Water, Food and Energy Nexus in Asia and the Pacific

Discussion Paper

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The Status of the Water-Food-Energy Nexus in Asia and the Pacific

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For further information on this publication, please contact: Mr Raekwon Chung
Director
Environment and Development Division
ESCAP
Rajadamnern Nok Avenue
Bangkok 10200, Thailand

Tell No: +66-2288 1234
Fax no: +66-2288 1048/1059

email: escap-esdd-ers@un.org

"This publication was prepared under the guidance of Hongpeng Liu, the Chief and Salmah Zakaria, Economic Affairs Officer, of Energy Security and Water Resources Section (ESWRS), Environment and Development Division (EDD) of ESCAP"

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ADB	Asian Development Bank
EU	European Union
FAO	Food and Agriculture Organisation

FELDA	Federal Land Development Authority
IWRM	Integrated Water Resource Management
ICWC	Interstate Commission for Water Coordination (ICWC) of Central Asia
IEA	International Energy Agency
IFAS	International Fund for Saving the Aral Sea (IFAS)
IPCC	Inter-Governmental Panel on Climate Change
MRC	Mekong River Commission
MENA	Middle East and North Africa
UNESCAP	United Nations Economic and Social Commission for Asia and the Pacific
WFE	Water, food, and energy

Discussion Paper

WATER-FOOD-EN

ERGY NEXUS IN ASIA AND THE PACIFIC

A position paper comissioned by the United Nations Economic and Social Commission for Asia and the Pacific

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Economic and Social Commission for Asia and the Pacific

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Foreword

As the regional arm of the United Nations, ESCAP continues looking for better policy options and initiatives in the area of resources management. ESCAP, in its "Low Carbon Green Growth Roadmap for Asia Pacific" publication has articulated on "Turning resource constraints and the climate crisis into economic growth opportunities. ESCAP's works on water and green growth identify the needs for preemptive development planning in managing climate change impacts, such as in improved governance.

This water-food-energy nexus looks at the debate on 'resource scarcity", with new scientific findings that suggested humanity has exceeded the planetary boundaries, threatening its own safety. Of all natural resources, energy, water and food are most needed to sustain life on earth. The three resources are tightly interconnected, forming a policy nexus. The increase in resource use in the region has been above the world average. The reliant on fossil fuel sources for their economic growth has resulted in the countries of Asia and the Pacific, accounting for almost half the world's CO_2 emissions in 2008. The security of water, energy and food resources has been compromised in parallel with decades of economic development in Asia and the Pacific and hence the needs to study these three resources together in a nexus approach.

It is with great pleasure that ESCAP published this latest discussion paper, targeted for discussions at the 2APWS, in Chiang Mai, May 201 3, to provide background materials for the discussions at both the Technical workshops and the Focus Area Sessions

Rae Kwon Chung
Director, Environment Development Division
ESCAP

Discussion Paper

Water-Food-Energy Nexus in Asia and the Pacific Region

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Executive Summary

The debate on natural resource scarcity was rece ntly reignited. New scientific findings suggest that humanity has exceeded the planetary boundaries, threatening its own safe operation. Five attributes characterize the new realism of physical and economic scarcity of key resources: lack of undeveloped resource preserves, challenges of exploiting new resources, emergence of new consumers, volatility of resource prices and broadening of actors in governing resources. Of all the natural resources, water, food and energy are most needed to sustain life on earth. These three resources are tightly interconnected, forming a resource and policy nexus. Their insecurity is an impediment to social stability and economic growth.

This report traces the debate, analysis and action on the water, food and energy (WFE) security nexus. Considering the complex interactions of these three resources will require new institutional capacity in both industrialized and developing countries. For the nexus approach to achieve the twin goals of human well-being and green growth, sustainability must move center-stage, with attention given to ecosystem services.

The increase in resource use in Asia and the Pacific region between 1970 and 2005 was above the world average. This economic growth resulted in the region's reliance on fossil fuel sources. Countries in Asia and the Pacific region accounted for almost half the world's CO_2 emissions in 2008. The security of water, food and energy resources in the region has been compromised in parallel with decades of economic development. The fastest increase in water demand in Asia is now coming from the industry and urban households, not agriculture. For decades, economic growth in Asia has required ever-expanding amounts of energy. On food security, over 20 per cent of the undernourished populations live in South and South-West Asia, with the most acute problems in Afghanistan.

Currently, there is only rudimentary understanding of the complex and pervasive connections between water, food and energy security in the region. This position paper reviews the region's experiences with the interlocking effects of the WFE nexus, which results in challenges that cross two or even all three of the domains. Examples include biofuel; hydropower; thermoelectric production and water security; irrigation and food security; irrigation and energy security; food trade and virtual water, land and food security; and the intertwining effect of water production and energy security.

The meaning of the nexus is further explored by using two case studies, namely Central Asia and the Mekong Basin. Not surprisingly, in existing policy frameworks, energy and water policies are developed largely in isolation from one another.

The concluding section outlines five key areas of policy interventions needed to mainstream the nexus concept in Asia and the Pacific region.

Background

1.1 The debate on resource scarcity

Scholars have been debating the central role of natural resources for economic development and human survival for more than two centuries. The general argument goes that as the extraction rates of resources increase, the horizon of scarcity shortens (see Norgaard, 1990). In the last decades, the concern over resource depletion not only continued but also seemed more polarized than ever. Scientists contend that the earth cannot for long continue to support current and projected levels of demand for exhaustible resources. For them, resource scarcity may compromise the welfare of future generations and pose a threat to sustainable development. In the book, The Limits to Growth, the authors developed a scenario analysis of 12 possible futures from 1972 to 2100. The analysis concluded that continued growth in the global economy would lead to significant resource scarcities in the first decades of the twenty-first century (Meadows et al., 1974). Committed conservationists then demanded a lowering of the environmental impact per unit of gross domestic product.

In the 1980s, real energy and mineral prices fell, p roducing little evidence of looming shortages (Tilton, 1996). This corroborated the position of those parties indifferent about resource depletion, who deemed that natural resources can amply provide for mankind's needs with the help of new technology and appropriate public policies. These 'technological optimists' argue that there are no limits to growth in ingenuity. The future, they believed, will be better than the present and the past. As a result, quantitative growth continued apace after the 'lost decade' of the 1 980s. The 'roaring' 1 990s saw a further i ncrease in global integration in goods, services and investment flows. The material ramping up of the world economy brought not only prosperity but also unprecedented environmental change.

Of late, the debate on natural resource scarcity has been reignited. A study by the McKinsey Global Institute showed that real commodity prices increased by 147 per cent since the turn of the century (Dobbs et al., 2011). Fresh scientific findings suggest that humanity is now approaching limits in global resource availability and the strength of the Earth as a sink for wastes. Many indicators point to the unprecedented planetary changes such as biodiversity loss, climate change and nitrogen removal from the atmosphere (Rockstrom et al., 2009). Today, an estimated 60 per cent of the world's ecosystem services have been degraded since the mid-twentieth century (Millennium Ecosystem Assessment, 2005).

Resource problem was mainly a local (or national) issue, but in recent years, problems crossing boundary had scaled up. The focus of concern shifted slightly, from resource exhaustion per se to the environmental damage and geopolitical security implications associated with the current global resource scramble. This report argues that the idea of scarcity is currently being revisited both in the policy and academic domains. Specifically, the report considers the strategic resources of water, food and energy (WFE) to be inextricably linked. The Asia-Pacific region is considered as a critical area where the WFE inter-linkages are very prominent.

1.2 New resource realism

Five attributes characterize the recent perception of resource scarcity. The first attribute is the lack of undeveloped resource zones and preserves, which is driving the pursuit of vital materials in the Arctic, the deep seas and other resource frontiers. "The race for what is left," according to security expert Michael Klare, "presents a new stage in humanity's persistent hunt for critical materials" (Klare, 2012, p. 15). This realization has also encouraged countries to "dematerialize" their economic development by reducing and circulating resource usage. Examples include China's Circular Economy and Japan's Low Material Society policies.

The second attribute has to do with technical, social and environmental challenges on the expl oitation of new resources in remote and marginal areas. One example is the recent trend of "land grabbing," which is intensifying clashes between foreign investors and the communities who occupy these areas (Pearce, 2012). The move by the European Commission to identify 14 economically important raw materials that are defined as critical due their importance in technology development and that are subject to a higher risk of supply disruption presents anot her case. In addition, planetary global warming is set to am pl ify the existi ng envi ron mental challenges. The Working Group on the Economics of Climate Adaptation projects that some regions are at risk of losing 1 to 12 per cent of gross domestic product annually as a result of existing climate patterns.

