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**Economic and Social Commission for Western Asia (ESCWA)**

**Conceptual Frameworks for Understanding the  
Water, Energy and Food Security Nexus**

**Working Paper**

## Acknowledgements

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The paper is issued to support inter-governmental and expert deliberations on the water-energy-food security nexus in the Arab region.

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## I. Introduction

Over the last few years, discussion of the interconnectedness of water, energy and food (WEF) security has been gaining global momentum. While the water, energy, and food sectors each face their own specific supply risks in the face of increases in global demand driven by population growth, urbanization, changing lifestyles and diets, and climate change, these sectors are also interdependent as part of the water, energy and food security nexus (Beisheim, 2013).

Water, energy, and food systems draw from common stocks of natural resources and require connected (and in some instances shared) infrastructures to provide essential inputs to social-ecological systems. The interdependencies of these infrastructures create a shared set of policy spaces which have crucial implications regarding national planning and management decisions which bear the potential to cause adverse cascading effects on the security of these vital resources (Waksom *et al.*, 2014). Consequently, context-specific paths of coherent institutionalization of shared governance, and horizontal, vertical and financial governmental coordination become essential to prevent negative externalities across resources to become co-constraints of sustainable development.

The interdependencies between the water, energy, and food (and more generally land) systems are traditionally characterized by the three bilateral interfaces of energy-water, energy-food, and food-water, which consist of linkages representing resource supplies, end-use demands and requirements, and natural and human engineered technologies, processes, and infrastructures necessary to produce, supply, and deliver the resource to meet the end-use demand. These bilateral interfaces form a dynamic set of nonlinear interacting processes linked through a complex network of feedbacks, rendering the analysis of sector-to-sector interfaces insufficient to capture the complexity of the WEF system (Hibbard *et al.*, 2014). These interactions and feedbacks are of varying intensity and timing, and depend on the scope, characteristics and geography of the WEF system considered.

Nexus interactions are complex and dynamic, and take place within a context of transformational processes. Policies targeting sector specific optima can result in cross-sectoral and cross-scales risks and uncertainties that can substantially impact the initial conditions which governed the design of these policies such as societal structures, resources availability and financial conditions (FAO, 2014). Consequently, understanding the natural resource nexus requires addressing the complexity of its component systems. This involves disciplines or analytical structures that convey findings in terms of efficiency, trade-offs, synergies and co-benefits, such as economics, hydrology and engineering, or life cycle analysis, scenario analysis and systems analysis. Furthermore, the political ecology of the nexus cannot be neglected, as it highlights the historical, cultural and socio-political dimensions that underpin a given resource nexus (Foran, 2013; Allouche *et al.*, 2013). This line of research contends that the current discourse on the WEF nexus, which is principally top-down, fails to adequately consider the politics inherent in most of the decisions around food, water and energy, which are often taken within arenas of unequal power relations.

## II. Natural Resource Realism, Sustainable Development and the Birth of the Nexus Concept

Framed around a global scarcity crisis narrative, the water, energy and food nexus, more generally the “natural resource” nexus concept, came into existence following the global crises in food, energy and global finance in 2008, compounded by concerns about the long-term availability of non-renewable resources (Allouche *et al.*, 2013). This was complicated by the declining quality and functions of natural resources, and new scientific evidence suggesting that humanity has already transgressed at least three of the so-called planetary boundaries, namely, the rate of biodiversity loss, changes to the global nitrogen cycle, and climate change (Rockstrom *et al.*, 2009).

Input-output natural resource accounting and the systems analysis approach of Meadows *et al.* (1972) in their seminal work *The Limits to Growth*, originated the concept that natural resource depletion will ultimately affect the ability of an economy to grow. Deliberations on what was a radical concept at its time, led to the formulation of the concept of ‘sustainable development.’ The concept was articulated in the “Report of the World Commission on Environment and Development: Our Common Future” (1987), which was led by Gro Harlem Brundtland and set forth a new ‘global agenda for change’ that was premised on the importance of incorporating the environment and natural resource dimensions in the development discourse. Sustainable development frameworks expose the interdependencies between social, economic and environmental policies and the need for more integrated development paradigms. The concept has since become mainstreamed in global, regional and national development planning and in global development agendas promoted in the economic, social and economic spheres. However, the integration of these three development pillars remains segmented, and improved governance has become increasingly introduced as a core component of efforts to achieve sustainable development.

Following the emergence of complementary approaches promoted by integrated water resources management and the green economy, the nexus conceptual framework emerged and represents a significant influence on a new physical and economic resource realism that has permeated the global community (Bazilian *et al.*, 2011; Overseas Development Institute, European Centre for Development Policy Management and German Development Institute, 2012; Foran, 2013). This paradigm can be characterized by five attributes: the lack of undeveloped resource preserves; the challenges of exploiting new resources; the emergence of new consumers; the volatility of resource prices; and the broadening of actors engaged in governing resources (UNESCAP, 2013).

The World Economic Forum first brought the issue of the risk correlation between the water, energy and food sectors to political attention at the Davos Summit through the issuance of the *Global Risks 2011* report. As reviewed by Bizikova *et al.* (2013) and UNESCAP (2013), many global and regional conferences and meetings were later held during the preparation phase for the United Nations Conference on Sustainable Development (Rio+20 held in June 2012) that highlighted the interdependencies between water, energy and land resources (see Figure 1).

**Figure 1: Selected events on the WEF nexus (2011-2012)**

TITLE/NAME OF THE CONFERENCE/WORKSHOP	LOCATION
Bonn2011 Nexus Conference <sup>2</sup>	Bonn
Mekong2Rio International Conference on Transboundary River Basin Management <sup>3</sup>	Vientiane
6 <sup>th</sup> World Water Forum (water, energy and food are all included in the conference's priorities) <sup>4</sup>	Marseille
Water-Energy-Food Security: New challenges and new solutions for water management <sup>5</sup>	Winnipeg
Water, Energy, Environment and Food Nexus: Solutions and adaptation under changing climate <sup>6</sup>	Lahore
South African Water, Energy and Food Forum: "Managing the mega-nexus" <sup>7</sup>	Sandton
Powering Progress Together: Forum on Energy, Water and Food <sup>8</sup> Forum sponsored by Shell and the City of Rotterdam	Rotterdam
Corporate Sustainability in Africa 2012: "Living in the water, food and energy nexus" <sup>9</sup>	Johannesburg
Water Food Energy Nexus—Blue aquaculture as an integrative part to minimize use of resources for animal and plant production <sup>10</sup>	Berlin
"Food Energy Water (for all)" (organized by ReSource) <sup>11</sup>	Oxford
Managing Water, Energy, & Food in an Uncertain World (Universities Council on Water Resources UCOWR) <sup>12</sup>	Santa Fe
World Water Week (theme for 2012 was water and food security) <sup>13</sup>	Stockholm
10 <sup>th</sup> Gulf Water conference <sup>14</sup>	Doha

Source: Bizikova et al. (2013)

In particular, the Bonn 2011 Nexus Conference, "The Water Energy and Food Security Nexus – Solutions for the Green Economy", organized by the Federal Government of Germany, called for a more integrated approach for achieving food, water, and energy security as a key aspect of moving towards a green economy. Specifically, the conference elaborated a set of normative principles to inform nexus thinking, namely, sustaining ecosystems and their services; creating more with less; accelerating access; and integrating the poorest. Segmented, fragmented, and uncoordinated sectoral decision-making were identified as key challenges leading to wasteful, inefficient and unsustainable resource use. Discussions also called for the development of appropriate frameworks to manage trade-offs, target synergies and avoid tensions across sectors (Hoff, 2011). The Rio+20 declaration, 'The Future We Want' (2012), later stressed the need to address the core issues of food, water, and energy in a manner that reduces adverse impacts on biodiversity, air quality and climate, although the declaration made no specific reference to the nexus.

