogas-powered milk chillers

And third, biogas systems show the lowest payback period in cost-benefit analysis among possible energy technologies for milk chilling.

The project provided 500 small-scale farmers in Tanzania and Kenya—each with 5–20 dairy cows—with an affordable and durable milk chilling solution, using a proven technology ready for further upscaling. By-product solid waste is used by the farmers as fertilizer to improve agricultural yield.

The second component of the project—“Sanitation and Sewage Treatment for Boarding Schools”—involved an affordable and standardized mass-produced biogas system that could be adopted in schools and later in other private and public organizations.

Many boarding schools in East Africa, especially in rural areas, depend on fuel wood and/or charcoal for cooking. This has led to deforestation, indoor air pollution and high daily costs. Sanitation conditions are often poor, resulting in unhygienic conditions and the spread of diseases like diarrhea and cholera.

Currently, schools pay the equivalent of between EUR 850 and EUR 3,400 per year for (toilet) waste disposal (depending on the number of students and the location), money that could be spent on improving education. Water in many areas is scarce, and for drinking water schools are using boreholes that are often polluted due to the uncontrolled sanitation practices. Finally, many schools have sufficient space to grow crops, but the production is low due to a lack of nutrients in the soil.

The biogas system piloted in this project improved access to sanitation for school children in Kenya and Tanzania while producing biogas to provide modern energy services. OFID subsidized the provision and installation of systems in 28 schools, including three pilots, to benefit 14,000 school children and staff. Biogas is collected and used for cooking in the school kitchens, replacing firewood and dung. By-product solid waste is sold as fertilizer to generate income streams for the schools. The project has developed a proven concept for a safe and financially viable biogas-sanitation system for upscaling to a further 1,000 schools in Kenya and 500 in Tanzania.

Biogas digester in Nyabirongo girls school, Migori Region, Kenya

PHOTO: SNV

Planning of EWF-nexus projects

As stated before, while OFID stands ready to support nexus projects, the realization of such projects depends on partner countries recognizing and understanding the nature of the nexus challenge and planning their development strategies accordingly. However, OFID also acknowledges that decision makers need tools in order to be better informed about trade-offs and synergies between different development and management choices, and to help them identify options on how to sustainably manage resources.

To help address this need, in 2014 OFID provided financial support to the FAO to develop and publish the EWF Nexus Rapid Assessment Tool (RAT)[2] for use by stakeholders concerned with the development and management of resources, and in line with the global sustainability agenda.

The RAT can be used to assess the nexus interlinkages at any scale, from local to national level. It can highlight synergies between sector interventions—so-called "win-win" solutions—thus helping stakeholders to develop insights into different options, which might not be apparent at first glance. And it can assess and compare the performance of specific nexus interventions on the basis of the context status against a set of EWF sustainability goals.

Specifically, the RAT performs a quantitative analysis to determine the sustainability of the context. Data is collected and analyzed to identify and assess the interlinkages of energy, water and food systems within the context. This work seeks to clarify which environmental and social resources are under pressure and pinpoint the critical interlinkages and competing interests. This, in turn, allows for the identification of criticalities that may arise in the future. It also includes the development of possible scenarios, highlighting the effects of current trends (business as usual) or new policies on the natural environment and the society.