The unprecedented demand for more and new natural resources makes the third attribute. The sudden emergence of insatiable new consumers as a result of surging economic growth in China, India and other Asian economic powerhouses enhances this demand. Up to 3 billion middle-class consumers are expected to emerge in the next 20 years, compared with 1.8 billion today (Dobbs et al., 2011).[1] The market distortion of resource pricing for populist reasons is deepening the scarcity crisis. According to the McKinsey Global Institute, up to USD 1.1 trillion is spent annually on resource subsidies.

As opposed to being confronted only with the physical scarcity of single natural resources, the world is now grappling with multiple resource scarcities. The dwindling natural resource stocks began to send shocks to the global economic system as reflected in the market. From

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1 This report is published by the McKinsey Global Institute.

2007 to 2008, food prices rose sharply. Since then, their persistence and high volatility have resulted in far-reaching implications. The World Bank (2011) stated that in the second half of 2010, rising food prices drove 44 million people into poverty. The main causes included greater demand for biofuels and trade decisions by exporting countries. The food crisis also sparked riots in over 30 countries and arguably precipitated the fall of governments in the Middle East (Bush 2010). In July 2008, oil prices reached USD 147 per barrel. The oil price hike has destabilized economies and threatened basic securities of the people. Its rise in 2008 and 2009 convinced some that the peak in oil production was already looming. Such inter-connectedness of price volatilities underlines the fourth attribute, with WFE resources gaining more traction in policy discourses.

The fifth attribute has to do with the broadening of actors in governing resources beyond governments. In addition to international institutions and regimes is the role of commercial interests in governance. One example of private sector influence in public policy is seen in the CEO Water Mandate[2], whereby leading corporations asked governments to assert more control on water resources. Similarly, in the food sector, the Sustainable Agriculture Initiative, which includes big businesses such as Danone, Nestle, Unilever, Kellogg's Kraft, McDonalds and Pepsi Cola, has been engaging other stakeholders involved in influencing food policies (Lang and Barling, 201 2). However, the presence of state governments prevails. Recent years have seen the rise of resource nationalism as a strategic response to the perceived resource exhaustion (e.g., state-owned petroleum companies).

1.3 Rationale to integrate water, food and energy

The idea of "limits" as brought about in the 1970s and 1980s did not simply fade into obscurity despite its limited adoption in public policy. Rather, it is becoming more complex. For development activities to be sustainable, the following limits must be taken into account (United Nations, 2011, p. 54):

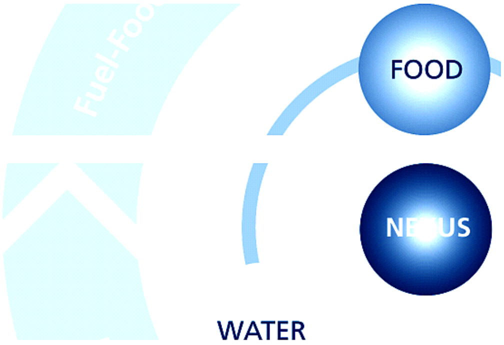
- **Biophysical limits – What is possible within planetary limits and according to the laws of nature?**
- **Economic limits – What is affordable?**
- **Scientific-technical limits – What is doable technically?**
- **Socio-political limits – What is socially and politically acceptable?**

Of all natural resources, water, food and energy are most needed to sustain life on earth (Figure 1). These three resources share many comparable characteristics: there are billions of people without access to them; they have a rapidly growing global demand; all face resource

2 The CEO Water Mandate is a unique public-private initiative designed to assist companies in the development, implementation and disclosure of water sustainability policies and practices. The UN Secretary-General launched the Mandate in July 2007.

constraints; all three are "global goods" involving international trade with global implications; each has different regional availabilities and variations in supply and demand; and all operate in heavily regulated markets (Bazillian et al., 201 1). Moreover, global water cycles, carbon energy cycle, food production and climate change are inseparably linked. Because of these reasons, they present deep security issues as they are fundamental to the functioning of society.

Figure 1. The water-food-energy nexus and its drivers.



ENERGY

Water, food and energy resources are tightly interconnected, forming a policy nexus (Vogt et al., 2010). Food production is the largest user of water globally. It is responsible for 80–90 per cent of consumptive water use from surface water and groundwater. Water, however, is also used to generate electricity, and about 8 per cent of global water withdrawal is used for this purpose. Energy, in turn, is needed to transport and fertilize crops. Food production and supply chains are responsible for around 30 per cent of total global energy demand. Crops can themselves be used to produce biofuels (Hoff, 2011).

In 2050, with a forecast 9.2 billion people sharing the planet, it is expected that there will be a 70 per cent increase in demand for food and a 40 per cent rise in demand for energy (Hoff, 2011). Further, by 2030, the world will have to confront a water supply shortage of about 40 per cent. The current "business-as-usual" economy, therefore, cannot run on the same finite WFE resources far into the future.

Water, food, and energy insecurities are impediments to social stability and economic growth. The World Economic Forum (2011) outlines a set of direct and indirect impacts stemming from the nexus of water, food and energy security. Table 1 lists the impacts of risks related to the WFE nexus.

Table 1. Impacts of risks related to water-energy-food nexus.

	Direct impacts	Indirect impacts
Impact on governments	• Stagnation in economic development • Political unrest • Cost of emergency food relief • Significantly reduced agricultural yields • Threats to energy security	• Increased social costs linked to employment and income loss as agriculture is negatively effected • National security risks/conflict over natural resources
Impact on society/populations	• Increased levels of hunger and poverty • Increased environmental degradation • Severe food and water shortages • Social unrest • Food price spikes	• Migration pressures • Irreparably damaged water sources • Loss of livelihoods
Impact on business	• Export constraints • Increased resource prices • Commodity price volatility as shortages ripple through global markets • Energy and water restrictions	• Lost investment opportunities

Source: World Economic Forum (2011).

1.4 Benefits of the nexus approach

The nexus perspective focuses on the interdependence of water, food and energy by understanding the challenges and finding opportunities. The nexus approach recognizes the inter-connectedness of WFE across space and time. Its objectives are to:

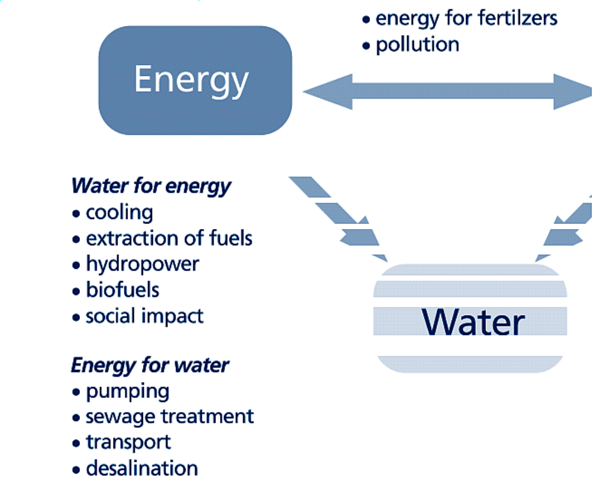
- **improve energy, water and food security;**
- **address externality across sectors and decision-making at the nexus; and** ▪ **support transition to sustainability.**

In *The Global Resource Nexus* report by the Transatlantic Academy, the nexus approach allows a systemic consideration of potential impacts from resource utilization (Andrews-Speed et al., 2012, p. 2):

"The range of potential risks and uncertainties relating to a single resource is magnified when the links between different resources are taken into account."

In practice, the nexus consideration is often pursued with "two at one time" analysis. For instance, energy-water nexus is analyzed through a two-way interaction in the use of water for energy production and the use of energy for water production (see Figure 2). The same principles apply when studying the interactions of water-food nexus and food-energy nexus (Bazillian et al., 2011). Another layer of complexity is introduced with the further link of energy-water to food security. According to Hussey and Pittock (2012), this will demand "an even finer scale understanding of the relationships and interconnections between water,
energy, land, and the implications of climate change".

Figure 2. Schematic of the WFE nexus and its constituent issues.