More recently, the Bonn 2014 conference, "Sustainability in the Water-Energy-Food Nexus", emphasized the need for coherence of cross-sector policy efforts and cross-border cooperation as necessary for the successful governance of the complex risks to sustainable supply of water, energy, food and ecosystem services. The conference called for responsible governance of natural resources; a broad involvement of stakeholders to collaboratively work toward sustainable development; and the need to expand financial, institutional, technical, and intellectual resources for nexus research. In addition, the latest report of the Working Group II of the Intergovernmental Panel on Climate Change in March 2014, featured the "Water-Energy-Food/Feed/Fiber Nexus as Linked to Climate Change" as a cross-chapter theme; and the WEF nexus was central to the agenda of the Stockholm World Water Week 2014.

### III. Nexus Thinking, the SDGs and the post-2015 development agenda

Nexus thinking increasingly features in a number of processes launched by the United Nations General Assembly in their preparations for the post-2015 development agenda and during deliberations on the sustainable development goals (SDGs). For instance, the Open Working Group, established by the United Nations General Assembly to prepare a proposal for the SDGs, emphasizes in its 10<sup>th</sup> session the interlinkages between the goals related to poverty eradication, sustainable agriculture, food security and nutrition, water and sanitation, health and population dynamics, sustainable cities and human settlements, ecosystems and biodiversity, climate, and sustainable production and consumption; even though no reference was made to nexus terminologies (see Open Working Group on Sustainable Development Goals 10<sup>th</sup> session, 2014, “Annex 1: Interlinkages”). Later, the *Proposal of the Open Working Group for Sustainable Development Goals*, submitted in July 2014, stated in its introduction that the “goals and targets integrate economic, social and environmental aspects and recognize their interlinkages in achieving sustainable development in all its dimensions.”<sup>1</sup>

A background issues brief to the 2<sup>nd</sup> Meeting of the High-Level Political Forum in July 2014 emphasizes integrated policy-making and coordination as essential for the overall policy coherence of a universal, people-centred, sustainable development in the post-2015 development agenda (HLPF, 2014). While the document notes that the integration and harmonization of economic, social and environmental policies and plans is firmly embedded in the history of sustainable development and can be traced back to the United Nations Conference on Environment and Development in 1992, the authors stress the increasing necessity of integrating climate change mitigation and adaptation with traditional development concerns, particularly through cross-sectoral and cross-scale decision-making and policies at the water, energy, land, and climate nexus, which are seen as essential to successfully addressing the dimensions of sustainable development. Furthermore, by identifying and quantifying trade-offs and synergies, a nexus approach has important implications in terms of investment requirements and policies, and influences the financing of sustainable development objectives at the local and international levels.

In this respect, Weitz *et al.* (2014) offer some recent reflections on cross-sectoral integration in the design of the SDGs. The authors note that as SDG targets cut across and support multiple development goals, identifying targets at the nexus of different sectors can be instrumental in producing a more concise SDG framework with more robust solutions, avoiding redundancies and contradictions, while helping managing complexity. Similarly, taking into account the water, energy, land nexus is seen as necessary for achieving coherence across goals for Brandi *et al.* (2013). The integrative character of the SDGs can be ensured by using second-order conditions related to the different dimensions of sustainable development, e.g. where the *social* and *environmental* dimensions are

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<sup>1</sup> In a framework proposed by UNEP (2013) for embedding environmental sustainability into the SDGs, the overall set of goals and targets are recommended to be complementary and reinforcing: every goal should be integrated and embody all three dimensions of sustainable development; with a mix of integrated and non-integrated targets.

binding on the target and goal setting of an *economic goal*; while taking into account cross-sectoral interdependencies and constraints along the water, energy, land and ecosystems nexus.

#### **IV. Governing the Nexus**

It is politically challenging to overcome the entrenched silo mentality in existing national and international institutional arrangements, which challenges integrated planning and policy-making at the nexus of water, energy and land systems. At the national level, policy making remains organized along sectoral lines, with a lack of effective cross-sectoral structures and coordination arrangements; while at the international level, agreements, targets and financial commitments remain largely organized by sector (HLPF, 2014).

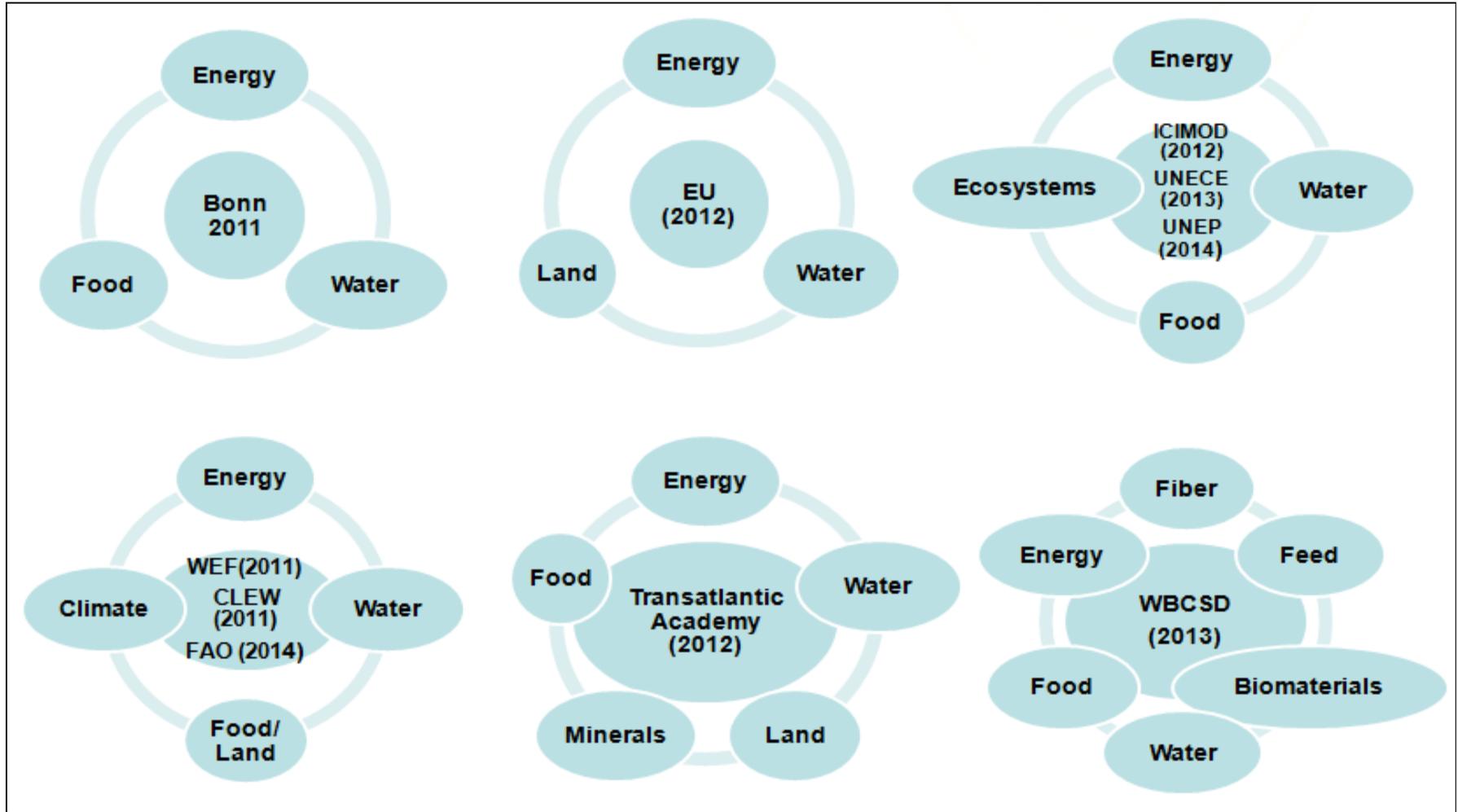
In addition, nexus thinking is permeating governance considerations at the global, regional, basin, national and local scales. At a global level, the approach recognizes interregional spillover effects of national and regional policies as a manifestation of global interdependences due to trade, production, consumption, climate and the movement of people. At a regional level, the nexus calls for an improved coordination of energy, water and agricultural priority setting and planning, while at the water basin level there is also a rationale for regional policy formulation and infrastructure development, particularly in water-scarce regions with member States that are highly dependent on transboundary water systems. At the national and local levels, coherence in planning should be achieved through cross-sectoral consultation and decision processes that taking into account interlinkages among different areas of policy at the formulation stage.