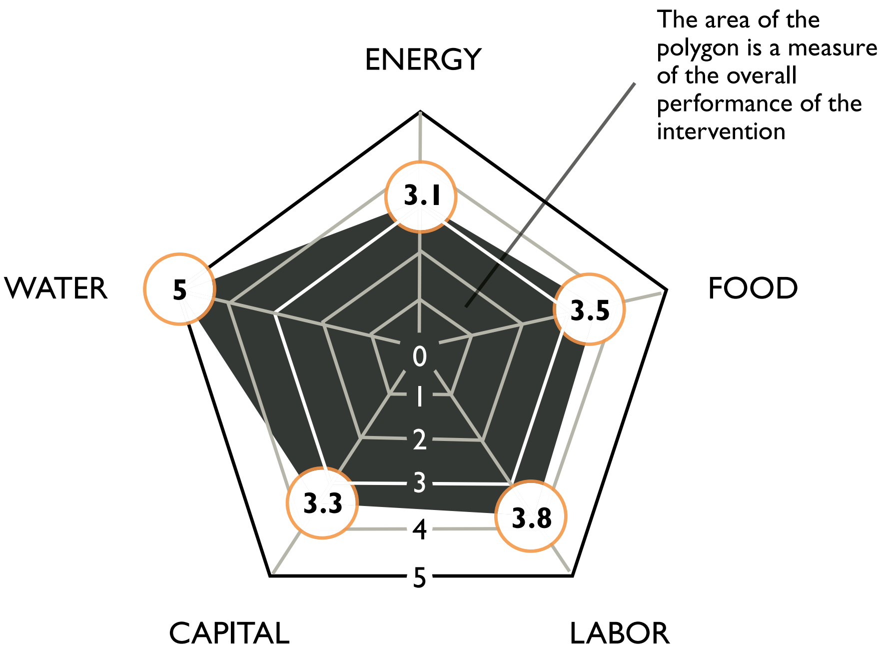
In the RAT, specific interventions are assessed in terms of their performance, i.e. how efficiently the environment and human resource bases are used. The efficiency of energy-, water-, land- and human-time-use can vary before and after an intervention, as well as among different interventions. The RAT proposes a set of performance indicators that use data already collected. This set of indicators is relevant to understand the context in which an intervention is supposed to be implemented and the level of stress to which the

2 FAO, Walking the Nexus Talk: Assessing the Water–Energy–Food Nexus, 2014

environment and / or society is exposed. However, depending on the specific "nexus issue," other indicators could be necessary for the context analysis. At the national level, for example, such indicators can include energy security considerations including energy mix and infrastructure; and greenhouse gas emission of production and consumption. The results of the assessment can then be presented visually in one single graph as shown in Figure V.2. The figure displays the quantification of the sustainability of energy, water and food (the three main nexus elements) but also the situation regarding the two additional factors of labor and capital, the sustainability status of which the RAT considers useful to contextualize also in relation to human resources. These relate to labor intensity requirements, which could include information on wages and employment, and capital intensity requirements, which could include information on capital availability as well as costs.

Visualizing the performance of an EWF intervention[3]

Figure V.2



Interventions are then compared. Here, different stakeholders need to engage in an open and participatory policy dialogue to build consensus among themselves on specific policy issues related to the effects of interventions. This can involve key decision makers and experts to discuss replication, upscaling or revision of the design and scope of the interventions. At the national level this exercise typically involves representatives from different sectors and ministries, and from different backgrounds (technicians, politicians, etc.).

3 Source: FAO, Walking the Nexus Talk: Assessing the Water–Energy–Food Nexus, 2014

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Glossary of terms

ADA	Austrian Development Agency
ADC	Austrian Development Cooperation
Aquifer	An underground layer of rock, sand, or earth that contains water or allows water to pass through it, and from which groundwater can be extracted
bcm	Billion cubic meters
Capex	Capital expenditure, i.e. the cost of developing or providing non-consumable parts for a product or system
Cellulosic biomass	The organic structural material that comprises much of the mass of plants and that can be used for energy production. Cellulose is an insoluble substance which is the main constituent of plant cell walls; wood chips are an example
Crop transpiration	The process by which moisture is carried through plants from roots to small pores on the underside of leaves, where it changes to vapor and is released to the atmosphere
DFIs	Development Finance Institutions
DIE	*Deutsche Institut für Entwicklungspolitik* (German Institute for Development Policy)
Drip irrigation	A watering system that delivers a slow moving supply of water at a gradual rate directly to the soil
End-use energy demand	Energy demand measured at the end user after all losses, technical or otherwise, are accounted for between the point of production and the point of consumption
ESMAP	Energy Sector Management Assistance Program
EU	European Union
EUR	Euros
EWF nexus	Energy–water–food nexus

External resource footprints	The part of the resource footprint of national consumption that falls outside the nation considered
FAO	Food and Agriculture Organization of the United Nations
Feedstock	A raw material to supply or fuel a machine or industrial process
Final energy demand	All energy supplied to the final consumer for all energy uses
First-generation biofuels	Mainly liquid transportation fuels that are derived directly from food crops such as corn, sugarcane, soybeans, wheat and rapeseed
Flood irrigation	An irrigation system where water is delivered to the field by ditch, pipe, or some other means and flows over the ground through the crop
Freshwater withdrawals	Freshwater taken from ground or surface water sources, either permanently or temporarily, and conveyed to a place of use; also includes water from desalination plants in countries where they are a significant source
GDP	Gross domestic product
GEF	Global Environment Facility
GIZ	German Agency for International Cooperation
Gray infrastructure	Familiar urban infrastructure such as roads, sewer systems and storm drains; such conventional infrastructure often uses engineered solutions typically designed for a single function
GIST	Green Indian States Trust
Groundwater	Water found underground in aquifers
Groundwater discharge	The volumetric flow rate of groundwater through an aquifer
GW	Gigawatt
ha	Hectare
ICA	Infrastructure Consortium for Africa
IEA	International Energy Agency
IEA Current Policies Scenario	Assumes no changes in policies from the mid-point of the year of publication