• energy for fertilzers
• pollution
Energy
Water for energy
• cooling
• extraction of fuels
• hydropower
• biofuels
• social impact
Energy for water
• pumping
• sewage treatment
• transport
• desalination
Water


Food
Irrigation
• water productivity

- agricultural structure
- water tables
- overpumping

Political economy

- price volatility
- virtual water
- subsidy
- landgrab
- biofuels

Currently, despite the close relationship of energy and water, different people in separate agencies typically perform the funding, policymaking and oversight of these resources. This "silo" may lead to negative trade-offs impacting policy and technological choices. Hussey and Pittock (2012) outline the following negative or questionable trade-offs over integration of water and energy resources:

- proliferation of desalination plants and inter-basin transfers to deal with water scarcity (e.g., Pittock, 2011);
- extensive groundwater pumping for water supplies (e.g., Shah et al., 2003);
- decentralized water supply solutions such as rainwater tanks (e.g., Kenway et al., 2008); and
- choice of selected forms of modern irrigation techniques that are inefficient (e.g., Mukherji, 2007).

The development of first-generation biofuels represents another layer of complexity by imposing trade-offs on all food, water and energy resources concomitantly. Recognizing the WFE connection is necessary because these three resources are traditionally managed as separate issues across the spectrum of policy, planning, design and operation. Synergies and common solutions result when the hitherto isolated security problems are tackled together rather than through a "silo" or sector approach.

1.5 Report overview

Section 2 discusses the emergence of the WFE nexus in international policy and academic debates. This stems from the global concern with the security of strategic resources such as water, food and energy. Section 3 reviews the literature on the nexus, focusing on its assessments, institutional arrangements and the proposed policy options. Next, section 4 analyzes the looming resource challenge in Asia and the Pacific region. On the basis of the region's peculiarity, section 5 illustrates eight types of WEF inter-connectedness, with examples from within Asia and the Pacific. Section 6 delves deeper into the meaning of the nexus by using two case studies, namely Central Asia and Mekong Basin. Not surprisingly, in existing policy frameworks, energy and water policies are developed largely in isolation from one another. Before conclusions are provided, section 7 outlines five key areas of policy interventions needed to mainstream the nexus concept in Asia and the Pacific region.

Nexus at the forefront of policy and scientific debate

The concern over resource scarcity has encouraged many policy reforms in the past. In 1974, the United States of America reacted to the oil embargo in late 1973. The government of the United States of America established the National Commission on Supplies and Shortages as a public policy response to the perceived resource exhaustion challenge.

Similarly, the emerging fear of water, food and energy crisis has escalated the importance of the nexus perspective onto the international policy discourse. It now receives increasing political reference due to its strategic importance. A 2012 YouGov Poll, an online market research agency, placed ensuring continued supply to water, food and energy as second to terrorism as a foreign policy priority in Britain. The nexus of water, food and energy, indeed, is currently gaining attention from strategic circles in the policy and academic domain.

2.1 Policy conferences

Key international policy meetings giving an explicit attention to the nexus include the following:

- **the World Economic Forum, regularly held in**

Davos, annually;

- Bonn 2011 Conference: The Water, Energy and Food Security Nexus held in Bonn, Germany in 2011;
- World Water Forum's Ministerial Roundtable on Water, Energy and Food Security, held in Marseilles, France in 2012;
- World Water Week, in Stockholm, Sweden, 2012 (theme: water and food security);
- Mekong2Rio International Conference on Transboundary River Basin Management, held in Vientiane, Lao People's Democratic Republic in 2012;
- South African Water, Energy and Food Forum: "Managing the Mega-nexus", held in Sandton, South Africa in 2012;
- The Water Summit 2013: Bringing WEF Nexus to Life, held in Abu Dhabi, United Arab Emirates in 2013:
- Managing Water, Energy, & Food in an Uncertain World (Universities Council on Water Resources) held in Santa Fe, United States of

America in 2012;

- **Corporate Sustainability in Africa 2012: "Living in the Water, Food and Energy Nexus", held in Johannesburg, South Africa, in 2012; and**
- **Water, Energy, Environment and Food Nexus: Solutions and Adaptation under Changing Climate, held in Lahore, Pakistan in 2012.**

The meeting in Bonn in 2011 gave birth to an active and informative website covering the latest issues and events on the WFE nexus. The website is accessible at: http://www.water-energy-food.org. The goal of the Bonn meeting was to create:

"...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. It is an approach that better understands the inter-linkages between water, energy and food

sectors as well as the influence of trade, investment and climate policies."

The Bonn 2011 nexus approach emphasizes the guiding principles of investing to sustain ecosystem services, creating more with less, accelerating access and integrating the poorest.

The annual World Economic Forum brought the WFE security nexus to full political attention at the Davos Summit through the Global Risks 201 1 report. It described the interconnected security problem as follows (World Economic Forum, 201 1):

"A rapidly rising global population and growing prosperity are putting unsustainable pressures on resources. Demand for water, food and energy is expected to rise by 30-50% in the next two decades, while economic disparities incentivize short-term responses in production and consumption that undermine long-term sustainability. Shortages

could cause social and political instability, geopolitical conflict and irreparable environmental damage. Any strategy that focuses on one part of the water-food-energy nexus without considering its interconnections risks serious unintended consequences."

2.2 Academic conferences

One of the earliest scientific meetings on the nexus was the 9th Royal Colloquium, held in Bönham, Sweden, from 14 to 17 June 2009. His Majesty King Carl XVI Gustaf of Sweden hosted the meeting and 19 renowned international scholars participated, to explore issues relating to "Climate Action: Tuning in on Energy, Water and Food Security". The Bönham Declaration stated the following:

"Due to the complexity of the climate system and its interactions with all facets of nature and society, the step from analysis to action becomes critical.

To provide water, food and energy to a growing world population in an equitable manner is a monumental challenge. [...] To reach a sustainable balance between supply and demand of natural resources, efficiency of use is seen to be a key to progress. To meet the challenges of energy, food and water security, we need:

- to apply transdisciplinary scientific approaches;
- to find ways of speeding up technical innovation through increased research and development (R&D) in relevant areas and
- to rethink policy and to focus on actions that address not just climate change, but a wide spectra of fundamental human needs for development."

(Anonymous, 2010, p. 199)

In July 2012, 250 high-level participants gathered at Oxford University to attend RelSource: Food-Energy-Water for All, 2012. The conference brought together financiers, political l eaders, captains of industries and top academics to critically discuss how scarce resources such as water, food and energy can be better managed to ensu re that we can meet the needs of the 5 billion middle-class individuals by 2030. The luminaries included former US President William Clinton, Nobel Laureate Amartya Sen and investor Jeremy Grantham. A suite of key questions were posed at the conference, particularly in relation to markets and business operations.

Some of the questions are:

- **How will resource scarcity and volatility affect global businesses?**
- **How does the military look at future resource-related scenarios?**
- **What new growth and disruptive innovations are around the corner?**
- **How can markets be shaped by regulators to encourage long-term investment?**
- **The economic growth of the twentieth century was built on cheap commodities.**

What will happen as prices rise?

- **Is resource efficiency an accurate predictor of future performance?**
- **If resource subsidies were removed, how would markets react?**
- **Do we have the correct measures of growth?**
- **How will capitalism change in a resource-capped world?**
- **How can the creative energy of finance be directed to global resource challenges?** In preparation for the Rio+20 Meeting in June 2012, over 3,000 scientists, policymakers, and industry and media representatives gathered in London for the Planet Under Pressure: New Knowledge Towards Solutions conference. Special sessions on energy, water and climate nexus were a part of over 160 breakout discussions and plenaries (Bogardi et al., 2012). Together, all these high-profile meetings send a clear message to decision-makers in governments, businesses and the civil society.

The message is that the ways in which countries deal with water, food and energy security heavily influence economic growth, human welbeing and the environment that we live in and rely on. These fora also provided platforms for international dialogue and for suggesting investment and policy recommendations.

2.3 Nexus elements in major documents and initiatives

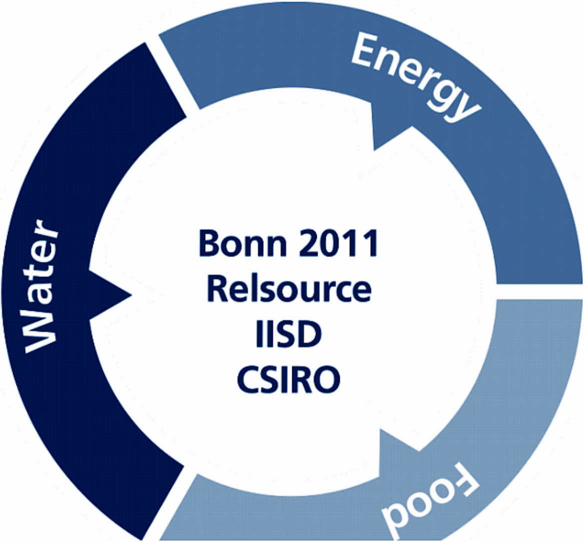
The WFE security nexus is now a part of international development canon and is a recognized policy paradigm. The list below shows the central position of the WFE nexus in key initiatives of international agencies.