#### **V. Main Conceptual Frameworks for Understanding the Nexus**

In practical terms, the WEF nexus can be defined as an approach to assessment, policy development and implementation that focuses simultaneously on water, energy and food security (Bizikova *et al.*, 2014). More broadly, it presents a conceptual and analytical approach to socio-ecological systems and offers a framework for coordinated management and use of natural resources across sectors and scales (FAO, 2014).

The literature features different conceptualizations of the nexus which vary in their scope, goals, and understanding of drivers and pressures. Figure 2 illustrates the modular aspects of the nexus and how different sectors and issue areas have been incorporated into nexus frameworks. Over time, it is evident that organizations have sought to expand the scope to include additional issues of particular concern to their specific mandates. This ‘additionality’ is evident in Figure 2, which also shows how interlinkages between water, energy and food/land remain at the core of the concept.

Figure 2: Some conceptual frameworks for illustrating the resource nexus



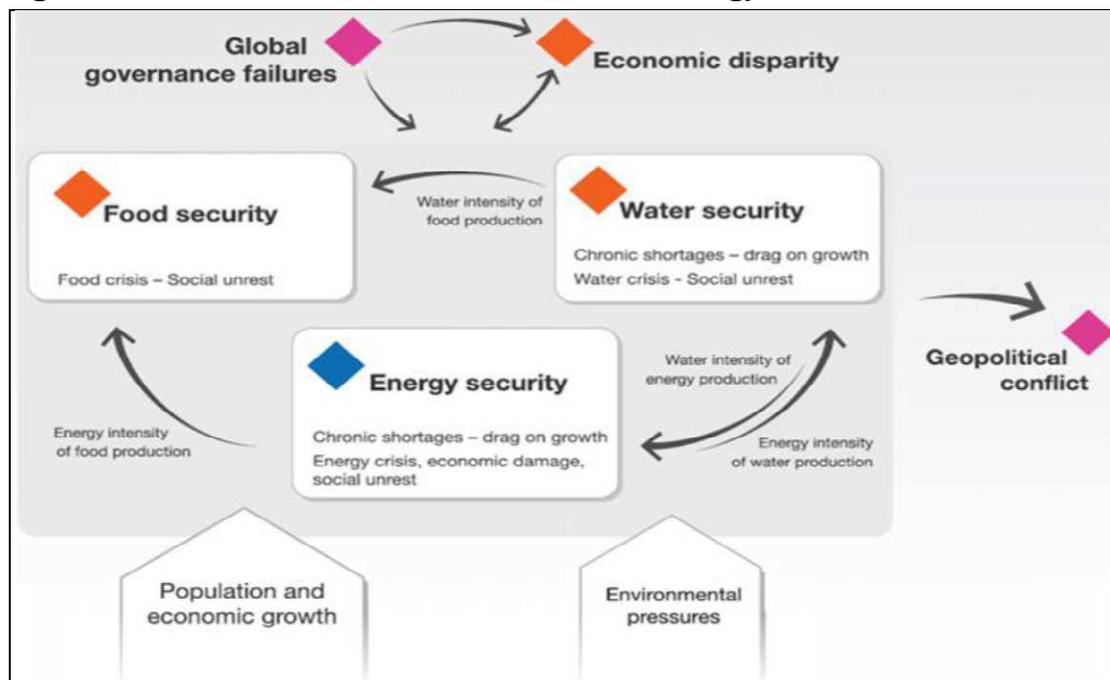
Source: ESCWA.

This section briefly presents the conceptual frameworks and methodologies advanced on the nexus by the World Economic Forum (2011); the Bonn 2011 Nexus Conference; the International Centre for Integrated Mountain Development (ICIMOD, 2012); the United Nations Economic Commission for Europe (UNECE, 2013); the United Nations Environment Program (UNEP, 2014); the International Institute for Sustainable Development (Bizikova *et al.*, 2013, 2014); the European Development Report (2012); the Transatlantic Academy (Andrews-Speed *et al.* 2012); the World Business Council for Sustainable Development (2013); the FAO (2014); the CLEW (2011) approach; and BMZ (2013).

#### A. The World Economic Forum (2011)

The World Economic Forum (2011) presented a framework to support decision-makers to better analyze the global risk landscape and respond proactively and adequately to shocks and crises. Along with the “macroeconomic imbalances” nexus and the “illegal economy” nexus, the WEF nexus is presented as a major global risk area. The framework includes population and growth dynamics, environmental pressures, and climate-change related risks affecting the nexus; and identifies some important interactions among the elements of the nexus, such as water use in the food and energy sectors, and energy intensity in the food agro-chain. Resource security is further featured as one of the main risks to monitor; specifically, food, water and energy security are linked to economic risks, economic disparity, and global governance failures. The main policy recommendations include integrated and multistakeholder resource planning; community-level empowerment and implementation; market-led resource pricing; and technological and financial innovation for managing the nexus.