IEA New Policies Scenario	Takes account of broad policy commitments and plans that have been announced by countries, including national pledges to reduce greenhouse-gas emissions and plans to phase out fossil-energy subsidies, even if the measures to implement these commitments have yet to be identified or announced
IMF	International Monetary Fund
IRENA	International Renewable Energy Agency
IUCN	International Union for Conservation of Nature
IWA	International Water Association
kg	Kilogram
LDCs	Least-developed countries
MDGs	Millennium Development Goals
MENA	Middle East and North Africa
Modern biomass	Includes technologies other than those defined for traditional biomass, such as biomass cogeneration for power and heat, biomass gasification, biogas anaerobic digesters, and liquid biofuels for vehicles
mtoe	Million tonnes of oil equivalent
Non-conventional fossil fuels	Fossil fuels found within pore spaces throughout a wide geologic formation, requiring advanced extraction technologies, such as: oil shale, tight oil, oil sands, tight gas, gas hydrate and coalbed methane
OECD	Organization for Economic Cooperation and Development
OMIF	Official Monetary and Financial Institutions Forum
O&M	Operation and maintenance
Opex	Operational expenditure, i.e. the ongoing cost for running a product, business, or system
PES	Payments for Ecosystem Services
Peak demand	The highest (electricity) demand that has occurred over a specified time period. Typically characterized as annual, daily or seasonal and has the unit of power

Primary energy	Energy extracted or captured directly from natural resources, such as crude oil; coal; natural gas; wind and solar radiation, which has not been subjected to any human engineered conversion or transformation process
REEEP	Renewable Energy and Energy Efficiency Partnership
Rio+20	The United Nations Conference on Sustainable Development (UNCSD) took place in Rio de Janeiro, Brazil on 20–22 June 2012; Rio+20 was a 20-year follow-up to the 1992 Earth Summit / UNCSD, held in the same city
Runoff	That part of precipitation that does not evaporate and is not transpired, but flows through the ground or over the ground surface and returns to bodies of water
Run-of-river schemes	A type of hydroelectric generation whereby the natural flow and elevation drop of a river are used to generate electricity; run-of-river power schemes may have no water storage at all or a limited amount of storage
SDGs	Sustainable Development Goals
Second-generation biofuels	Mainly liquid transportation fuels that are manufactured from inedible biomass and could hence prevent conversion of food into fuel
SEforALL	United Nations Sustainable Energy for All initiative
Silo thinking	Is an attitude that is found in some organizations; it occurs when several departments or groups within an organization do not want to share information or knowledge with other individuals in the same organization
Single-phase electricity	The distribution of alternating current electricity using a system in which all the voltages of the supply vary in unison. It is used when loads are mostly lighting, heating and few small electric motors
Surface water	Natural water in lakes, rivers, streams or reservoirs

Three-phase electricity	An electricity transmission and distribution system in which three alternating currents are uniformly separated in phase angle; it is the most common method used by electrical grids to transmit power; it is used to power large motors and other heavy loads
toe	Tonnes of oil equivalent
Traditional biomass	Biological material used as a non-commercial energy source in the form of unprocessed agricultural waste, forest products waste, collected fuel wood, and animal dung, which is burned in stoves or furnaces to provide heat energy for cooking, heating, and agricultural and industrial processing, typically in rural areas
UNESCO	United Nations Education, Scientific and Cultural Organization
USA	United States of America
USGS	US Geological Survey
Watercourses	A natural or artificial channel (such as a river, brook, or underground stream) through which water flows
Water consumption	The volume withdrawn that is not returned to the source (i.e. it is evaporated or transported to another location) and by definition is no longer available for other uses
Water withdrawals	The volume of water removed from a source; by definition withdrawals are always greater than or equal to consumption
WB	World Bank
WEC	World Energy Council
WWF	World Wildlife Fund

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