	Organization/Body	Documents/Meeting	Position on nexus or its elements
1	Food and Agriculture Organisation of the United Nations	The Energy and Agriculture Nexus. 2000. Energy and Natural Resources Working Paper No. 4	Energy-agriculture nexus is a coherent system. Bioenergy could boost agricultural productivity for rural development. Link between energy, biomass and carbon flows.
2	United Nations Economic and Social Commission for Asia and the Pacific	Low Carbon Green Growth Roadmap for Asia and the Pacific, 2012	WFE security is mentioned as one of resource efficiency strategies.
3	Asian Development Bank	Asian Water Development Outlook 2013: Measuring Water Security in Asia and the Pacific	Embraces the nexus perspective in one of its 12 key messages.
4	Transatlantic Academy	The Global Resource Nexus: The Struggles for Land, Energy, Food, Water and Minerals	Broadens the debate on WFE security to include land and minerals.
5	Stockholm Environment Institute	Prepared the background paper for Bonn 2011 Nexus	Promote reduction of trade-offs and generating additional benefits that outweigh transaction costs.
6	International Food Policy Research Institute	A co-organizer of the Bonn 2011 Nexus Conference	Publishes on the food-water-climate change nexus in scientific journals.
7	International Energy Agency	World Energy Outlook 2012	Examines water for energy relationships and estimates. Total freshwater needs by energy source and region.
8	The World Bank	Overcoming Barriers to International Cooperation of River Basins Critical for Food, Water, Energy Security	A report on the importance of river resources for the WFE nexus
9	United Nations Conference on Sustainable Development	Outcome document "The Future We Want"	Paragraphs 108 to 129 cover the topics of food security, water and sanitation, and energy.
10	Asia- Pacific Center for Water Security, Tsinghua and Peking Universities	Established a regional program on R&D on WFE security	Collaborating with ADB to publish the Third Water Development Outlook for Asia and the Pacific.

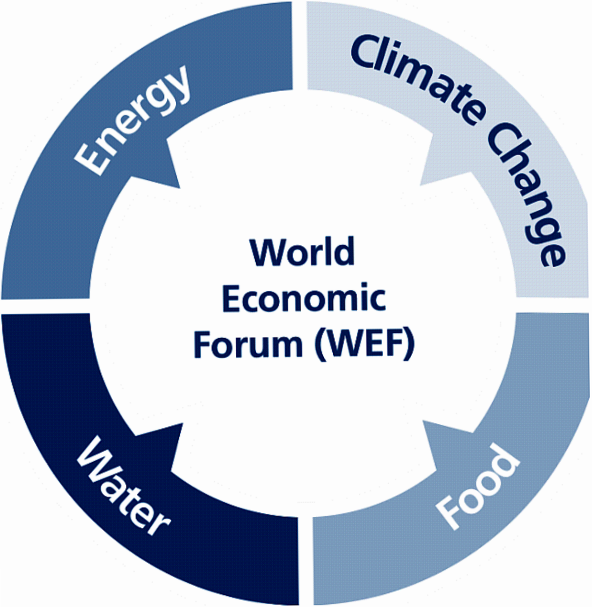
The nexus approach is not limited to the three-way water-food-energy security concept but could also include other concerns such as land, minerals and climate change (see Figure 3). The European Union (EU) focuses on water, energy and land as three crucial resources for development and human well-being (Overseas Development Institute, European Centre for Development Policy Management, German Development Institute, 2012). The EU's report entitled Confronting Scarcity: Managing Water, Energy and Land for Inclusive and Sustainable Growth examines the constraints on each resource and the interrelationships between them. The report also considers how they can be managed together to promote growth in developi ng countries in a way that is both socially inclusive and environmentally sustainable. Its scope is made relevant to the sustainability goal by disaggregating land into four functions. These are land for forests, land for biodiversity, land for agriculture and land for human settlements and infrastructure.

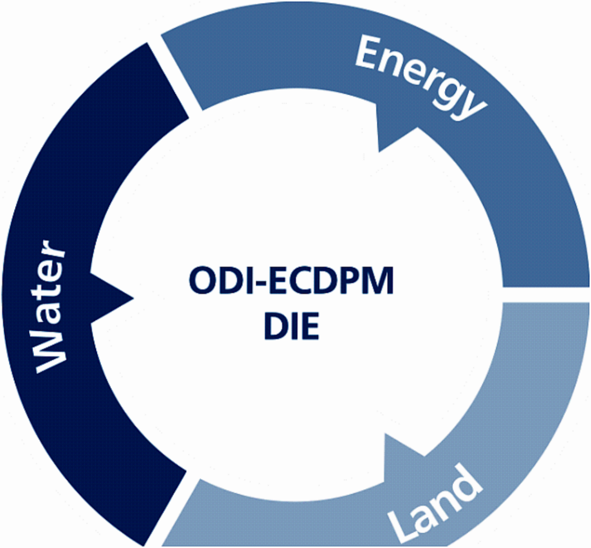
The Transatlantic Academy identifies that five resources, land, energy, food, water and minerals are essential for human security. These resources are keys in terms of international trade and, if unchecked, these resources may set off international conflict (Andrews-Speed et al., 2012). The Transatlantic Academy report calls for leadership on the part of United States of America, Canada and Europe in addressing unprecedented global demand for these resources, or the world may face severe market disruptions and conflict at the interstate and local level.

Figure 3. Different emphasis on nexus by various organizations.



Energy
Water
Food
Bonn 2011
Relsource
IISD
CSIRO


Energy
Climate Change
World Economic Forum (WEF)
Water
Food


Energy
Water
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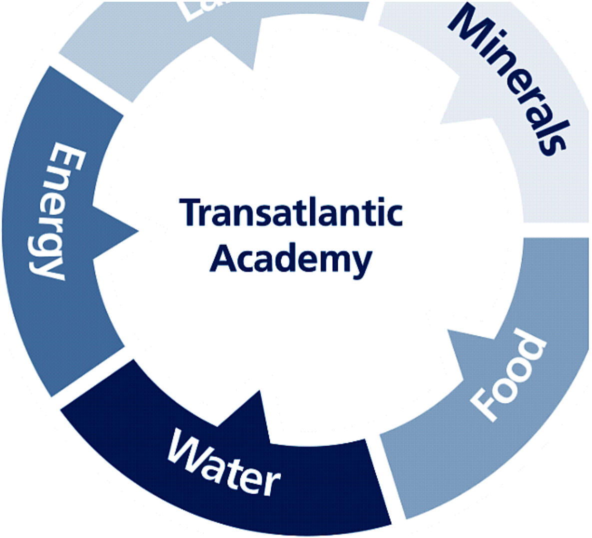
Land



Understanding of the Nexus

The academic and policy literature on current and future challenges in water, food and energy secu rity explores three main themes. The first theme is the nature of the relationships among the three elements (through input-output analysis). The second is the consequences of their changes and changes in other sectors, including geopolitical implications. Lastly, the third includes implications for policy development and actions for addressing the three securities (Bizikova et al., 2013).

3.1 Input-output relationship accounting

A major proportion of the scientific literature on the nexus focuses on the analysis of inputoutput relationships. The nexus accounting is characterized mainly in resource efficiency terms. I n a country-level analysis of water input into energy production, the energy sector in the United

States of America is the single biggest user of water in the economy (Carter, 2010). In an industrybased assessment of water use in energy production, Pan et al. (2011) calculated information about water withdrawal, consumption and wastewater drainage at each stage of the coal supply chain in China. It showed that without effective regulations or water-saving measures, China's demand in the coal industry could surpass its near-future water supply capacity.

In a comparative analysis of water-for-energy and energy-for-water, a study estimated that in Texas, United States of America, approximately 595,000 ML of water (enough for 3 million people for a year) is consumed annually by cooling the state's thermoelectric power plants (Stillwell et al., 2011). Each year, Texas uses 2.1–2.7 TWh[3] of electricity for water systems and 1.8–2.0 TWh for wastewater systems. This value is enough to cover the electricity need for 100,000 people for a year. The study suggests that increased efficiency advances the sustainability of both water and energy systems and, by extension, reduces the costs to water and power consumers.