**Figure 3: The World Economic Forum Water-Energy- Food Nexus Framework**

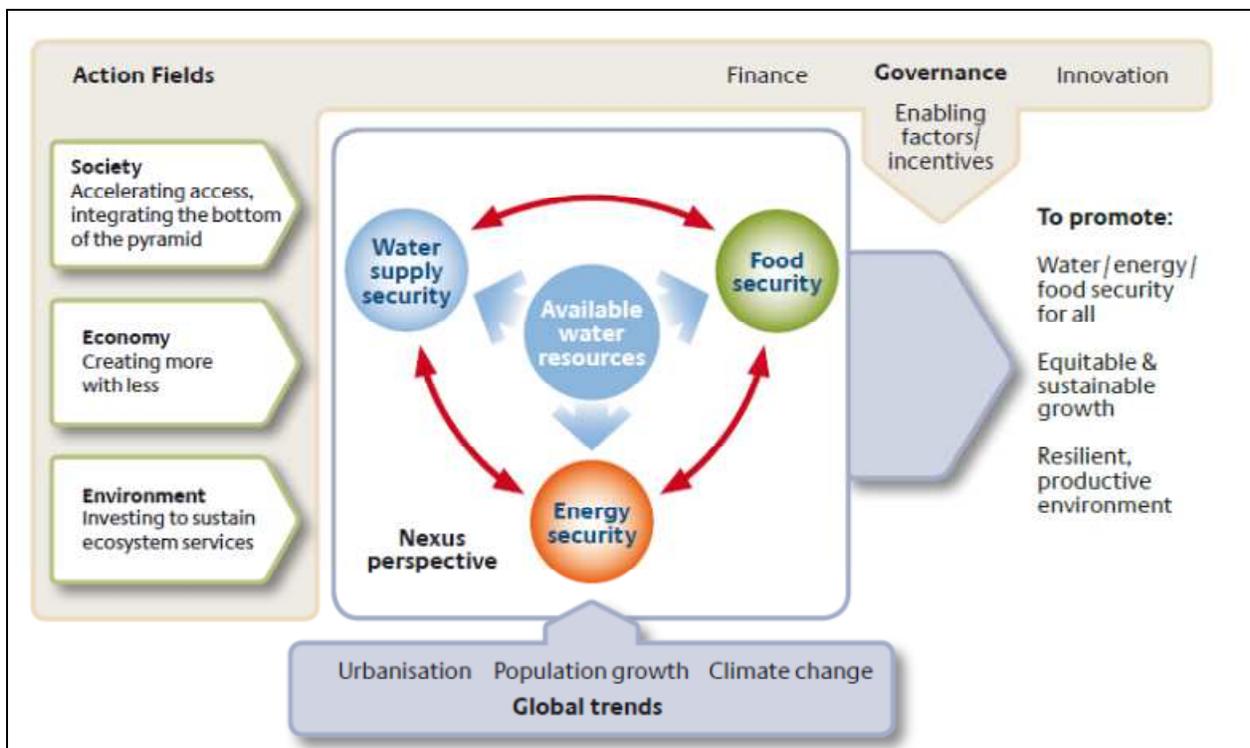


Source: WEF (2011).

## B. Bonn 2011 Nexus Conference

The framework presented at the Bonn 2011 Nexus Conference aimed to develop “a new nexus-oriented approach which is needed to address unsustainable patterns of growth and impending resource constraints and, in doing so, promote security of access to basic services.” The framework is centered around water availability and on the interdependencies needed to achieve water supply security, energy security and food security. The framework accounts for global trends including urbanization, population growth and climate change (Figure 4). Opportunities to improve water, energy and food security included increasing resource productivity; using waste as a resource in multi-use systems; stimulating development through economic incentives; governance, institutions and policy coherence; benefiting from productive ecosystems; integrated poverty alleviation and green growth; and capacity building and raising awareness. The framework highlighted the importance of implementing policies which would generate sufficient additional benefits to outweigh transaction costs associated with stronger integration across sectors.

**Figure 4: Water-Energy-Food Nexus Framework presented at the Bonn 2011 Nexus Conference**



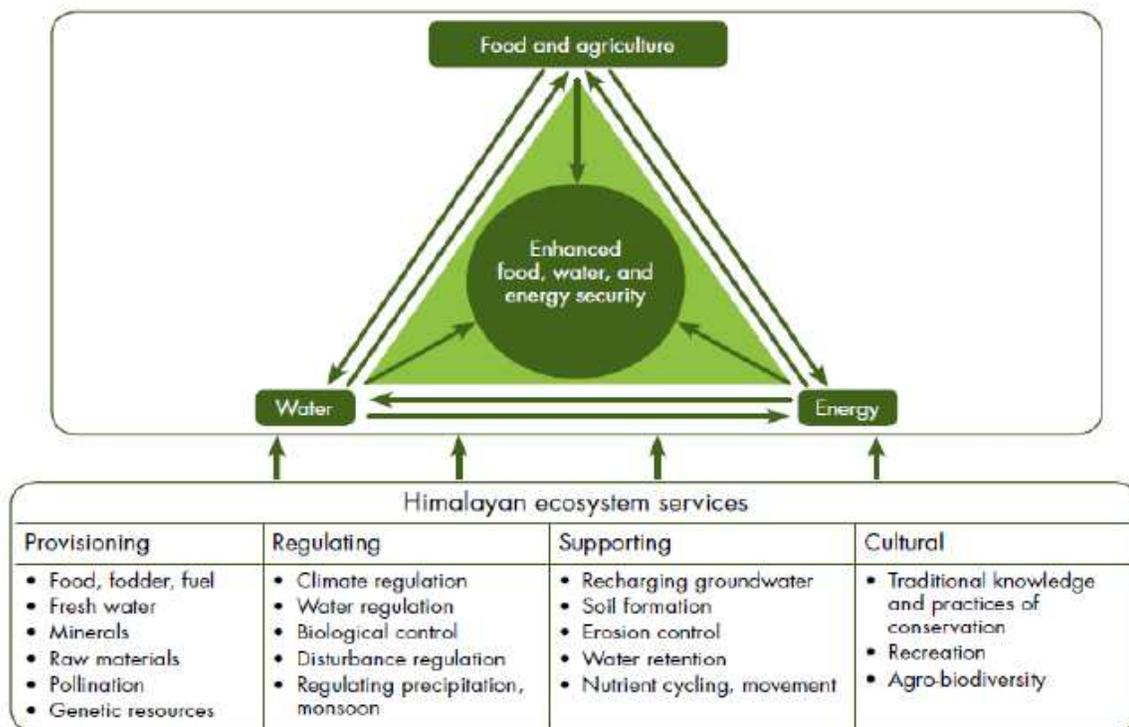
Source: Hoff (2011).

## C. ICIMOD (2012)

A third conceptual framework has been developed by the International Centre for Integrated Mountain Development (ICIMOD), and has been applied to the Himalayas and

South Asia (ICIMOD, 2012; Rasul, 2014). The approach centers on ecosystems goods and services, which, according to the authors, must be protected and enhanced to ensure their resilience and their support to the water, energy, and food sectors (Figure 5). Policy recommendations include the restoration of natural water storage capacities, the development of a climate-smart and socially sound infrastructure, and the introduction of incentive mechanisms for managing ecosystems.

**Figure 5: Water-Energy-Food Framework developed by ICIMOD**



Source: ICIMOD (2012).

#### D. UNECE (2013)

A closely related approach was adopted by the United Nations Economic Commission for Europe (UNECE) in 2013, and links water, energy and food to ecosystems. On this basis, the Parties to the *UNECE Water Convention*<sup>2</sup> decided to conduct an assessment of the water-food-energy-ecosystems nexus in 2015 on a set of transboundary basins in the pan-European region and beyond.<sup>3</sup> The framework recognizes that the functioning of ecosystems should not be compromised by development objectives. Shortcomings in inter-sectoral coordination are further presented as a major challenge on

<sup>2</sup> The *Convention on the Protection and Use of Transboundary Watercourses and International Lakes* was adopted by UNECE member States in Helsinki in 1992 and entered into force in 1996. The Convention “aims to protect and ensure the quantity, quality and sustainable use of transboundary water resources by facilitating cooperation.” See <http://www.unece.org/env/water/text/text.html>.

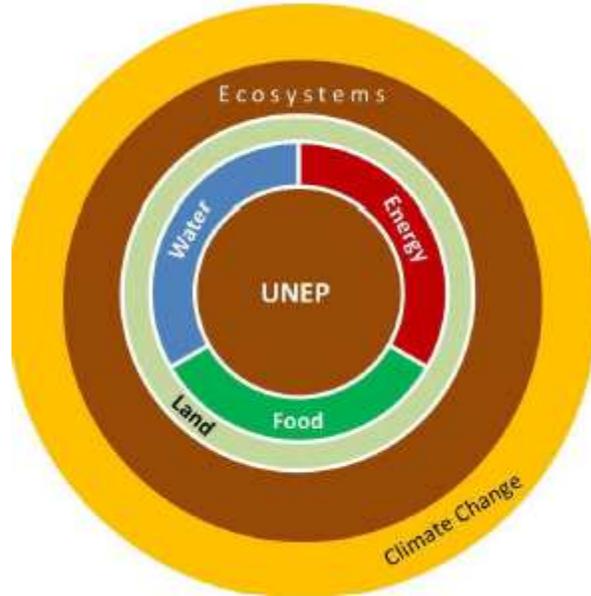
<sup>3</sup> A pilot assessment was undertaken in the Alazani/Ganikh River basin, and other transboundary river basins nexus assessments are expected to be conducted in 2014-2015 including the Sava, Isonzo/Soca, Narva, Syr Darya, Niger, Mekong and the North-West Sahara Aquifer. See <http://www.unece.org/env/water/nexus>.

the national and transboundary levels, where the trade-offs and externalities may cause frictions between riparian countries and different interests.

#### E. UNEP (2014)

The United Nations Environmental Program (Bolee *et al.*, 2014; Hoa, 2014) conceptual framework considers ecosystems both "inside" and "surrounding" the nexus (Figure 6). The framework recognizes the interlinked securities and sustainabilities of water, energy and food systems, and incorporates the land dimension and climate change external influence. The approach considers the opportunities for basin organizations to implement a nexus approach to water governance, playing a key role with regard to ensuring energy and food security, particularly in terms of hydropower and balancing biofuel production with food crop production.

**Figure 6: Ecosystem Approach to the Nexus by UNEP**



Source: Boelee *et al.* (2014).

#### F. IISD (2013, 2014)

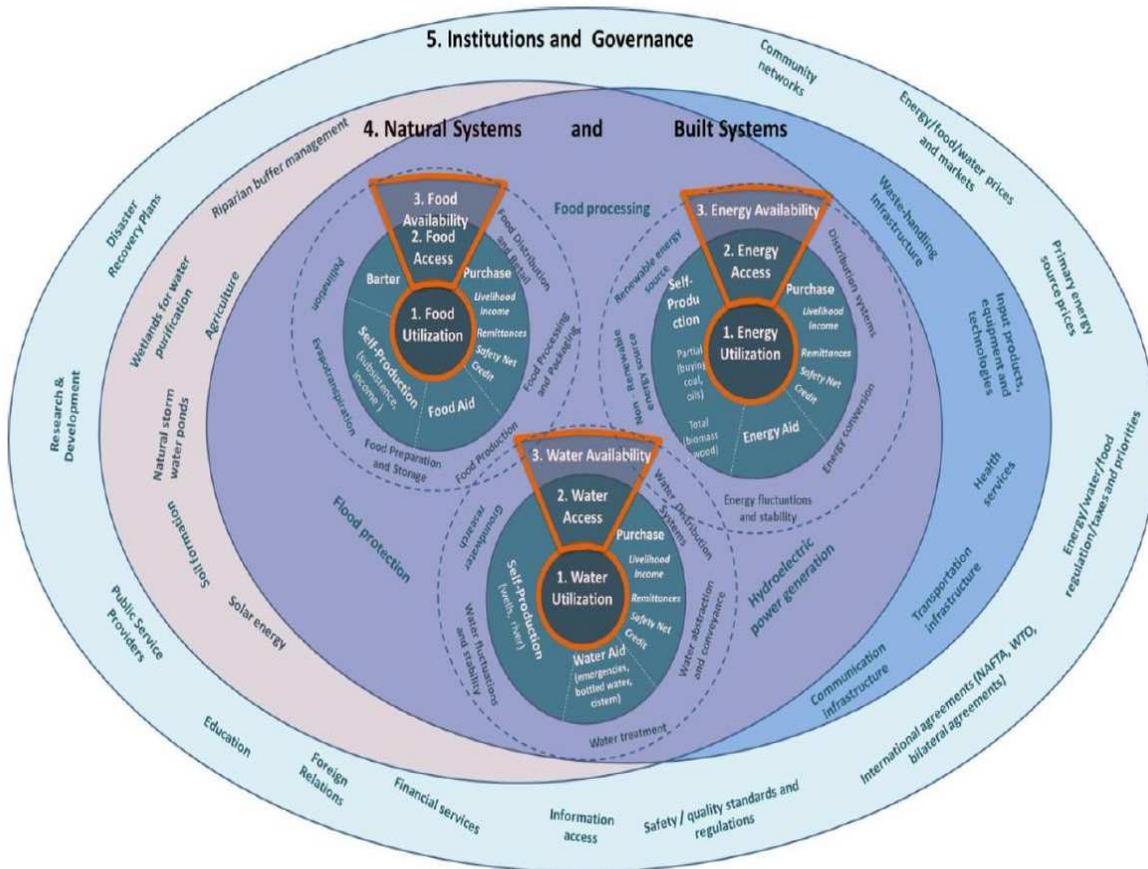
Similarly, the approach taken by the International Institute for Sustainable Development (IISD) (Bizikova *et al.*, 2013, 2014), centers on ecosystem management, and makes the case for an integrated approach to policy design, land and agricultural investments, and adaptive management of opportunities and risks (Figure 7).

This watershed-scale ecosystem-based approach recognizes that restoring and managing ecosystem goods and services provides a practical means to optimizing the water-energy-food security. Bizikova *et al.* (2013) develop on the need for an integrated approach linking not only the three securities, but also their underlying capitals. The

framework is built around three independent security clusters, each one around the utilization of each resource. A second layer describes how watershed communities access their water, energy and food. Access to water, food and energy are then determined by their availability (e.g. water flow, agricultural production, food processing, energy production, and energy supply). Two overall contextual systems then influence availability and access: natural and built systems; and human and institutional systems. The framework sees ecosystem goods and services as specific elements of natural systems, while built systems include aspects such as irrigation pipes, food production or storage facilities. Human systems are institutions such as markets, communication networks, and governance and management.

This analytical framework is then embedded within a place-based, four-stage,<sup>4</sup> practical participatory planning process that allows communities to identify key ecosystem services that would optimize their water–energy–food security system.

**Figure 7: WEF Nexus Framework by IISD**



Source: Bizikova et al. (2013).

<sup>4</sup> The four stages are: assessing the Water-Energy-Food security system; envisioning future landscape scenarios; investing in a Water-Energy-Food secure future; and transforming the system.