Cuellar and Webber (2010), in an analysis of ene rgy for food production, argued that the practice of intensive agriculture today is energy hungry. Contributions are through mechanized land preparation, fertilizer, irrigation and other inputs. Almost 8 per cent of all energy consumed in the United States of America is for food production. About 27 per cent of food is wasted and 2 per cent of energy is wasted in unconsumed food.

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3 TWh: terawatt-hour.

In an analysis of energy requirement in the production of biofuels, Murphy and Allen (2011) analyzed the energy needed to manage the water used in the mass cultivation of microalgae that is currently considered a potential feedstock for the production of biofuels. Estimates of both direct and upstream energy requirements for obtaining, containing and circulating water within algae cultivation systems are calculated for each of the 48 states within the continental United States of America. The analysis indicates that, for current technologies, energy required for water management alone is approximately seven times greater than energy output in the form of biodiesel and more than double that contained within the entire algal biomass.

Li et al. (201 2), in a study of water for energy and its impact on climate mitigation, reported that China's wind energy consumes 0.64 l/kWh[4] of water. Wind energy sources also produce 69.9 g/kWh of CO_2 emission. Wind power could contribute to 23 per cent of carbon intensity reduction, saving 800 million m^3, sufficient for use by 11.2 million households.

Using the case study of the southern Murray Darling Basin in Australia, Khan et al. (2009) presented an empirical application of the WFE nexus through an analysis of environmental footprints of water and energy use in food production systems. The study identified the main pathways to reduce environmental footprints in the agricultural system of rice, wheat and barley production in selected farms. Th e analysi s i nd i cates that boosti ng water prod uctivity and improving energy use efficiency in crop production operations are the two possible pathways to reducing the environmental footprints of water and energy inputs in food production.

3.2 Analysis of institutional and policy dimensions of resource coupling

There are fewer scientific and gray literatures focusing on the institutional and policy dimensions of resource coupling (i.e., energy-water, water-food, etc.). The sample below revolves around the subjects of cost, price and polycentric governance.

- **The dramatic increase in energy costs led to decreased domestic water access in Alaska's Northwest with adverse effects on household hygiene practices (Eichelberger, 2010).**
- **The low increase in diesel prices over the last few years has resulted in economic scarcity of groundwater, causing negative impacts on crop production and farm incomes in the eastern Indo-Gangetic basin, West Bengal (Mukherji, 2007).**
- **The literature also shows the importance of multi-tiered institutional arrangements and resource governance – laws, policies and organizations that operate across jurisdictional levels for management of resources (e.g., Scott**

et al., 2011).

4 kWh: kilowatt-hour.

- Malik (2010) examined the nature of water-energy nexus at the level of end users (as opposed to sector-based analysis) and their coping strategies. He used the case study of India, where the demand for both water and energy exceeds the available supplies of these resources. The paper also examined the nature of policy interventions that could help in moving toward bridging the gap between the demand and the supply of water and energy, especially in inter-linked activities.
- The findings of Henriksen and co-authors (2011) suggest that in Europe, there is much scope to encourage soil-management strategies that would mitigate greenhouse gas (GHG) emissions and increase energy and water efficiency.
- Siddiqi and Anadon (2011) performed

a country-level quantitative assessment of energy-water nexus in the Middle East and North Africa (MENA) region. The results show a relatively weak dependence of energy systems on fresh water but a strong dependence of water abstraction and production systems on energy. In the case of Saudi Arabia, it is estimated that up to 9 per cent of the total annual electrical energy consumption may be attributed to groundwater pumping and desalination. Other countries in the Arabian Gulf may be consuming 5–12 per cent or more of total electricity consumption for desalination. The results suggest that policy makers explicitly consider energy implications in water-intensive food imports and future restructuring of water demand. The study also recommended that an integrated decision may involve water reuse as well as changes in the agricultural sector and not the expansion of desalination systems that are energy intensive and financially expensive.

3.3 Nexus policy options

There are examples of policy options that could strengthen the nexus directly or indirectly. Although the interconnected nature of WFE has been widely recognized, "there is a relatively limited understanding of how to tackle these complex relationships when conducting assessments and taking action" (Bizikova et al., 201 3, p. 3). An exception is the case of water-energy nexus in the United States of America. As of November 2009, at least nine states had statutes recognizing the nexus between water and energy (Siddiqi and Anadon, 2011). Universities in the United States of America, Spain and Australia duly recognize the important role of research to deepen our understanding of the nexus. For instance, in the United States of America, there was a proposal to create institutio ns to administer and research WFE nexus issues.

The proposal was included in the Energy and Water Research Integration Act, which was never approved.

The other options to target synergies and avoid potential tensions include:

- **enforcement of legislations linking groundwater extraction to power use;**
- **development of technologies to build WFE infrastructure;**
- **Promotion of technologies that exploit the potential for more efficient, cost-effective and local close-loop solutions based on life cycle analysis;**
- **Creation of incentives (and sanctions) to private, public and civil society to accelerate the nexus goals;**
- **enhancement of agricultural power tariffs; and**
- **regulation of new power connections for groundwater wells.**

The Bonn 2011 meeting offered the following policy recommendations to address the three sustainable development pillars (social, economic and environmental challenges):

- **accelerating access and integrating the bottom of the pyramid (society),**
- **creating more with less (economy), and**
- **investing to sustain ecosystem services (environment).**

The Bonn 2011 meeting's specific policy interventions include (Hoff, 2011): increasing resource productivity;

- **using waste as a resource in multi-use systems;**
- **stimulating development through economic incentives;**
- **implementing governance, institutions and policy coherence; benefiting from productive ecosystems;**
- **integrating poverty alleviation and green growth; and**
- **building capacity and raising awareness.**

The World Economic Forum promotes the following interventions (World Economic Forum Water Initiative, 2011):

- integrated and multi-stakeholder resource planning;
- regionally-focused infrastructure development;
- market-led resource pricing;
- community-level empowerment and implementation; and
- technological and financial innovation for managing the nexus.

The International Institute of Sustainable Development also proposes its very own WaterEnergy-Food Security Analysis Framework, focusing on operationalizing the nexus concept (see Figure 4).

Figure 4. The International Institute of Sustainable Development framework on the stages of WEF nexus implementation. (*Source:* Bizikova et al., 2013).


1. ASSESSING THE WEF SECURITY SYSTEM
Assess Current Status and Trends in Natural, Built and Social Capital
Understand Past Stresses and Adaptations
Describe Future Risks
2. ENVISIONING FUTURE LANDSCAPE SCENARIO
Develop Shared Principles for the Future Landscape
Identify Critical Uncertainties and Craft Plausible Scenarios
Develop Adaptations and Transformations
3. INVESTING IN A WATER-ENERGY-FOOD SECURE FUTURE
Creating a New and Shared Story of the Future Landscape
4. TRANSFORMING THE SYSTEM
Communicate

Communicate	Implement
Develop the Investment Strategy and Scaling Mechanisms	Monitor, Adapt and Improve

The European Union's Third Development Report, Confronting Scarcity, analyzes and proposes action in five areas:

- radical reduction of environmental footprints of consumption to promote inclusive growth without increasing resource use;
- promotion of new innovations to increase agricultural productivity to sustainably feed more than 9 billion people by 2050 and scale up renewable energy technologies that help to deliver sustainable energy for all by 2030;
- establishment of reformation of institutions for an integrated approach towards managing resources;
- promotion of inclusive land policy to ensure access to land and water for the poorest and

most vulnerable; and

- **valuation (pricing) of natural resources and services comprehensively and appropriately (e.g., using instruments such as payments for ecosystem services), while safeguarding the welfare of the poorest.**

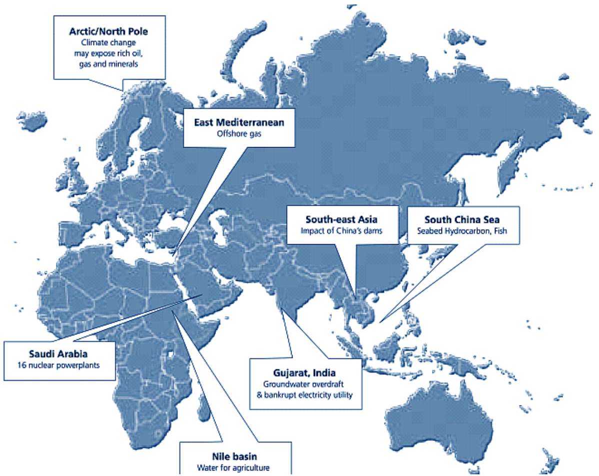
If implemented, these action areas may improve water, energy and land security for development and human well-being in the developing world (Overseas Development Institute, European Centre for Development Policy Management, German Development Institute, 2012).