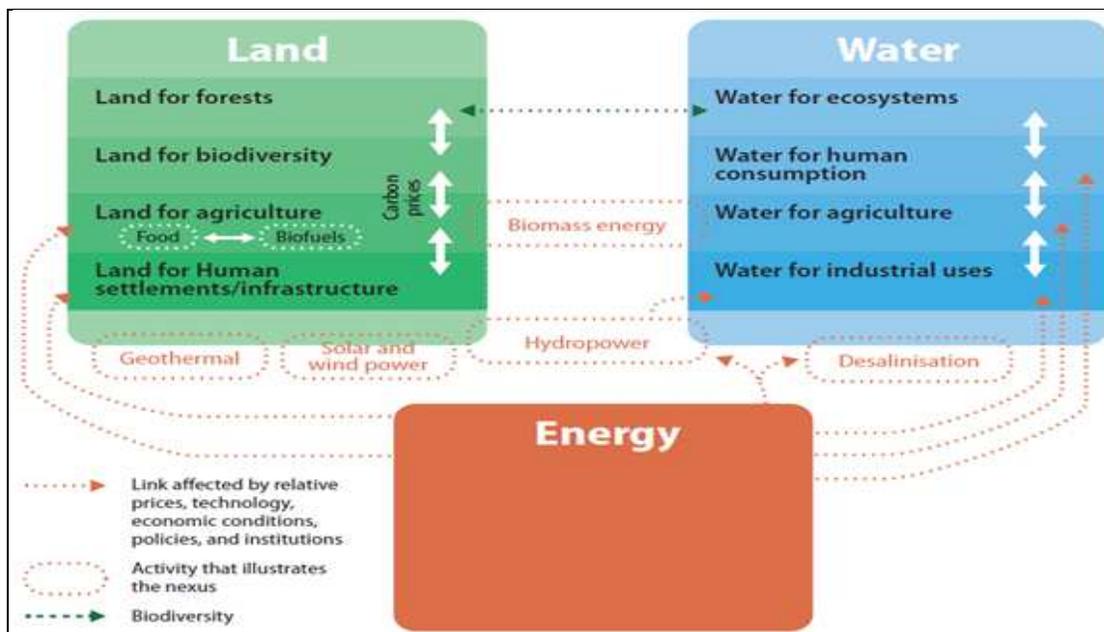
## G. ODI-ECDPM-DIE (2012)

The European Development Report (2012), entitled “Confronting Scarcity: Managing Water, Energy and Land for Inclusive and Sustainable Growth”,<sup>5</sup> emphasizes that the context in which natural resources need to be managed is changing rapidly, posing severe risks for inclusive growth and sustainability. As the world is moving towards absolute scarcities of certain resources and sink capacities, this new context presents both challenges and opportunities to identify integrated solutions.

The report calls for a radical rethink of the world’s approach to natural resources, and a transformative action in addressing the demand, supply, efficiency and resilience of natural resources management in meeting current and future consumption needs. Furthermore, a full range of integrated solutions for an appropriate management of pressures on water, energy and land needs to be considered.

The proposed framework broadens the nexus’ perspective by explicitly considering competing land uses, for agriculture, forest cover, human settlements and infrastructure, and biodiversity; and competing water sectoral demands (Figure 8). Three players are involved in the success of this transformation: the public sector, through the setting and coordination of policies and regulations; the private sector, through more inclusive and sustainable business models; and regional and global players, through policy, trade, global governance, and development assistance.

**Figure 8: The European Development Report (ODI-ECDPM-DIE) Framework**



Source: ERD (2012).

<sup>5</sup> The report was prepared by the Overseas Development Institute (ODI), the European Centre for Development Policy Management (ECDPM), and the German Development Institute (DIE).

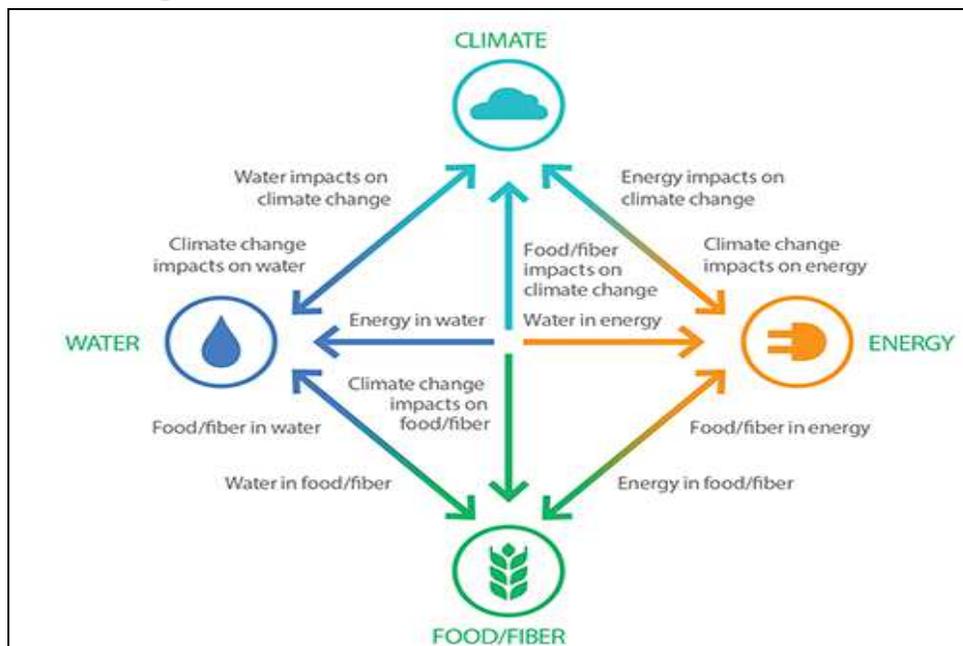
Hence, coordinated action is warranted in five main areas to confront scarcity: a concerted effort to reduce the environmental footprint of consumption globally; innovation in agriculture and renewable energy to meet the world’s increasing demand; a reform of national and global governance instruments and institutions towards a more integrated resource management; inclusive land policies to protect the rights of the poor and most vulnerable; and the appropriate pricing of natural resources and services, safeguarding the welfare of the poorest population groups, as the latter are disproportionately affected by all three nexus elements which are basic to their livelihoods.

#### H. WBCSD (2013)

The private sector is also increasingly recognizing the importance of adopting nexus thinking in order to better manage resource constraints and enhance efficiency. The World Business Council for Sustainable Development (WBCSD) developed a conceptual framework that aims at providing co-optimized solutions for water, energy and food that also incorporates the inputs needed for those sectors along the value chain, namely feed and fertilizers (Figure 9).

Analytical work is being carried out by the WBCSD to develop innovative policy and technology solutions to the world’s interconnected water, energy, food, feed, and fiber challenges, and introduces the additional stresses posed by climate change (WBCSD, 2013). Solution areas cover a range of opportunities including: bridging the knowledge gap; smart varieties; clever crop agronomy; mixed farming systems; better blue and green water productivity; efficient fertilizer production and farm operation and mechanization; and waste reduction.

**Figure 9: The WBCSD Resource Nexus Framework**



Source: WBCSD (2013).

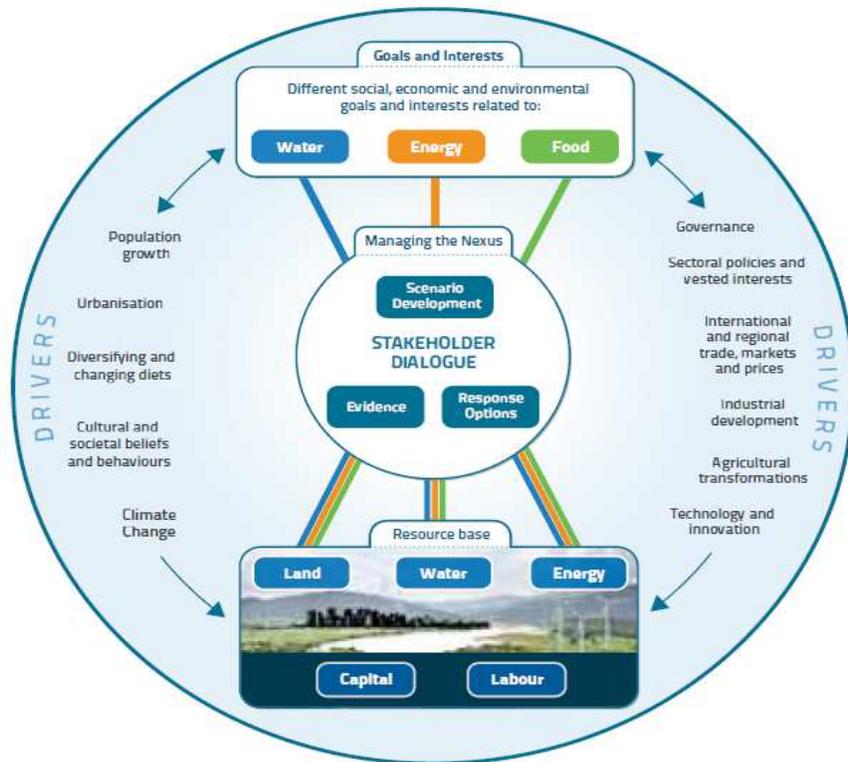
## I. The Transatlantic Academy (2012)

For the Transatlantic Academy (Andrews-Speed *et al.*, 2012), the natural resource nexus encompasses five resources, land, energy, food, water and minerals, which are likely to experience severe market disruptions and lead to violent conflicts. The interconnectedness of production and consumption of these natural resources, upon which the global economy depends, is key to international trade and presents threats associated with global supply chain interruptions, increased market volatility, increased poverty, and declines in human security. The report identifies several opportunities including gains in resource efficiency, the conversion of resource endowments into more sustainable development, greener growth, institutional building, and engaged cooperation to address security conflicts.

## J. FAO (2014)

The FAO frames the water-energy-food nexus within the broader debate on sustainable development and as part its vision of sustainable food and agriculture to achieve its mandate of eradicating hunger, reducing poverty, and sustainably managing and using natural resources and ecosystems (FAO, 2014a). It presents a framework which adopts a holistic vision of sustainability, and explicitly addresses complex interactions and feedback between human and natural systems (Figure 10).

**Figure 10: The FAO Approach to the Water-Energy-Food Nexus**



Source: FAO (2014a).

The resource base covers natural and socio-economic resources; and nexus interactions describe interdependencies, constraints and synergies (Weitz *et al.*, 2014; FAO, 2014), in the context of global drivers, which include population growth, urbanization, climate change, cultural and social beliefs and behaviors as well as governance. It also introduces the importance of technology and innovation as drivers that affect the resource base. The framework further presents three working areas: evidence, scenario development, and response options.

This conceptual framework has guided the development of a WEF assessment methodology based on a set of indicator matrices and tools used to conduct: 1) a qualitative and quantitative assessment of the context nexus status in order to understand societal priorities; identify competing local environmental, economic and social goals; and determine the sustainability of the reference system (territorial context) and its bio-economic pressures; 2) a quantitative assessment of the effects specific policies or project-level interventions on the natural environment and the society (FAO, 2014b).

The Multi-Scale Integrated Analysis of Societal and Ecosystem Metabolism (MuSIASEM), an innovative approach to natural resource accounting which simultaneously uses technical, economic, social, demographic, climate and ecological variables in the analysis of the metabolic pattern of modern societies, was also explored by FAO (Giampietro *et al.*, 2014; FAO, 2013). Applied to the water, energy, food nexus, MuSIASEM allows the integration of population dynamics, greenhouse gas (GHG) emissions and land-use changes to an integrated resources assessment at national or local levels.

#### K. BMZ (2013)

Efficient cross-sectoral resource management is further essential for sustainable urban development, in the context the projected increases in metropolisation trends. The interconnectedness of peri-urban and rural spaces and the associated increased competition over land use and resources call for the development of nexus solutions which curb the loss of biodiversity induced by unrestricted land development, the overexploitation of resources, and the ecological footprint of urban areas, while protecting and enhancing natural capital in the urban-rural continuum. Some practical solutions recommended by the German Development Cooperation (BMZ, 2013) in the context of “Urban Nexus” projects in several Asian and Latin American cities include the development of sustainable relationships between urban agri-food consumer markets and the surrounding rural areas; the management of urban and social mobility which takes into account conflicts over land use; and the reduction of waste and resource loss along supply chains with a view of generating economic and environmental gains and reducing consumption across sectors.<sup>6</sup>

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<sup>6</sup> Other proposed solutions include: the optimization of water and energy use in food production in the urban hinterland with a view of increasing resource productivity; the improvement of microclimates through management of green spaces in cities; and the targeted protection of areas of environmental value.

## L. Linking the Nexus to Climate Change

In view of the two-way relationship between climate change mitigation and adaptation policies and the WEF systems, informing decision-making requires conducting new research<sup>7</sup> to understand and simulate the interactions, feedbacks and tradeoffs between climate and each individual sector, as well as characterizing the complex systems dynamics among the three sectors, with due attention to scale-dependent interactions (Skaggs *et al.*, 2013).

One recent approach, a result of the collaboration between several international organizations and research centers,<sup>8</sup> points to the tight, quantifiable, relationships between Climate, Land, Energy and Water (CLEW), with land identified as the basic resource and underlying constraint for examining food.<sup>9</sup> This approach can give rise to the development of integrated holistic resource assessments. The framework focuses on energy, then conceptualizes Energy-Water-Food nexus interrelations through a quantitative framework that integrates water planning, energy planning and agro-ecological zoning models. The two-way relationship between Land-Energy- Water and Climate is further highlighted, where the importance of efficient resource management for both for mitigation and for adaptation purposes, as well as feedback loops and interdependencies between the different resources systems, against the backdrop of climate change, are adding an additional layer of complexity to the analysis (Basilian *et al.*, 2011). The authors contend that the integrated modeling of Climate, Land, Energy and Water strategies (CLEWs) could help policy makers to better manage energy, water and food needs. Such an approach would help decision makers assess the likely impacts of policy options on the broader CLEW system, by highlighting and quantifying the trade-offs and synergies associated with competing resource management and supply strategies. A CLEW approach is also instrumental for more inclusive assessments of developmental technological options, allowing a consistent elaboration of socio-economic-technological scenarios.<sup>10</sup>

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<sup>7</sup> This includes the development of new modeling capabilities which review is beyond the scope of this paper. Some recent initiatives include: a nexus tool developed by the Qatar Environment and Energy Research Institute (QEERI) that provides a platform for resource demands prediction and scenarios development based on choices of parameters related to food self-sufficiencies for locally consumed food products, water and energy mixes, and financial considerations as well as other dimensions (Mohtar and Daher, 2013); the OECD CIRCLE project, “The Costs of Inaction and Resource Scarcity: Consequences for Long-term Growth” (see [www.oecd.org/environment/circle.htm](http://www.oecd.org/environment/circle.htm)) that addresses relevant linkages between land, water and energy simultaneously and considers the biophysical impacts of socio-economic developments on land, water and energy, and their combined feedback on the economy; and a recent scenario-based conceptual framework developed by IRENA (2015) that proposes a tool to conduct preliminary assessments of basic nexus impacts of energy policy, with energy balances as the main inputs, and the basic resource requirements (water volumes and land use) as the main outputs.