Considering that complex interactions require new institutional capacity in both industrialized and developing countries, efforts are underway to develop a modeling framework that addresses the nexus with the ability to inform effective national policies and regulations (Bazillian et al., 2011). Existing analytical models used to support decision-making are sectororiented and, therefore, inadequate for nexus analysis. Examples include the Long Range Energy Alternatives Planning model for energy systems analysis, the Water Evaluation and Planning System for water modeling and the Global Policy Dialogue Model for food security modeling. To understand a nexus among land, water, food, energy and wealth, the Food and Agriculture Organization (FAO) is currently developing a multi-scale integrated modeling tool based on the Multi-Scale Integrated Analysis of Societal and Ecosystem Metabolism approach. FAO is cu rrently testing the model with cases of sugarcane production and diversion to biofuels in Mauritius and grain production and underground aquifers exploitation in India.

3.4 Geopolitical implications of the WFE nexus

There are many areas in which the WFE nexus presents situations of tension and conflict due to the finite nature of many natural resources, combined with a soaring increase in demand. This is true even for non-conventional security issues such as water, food and energy, which are rapidly acquiring the status of full-fledged security threats. The security literature is replete with case studies of regions and countries with existing or emerging risks (e.g., Chellaney, 201 1 ; Klare, 201 2). Figure 5 illustrates the potential flashpoints in Southeast Asia, India, the Nile Basin, Saudi Arabia, the Arctic Pole and the South China Sea.

Figure 5. Examples of nexus geopolitical flashpoints.



3.5 The WFE nexus as an economic and environmental strategy

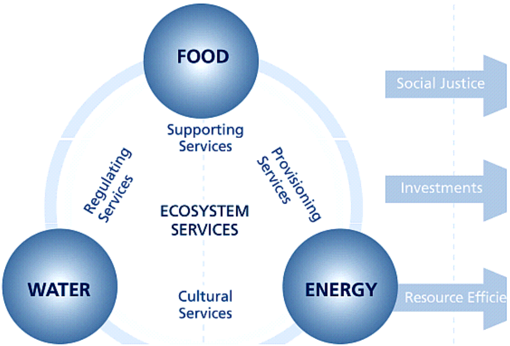
The preceding review of the WFE nexus approaches essentially points to the combination of a utilitarian objective to use resources for economic development. The review is also guided by the principle of sustaining ecosystem services rather than presiding over their continuing degradation. Nonetheless, the emphasis on economic development outweighs the ecosystems target. Krchnak and colleagues (2011, p. 3) from the International Conservation Union argue that:

"Policy failure drives unsustainability. The failure to place economic value on water, the relative political weakness of ministries of environment and water compared to ministries that finance infrastructure development, and a misperception that water allocated to the environment is water unavailable for humans all contribute to degradation of aquatic ecosystems and their vital services. Policy failure too often leaves ecosystems out of investments made in infrastructure for water, food and energy security, despite the value of the benefits ecosystem services provide to each."

Krchnak and colleagues (2011) essentially contend that nature is still an "unseen dimension" in the framing of the nexus. Therefore, we must explicitly recognize ecosystems as part of the infrastructure for economic development because unsustainable natural resource management has negative socio-economic consequences. Thus, strategic resources such as water, together with energy and food, must be viewed as the bloodstream of the biosphere. To achieve the twin goals of human well-being and green growth, sustainability must move to the center-stage, with attention given to ecosystem services. Figure 6 illustrates a conceptual framework integrating nexus assessment with policy levers that will lead to sustainability transition.

Figure 6. WFE security nexus as an environmental strategy.

W-E-F NEXUS ASSESSMENT **POLICY LEVERS**



SUSTAINABILITY TRANSITION

The Looming Resource Challenge in Asia and the Pacific

Since the 1990s, rapid urbanization, large investments in infrastructure development and the emergence of new consumers have characterized many of Asia and the Pacific region's developing economies. The increase in resource use in Asia and the Pacific between 1970 and 2005 has been above the world average (see Table 2). Domestic material consumption by Asia and the Pacific region grew more than fourfold, from 7.6 billion tons in 1970 to 31 .9 billion tons in 2005 (Schandl and West, 2010). The per capita increase is equally astounding. In 1970, the per capita domestic material consumption stood at 3.2 tons (approximately 25 per cent of the contemporary figure for the rest of the world), but by 2005, it had risen to more than 8.6 tons per capita (about 87 per cent of the corresponding figure for the rest of the world) (Schandl and West, 2010).

Table 2. Average annual growth rate of material use.

	Average annual growth rate of material consumption (per cent per year)			
	1970–1980	1980–1990	1990–2000	2000–2005
Asia and the Pacific	3.2	3.2	2.3	6.0
Rest of the world	1.9	0.5	1.3	0.8
The world	2.5	1.8	1.8	3.7

Source: United Nations Economic and Social Commission for Asia and the Pacific (2012).

Heavy reliance on fossil fuel as dominant sources of energy has been a consequence of the economic growth in the region. In 2008, countries in Asia and the Pacific region accounted for almost half the world's CO_2

emissions. This marks a jump from their 38 per cent share of world total in 1990 (United Nations Economic and Social Commission for Asia and the Pacific [UNESCAP], 201 1). This section discusses the trends, forecast and implications of the water, food and energy resource security in Asia and the Pacific region.

4.1 Water security

At the Second World Water Forum in 2000, the Global Water Partnership introduced an integrative definition of water security that considered access and affordability of water as well as human needs and ecological health (Cook and Bakker, 201 2). The concept of Integrated Water Resources Management (IWRM) has influenced reforms in the water sector. The Global Water Partnership also promotes IWRM, defining it as follows:

"...a process which promotes the coordinated development and management of water, land and

related resources, in order to maximise the resultant economic and social welfare in an equitable manner without compromising the sustainability of vital ecosystems."

The definitions presented accept that human dependence on water is not merely a technical issue involving water-supply-use (e.g., irrigation) but is much broader. Falkenmark (2001) recommends that water should be recognized and acknowledged as the bloodstream of the biosphere, pointing to its environmental importance. Cook and Bakker (2012) argue that the concepts of water security and IWRM share the same elements. Hence, the broad framing of the concept of water security will share the implementation challenges of IWRM. Therefore, there is a need to narrow down the scope of water security in order to operationalize it. This can be done by undertaking assessment at multiple scales – from the local to the national – for both human and ecosystem needs. The next step is to introduce the rules for use (e.g., water rights, water allocation, inter-sectoral reallocation) that are based on complex amalgam of existing water uses and competing interests. Thus, both IWRM and water security are broadly in line with a nexus perspective. The World Economic Forum (2011, p. 1) broadens the definition of water security by couching it within a wider political economy and trade context:

"Water security is the gossamer that links together the web of food, energy, climate, economic growth, and human security challenges that the world economy faces over the next two decades."

"The nexus approach differs from IWRM," according to Bach et al. (2012, p. 10), "in that whereas IWRM tries to engage all sectors from a water management perspective, the nexus approach treats the three issues – water, energy and food security as equally important."

4.1.1 Water trends

Asia and the Pacific region is largely a water-stressed region. As population growth and urbanization rates in the region rise, the stress on Asia's water resources is rapidly intensifying. Further, water security throughout the developing countries of Asia and the Pacific is poor. Table 3 shows the external dependency ratio of selected water-scarce countries.[5] These

5 The dependency ratio expresses the percentage of total renewable water resources originating outside the country – 0 per cent indicates that a country does not receive any water from the neighboring countries and 100 per cent is the opposite case.

countries face multiple water-related challenges of access, depletion, pollution and disaster, which are different components of water security. UNESCAP has identified "water hotspots" in the region through an index of vulnerability to water security, which may impede progress in implementing development agenda (UNESCAP, 2011; see Figure 7).