<sup>8</sup> FAO, IAEA, IIASA, IRENA, KTH, SEI, UNDESA, UNIDO and WBCSD participated to this research work.

<sup>9</sup> The approach was applied with a view to improve energy security in a vulnerable small island developing state, Mauritius.

<sup>10</sup> Recent applications also used the CLEW approach in conjunction with models of city metabolism to explore sustainable services provision through the mapping of interactions between resource-to-service systems and the identification of critical urban nexus points (Segerstrom, 2014).

## **VI. Regional Priorities and Projects for Examining the Water, Energy and Food Nexus**

The Arab countries face mounting challenges across the water, energy, food nexus due to healthy population dynamics, high economic growth and changing life-styles and diets, as well as increases in urbanization and other developmental pressures and societal transformations in the context of increasing environmental pressures with diminishing water availability, soil and land degradation, drought and flash floods, desertification, pollution, global warming and climate change and variability. These elements are amplified by the adverse impacts of conflicts and more or less smooth political transitional processes, on the governance and sustainable delivery of water, energy and food services.

Arab Governments are cognizant of the need to develop new, comprehensive and systematic methodologies to approach the water, energy and food nexus in order to insure sustainable development in the region. In addition, while supply bottlenecks due to co-constraints implied by water, energy and food (land) relative scarcities most notably play out at the national and local scales, governments are fully aware of the importance of regional cooperation across the nexus, in particular through flexible forms of inter-ministerial coordination, e.g. through high-level councils and inter-ministerial task forces.

For example, in June 2012, the United Nations Economic and Social Commission for Western Asia (ESCWA) hosted an intergovernmental consultative meeting on the water and energy nexus in the ESCWA region. The members of the ESCWA Committee on Energy and the ESCWA Committee on Water Resources participated in the meeting, or their delegated representatives. The meeting aimed to initiate reflection on issues related to the interrelation between the water and energy sectors and to identify regional priorities for further research of interest to ESCWA member countries. The goal of the meeting was also to examine the possible mechanisms and institutional arrangements to organize coordination and harmonization of water and energy sector policies.

The deliberations resulted in a number of recommendations and a set priority issues for the actions. Specifically, the following priorities were identified as areas for future work:

- (1) Raising awareness and disseminating knowledge
- (2) Improving harmonization of public policies
- (3) Examining the link between water security and energy security
- (4) Improving efficiency
- (5) Increasing knowledge of technological choices
- (6) Promoting renewable energy
- (7) Integrating climate change and natural disasters factors in decision making

Institutionally, the intergovernmental consultation also called for the establishment of a joint working group and the organization of cross-sector meetings. The ESCWA

Committee on Energy and ESCWA Committee on Water Resources also requested support with preparations for the post-2015 development agenda.

These recommendations and associated priority-setting process led to the launching of a capacity building project on “Developing the Capacity of ESCWA Member Countries to Address the Water and Energy Nexus for Achieving Sustainable Development Goals,” which is implemented by ESCWA. Under this United Nations Development Account project, seven regional policy toolkits for senior government officials are being prepared on the priority areas listed above, as well as three operational toolkits for technical staff of ministries responsible for energy and water-related resources and services on the following topics:

- (1) Resource efficiency: to improve efficiency during the production and consumption of water and energy resources and services;
- (2) Technology transfer: for water and energy considerations when pursuing the transfer of new technologies within the regional context; and
- (3) Renewable energy: for assessing costs and benefits related to application of renewable energy technologies in the region.

The project also includes the organization of regional workshops and the conduct of demand-driven pilot projects for applying nexus thinking through institutional or policy frameworks at the national level, which will contribute to a regional exchange of experiences on lessons learned.

A complementary regional project was also launched in 2014 on “Promoting Food and Water Security through Cooperation and Capacity Development in the Arab region,” which is led by ESCWA and implemented in consultation with the League of Arab States with funding provided by the Swedish International Development Cooperation Agency (Sida). The project formalizes the food and water security elements of ESCWA support to member States, and builds upon other initiatives that ESCWA is implementing and coordinating with regional partners on climate change, the promotion of a green economy, renewable energy, energy efficiency and integrated water resources management.

It is expected that these projects will contribute to work being initiated under the auspices of the League of States on the water, energy and food nexus by GIZ and ESCWA, which is being supported by the Arab Ministerial Water Council and Arab Ministerial Council on Electricity. Coordination is also underway to ensure complementarity between the aforementioned activities and a project launched by GIZ and the Arab Gulf University to prepare a series of five policy briefs on the water, energy and food nexus in 2015. The briefs are expected to focus on the political economy of the nexus, the institutional landscape, integrated planning and implementation mechanisms, the green economy and capacity development on the nexus in the Arab region. The briefs would then serve as the basis for fostering dialogue and exchange on the nexus at the regional level.

## VII. Developing a Regional Vision for the WEF Security Nexus: Key Questions for Discussion

Mainstreaming the economic, social and environmental dimensions of sustainable development into national strategies requires consideration of the natural resource nexus. A developmental path is necessary that achieves coherent and effective planning and management of water, energy and land systems, which balances consumption, production and climate change pressures with existing natural resource endowments and the ability to take advantage of appropriate technologies within the context of regional specificities. This requires developing shared regional and national assessments and perspectives on the relative socio-economic and environmental vulnerabilities within the framework of natural resource scarcity and abundance; and on the ways that these scarcities impact natural resource security and the attainment of sustainable development goals.

The availability and mixes of water, energy and land resources and services available at the national level varies across the region. Arab countries differ in their sources and quality of available water resources; natural and built infrastructure and technologies for water storage, distribution, treatment and usage; fossil fuel endowments and energy mix; land use and land cover; ecological characteristics; and observed and projected precipitation and temperature patterns. However, similar trends and tendencies are also present across these dimensions, which lend themselves to collective consideration and assessments of regional challenges and opportunities for moving towards sustainable development. This process can be enhanced by applying nexus conceptual frameworks for improving assessment, planning and policy formulation and implementation across sectors through a common vision based on a collective set of goals and priorities.

Some key questions for articulating a vision for improved understanding of the water, energy and food security nexus for achieving sustainable development in the Arab region are:

- How can the analysis and identification of the interlinkages and trade-offs between water, energy and food security priorities be considered within the context of natural resource scarcity in the region?
- How can improved understanding and assessment tools help in improving natural resource use efficiency within a framework that seeks to ensure water, energy and food security?
- What additional issues should be incorporated in the water, energy and food security nexus conceptual framework in the Arab region?
- To what extent can nexus thinking be integrated in national development planning?
- What are the implications of the incorporation of the water, energy and food nexus in regional and national policy-making in existing inter-governmental governance mechanisms, or governance structures that may be promoted at the basin scale or within the context of ecosystem management?

- How can governments promote an integrated development perspective across different levels of government and across borders?
- What are the most important research, modeling and knowledge gaps that can be bolstered by capacity building to generate plausible long-term assessments and simulations drawing upon nexus conceptual?
- How can policy-makers incentivize the private sector to invest in more innovative, resource-efficient water, energy, and food infrastructure and investments?
- How can the nexus between water, energy and food inform the post-2015 development agenda and the formulation of the sustainable development goals, including their respective targets and indicators?
- How can the nexus inform infrastructure investment decisions in the context of the financing the sustainable development agenda?

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