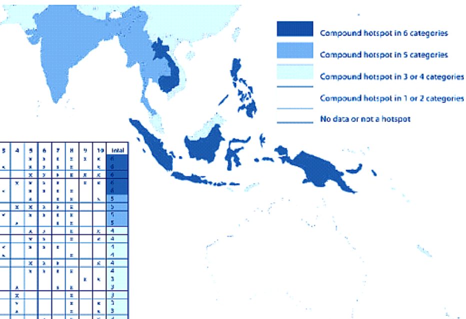
Table 3. Annual renewable water resources in selected Asian countries.

Country	External (million m^3)	Total (million m^3)	External dependency ratio (%)
Bangladesh	1,105,644	1,210,644	91.3
China	17,169	2,840,000	0.9
India	647,220	1,907,760	33.4
Indonesia	0	2,838,000	0
Japan	0	430,000	0
Malaysia	0	580,000	0
Burma (Myanmar)	165,001	1,045,601	15.8
Nepal	12,000	210,200	5.7
Pakistan	170,300	225,300	75.59
Philippines	0	479,000	0
South Korea	4,850	69,700	7
Sri Lanka	0	50,000	0
Thailand	199,944	426,744	47.4
Viet Nam	524,710	891,210	58.9

Source: Chellaney (2011)

Source: Chellaney (2011).

Figure 7. Water "hotspots" in Asia and the Pacific region.[6]



Compound Hotspots

	1	2	3	4	5	6	7	8	9	10	Total
Cambodia					x	x	x	x	x	x	6
Indonesia			x		x	x	x	x		x	6
Lao PDR					x	x	x	x	x	x	6
Papua New Guinea				x	x	x	x		x	x	6
Philippines	x		x		x	x	x	x			6
India	x				x		x	x		x	5
Myanmar				x	x	x	x	x			5
Thailand			x		x	x	x	x			5
Uzbekistan	x	x		x			x	x			5
Bangladesh					x	x		x		x	4
China					x	x		x		x	4
Malaysia			x		x	x	x				4
Pakistan	x	x	x					x			4
Timor Leste					x	x	x			x	4
Viet Nam					x	x	x	x			4
Afghanistan	x								x	x	3
Kazakhstan				x			x	x			3
Maldives	x			x				x			3
Mongolia				x				x		x	3
Nepal				x				x		x	3
Pacific Islands						x		x		x	3
DPRK				x	x						2
Kyrgyzstan				x			x				2
Tajikistan				x			x				2
Turkmenistan				x			x				2
Australia							x				1
Azerbaijan				x							1
Bhutan				x							1
Georgia				x							1
Iran								x			1
Republic of Korea					x						1
Sri Lanka								x			1
Prevalence (countries affected)	[illegible]	2	[illegible]	14	[illegible]	14	[illegible]	[illegible]	4	17	

Source: UNESCAP (2009)

Countries in the region are also under growing threat. The fastest increase in water demand in Asia is now coming from the industry and urban household sectors, not agriculture anymore (Asian Development Bank [ADB], 2013). At present, as many as 635 million people in Asia lack access to safe water, and 1 .9 billion people lack access to effective sanitation. Asia and the Pacific region requires further investments of USD 59 billion for water supply and USD 71 billion to provide access for improved sanitation (World Health Organization, 2010).

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6 Hotspots are countries, areas or ecosystems with overlapping challenges of poor access to water and sanitation, deteriorating water quality, inadequate water availability and increased exposure to climate change and water-related disasters.

4.1.2 Nexus challenges

Water is physically scarce in densely populated areas such as Central and West Asia. This scarcity mainly relates to water for food production. Further, many low-income countries in the region have enough water to meet their needs, but it is economically scarce because there is insufficient financial, human and technical capacity to provide and sustain the infrastructure to enable access. Poor management also influences water scarcity. Specifically, the nexusrelated challenges for the region include:

- *Environmental stress* – **Water insecurity caused by unchecked development or environmental stress** may have a material impact on the economy (World Economic Forum Water Initiative, 2011).

- *Climate change* – The Intergovernmental Panel on Climate Change (IPCC) predicts that freshwater availability in Central, South, East and South-East Asia is likely to decrease due to climate change, along with population growth and rising standard of living. This prediction could adversely affect more than a billion people in Asia by the 2050s. Specifically, climate change will significantly impact agriculture by increasing water demand, limiting crop productivity and reducing water availability in areas where irrigation is most needed (Turral et al., 2008). Climate change may cause at least some additional 50 million people to face serious hunger by 2020 and 130 million more by 2050 (FAO-ROAP, 2010).
- *Water demand* – Water availability has become a serious constraint to sustainable food systems in Asia in terms of its quantity and timing to meet the needs of farmers. Increasing competition over water is causing frequent water shortages. Poor

water quality in urban areas has become an issue for food safety, specifically in the irrigation of vegetables. Increased competition for water between sectors may transfer water out of agriculture.

- *Groundwater table* – Groundwater levels are falling in Northern India, Pakistan and the northern plains of China. For extended periods each year, some rivers such as Syr Darya in Central Asia do not discharge into the ocean (ADB, 2013).

These insecurities pose risks for public health, political stability and continued economic growth within Asia and beyond.

4.2 Energy security

The United Nations Advisory Group on Energy and Climate Change (2010) defines energy security as

"access to clean, reliable and affordable energy

services for cooking and heating, lighting, communications and productive uses."

According to energy historian Daniel Yergin (1988, p. 11), the objective of energy security "is to assure adequate, reliable supplies of energy at reliable prices and in ways that do not jeopardize major national values and objectives." Such a "[traditional thinking of energy security", according to Downs (2004, p. 23), is "state-centric, supply-side biased, overwhelmingly focused on oil and tends to equate security with self-sufficiency".

The state-centric understanding of energy security bears the conceptual imprint of traditional cold war studies. Fueled by concerns over global warming, recent security thinking extends the traditional focus on energy security as mainly the questions of availability, accessibility and affordability to encompass newer concerns such as efficiency and sustainability (or environmental stewardship). This re-definition is gaining ever more prominence on contemporary policy agendas.

4.2.1 Energy trends

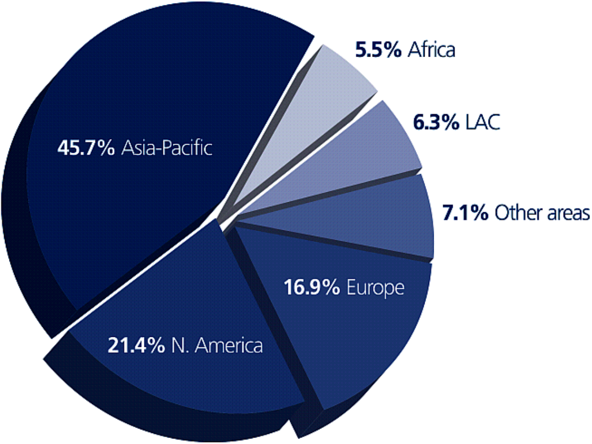
Over the past 200 years, global energy use has grown by 25 to 530 exajoules (United Nations, 201 1). The International Energy Agency (IEA; 2010) projects world primary energy demand to reach between 14,850 and 18,300 Mtoe[7] by 2035. This is equivalent to an increase of between 23 and 51 per cent from 2009.

Between 2000 and 2008, electricity production in Asia and the Pacific region grew by an average of 6.1 per cent per year, and its share of world production rose from 32 per cent to 42 per cent (UNESCAP, 201 1).
East and North-East Asia produced 5,051 billion kWh of electricity in 2008, almost 60 per

cent of the entire Asia and the Pacific, with China and Japan together accounting for 4,539 billion kWh. In 2008, Asia and the Pacific region accounted for 45.7 per cent of the total global primary energy supply, or 5,449 Mtoe of the world supply of 12,267 Mtoe (Figure 8).

7 Mtoe: million tons of oil equivalent.

Figure 8. Share of total primary energy supply in the world by region, 2008.



Source: UNESCAP (2011).

In the past two decades, energy demand in China, India and other emerging economies has grown tremendously. In 2009, developing countries consumed more than half of the primary energy. This allowed developing countries to join the bandwagon of energy-hungry states of the Western world.

For decades, economic growth in Asia has required ever-expanding amounts of energy. Asia's primary energy demand is expected to grow fastest globally, at 2.3 per cent per annum. This figure is significantly higher than the world average of 1.3 per cent per annum (IEA 2010). This is a result of a faster rate of population and economic growth as well as urbanization. Oil demand in Asia is expected to grow by 44 per cent (10.9 Mbpd[8]) between 2010 and 2015, accounting for some 86 per cent of the global demand increase. With respect to natural gas, Asia's demand will increase by 143 per cent, accounting for 45 per cent of global demand increase. Asia's coal demand, on the other hand, will increase by 47 per cent, accounting for 119 per cent of global demand increase, balanced only by declines in Organization for Economic Cooperation and Development countries (IEA 2010).

8 Mbpd: million barrels per day.

Rapid economic growth to serve a large population base leads China to be the largest energy consumer in Asia. Although China is expected to show a lower-than-regional average growth of 2.3 per cent per annum, it is still expected to be the biggest energy-consuming country in the world by 2035, at 6,711 Mtoe. Together with China, India's rise as one of world's energy juggernauts is what security experts term as the Chindia challenge (see Klare, 2009, and Hulbert, 2010). India is expected to show a stronger average growth of 3.1 per cent per annum, more than doubling its 2009 level of energy demand to become the third-biggest energy consumer in the world by 2035 at 1,500 Mtoe. Within the Association of Southeast Asian Nations, the Asia-Pacific Energy

Research Centre projects regional energy demand to increase by 1 70 per cent between 2007 and 2030, from 375 Mtoe to 1,019 Mtoe.

China's and India's energy demand has grown rapidly over the past decade. Most projections su ggest that their voracious thirst for energy will fu rther expand in the coming decades. Future projections suggest that the growth of energy use in the Asia-Pacific region, particularly in China, will have major consequences for geopolitics, financial and energy markets, and pollution, both regionally and globally.

4.2.2 Nexus challenges

More energy demand and uncertainties in supply characterize the future regional energy outlook. Serious doubts have risen about the oil industry's capacity to meet much higher levels of demand on natural gas, oil and coal for the future. The rise of demand from new consumers in Asia may be exacerbating price volatility and may lead to long-term price increases, which may, in turn, affect the security of other natural resources. Herein, geoeconomics may reconfigure geo-politics, which may manifest in more conflicts fuelled by energy resource scarcity. Opinions vary as to how this reconfiguration should be interpreted in geo-political terms. The nexus-related challenges arising from energy insecurity in the region include:

- *Energy scramble* – **There is fear that petroleum availability, both in the near and long term, will become increasingly scarce as countries in Asia and the Pacific absorb a growing global share of demand. This concern is not surprising, given that the three major Chinese national oil companies – China National Petroleum Corporation, Sinopec (China Petroleum and Chemical Corporation) and China National Offshore Oil Companyhave been pursuing ambitious internationalization strategies** since the 1990s. ▪ *Alternative energy* – Water quantity or quality constraints limits the leading options to address the need to increase energy security. Some of these options include increasing the domestic production of oil and oil substitutes and reducing GHG emissions through non-conventionals and renewables. Hydraulic fracturing (fracking) and first-generation biofuels, for instance, require large volumes of water. This is especially a challenge in a semi-arid area where water is already scarce and groundwater tables are declining. ▪ *Nuclear power plant proliferation* – Nuclear power generators use about 2.5 times water per unit of electricity than gas does and 25 per cent more than coal does. The World Nuclear Association reported that, in Asia, as of 2008, 111 nuclear reactors were in operation, 19 were under construction, 63 were being planned and 112 were being proposed (Symon, 2008). The largest existing nuclear power industries are in Japan and Republic of Korea. China is embracing nuclear power, and this is where the largest expansion of nuclear power in the region is to take place. As elsewhere in the world, South-East Asian countries' interest in nuclear power reflects growing concern over the economic cost and environmental impact of other fuel sources. Viet Nam, Indonesia, Thailand and Malaysia are examples of countries in the region with concrete plans for nuclear power implementation.

4.3 Food insecurity

Securing future food availability is a top priority in most countries. At the 1996 World Food Summit, food security was defined as (FAO, 2009, p. 8)

"...a situation that exists when all people at all times have physical, social and economic access to sufficient, safe and nutritious food to meet dietary needs and food preferences for an active and healthy life."

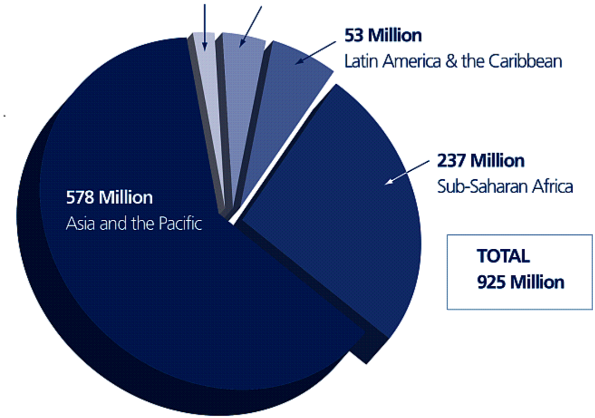
This definition implicitly singled out

undernourishment as one of the indicators of food insecurity. Among the targets agreed upon at the Summit included the call for at least halvi ng the number of undernourished people in the world by the year 2015. Although progress towards this target varies among countries, most undernourished people live in Asia and the Pacific region (see Figure 9).

Figure 9. Undernourished population by region, 2010.

19 Million Developed Countries

37 Million Near-East and North Africa

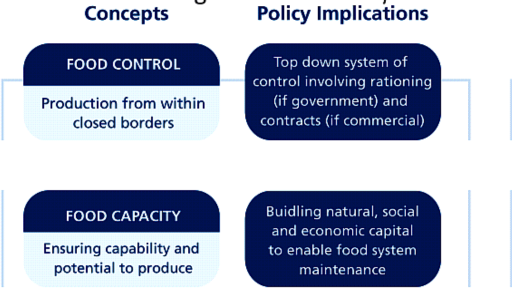


Source: FAO-ROAP (2010).

Arguably, accessibility to food is not the only food security concern in the region. Other related concepts such as food sustainability, resilience and defense influence food security challenges in Asia and the Pacific region. Figure 10 illustrates a set of overlapping social and policyrelevant meanings on food security that now compete for policy legitimacy and presence. To address all these distinct meanings of food security, countries should pursue a policy agenda combining all three time horizons of planning concomitantly (UNESCAP, 2009):

- **short term through improving access to food;**
- **medium term through practices of sustainable agriculture; and**
- **long term through adaptation to climate change impacts.**

Figure 10. Ideas informing the food security discourse.



Source: Adapted from Lang and Barling (2012).

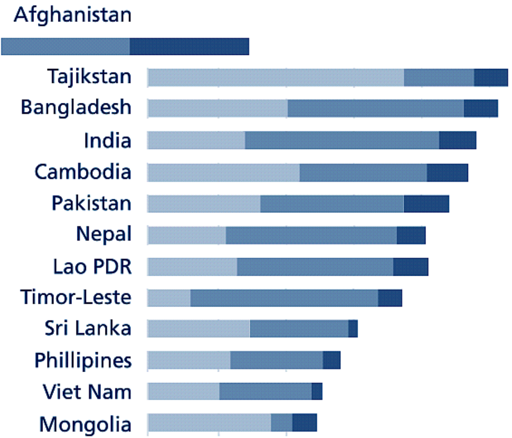
4.3.1 The trends

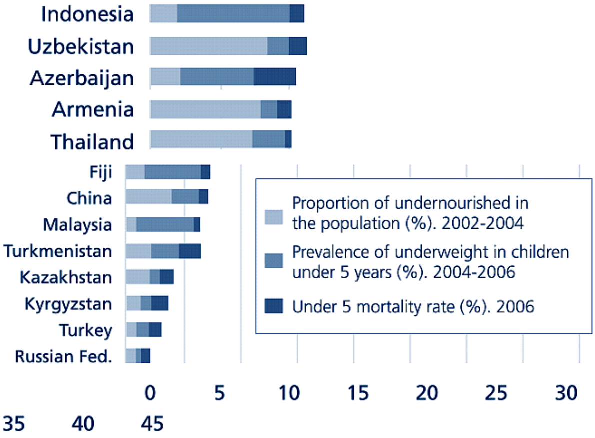
Concepts	Policy Implications


FOOD RESILIENCE
Capacity to recovers from or withstand shock
Requires assessment of risks and what is necessary to ensure recovery
FOOD RIGHTS
Ethical principles to shape supply
Building strong social networks to ensure people have a sense of entitlement
FOOD RISKS
Any factors that threaten goals
Having monitoring systems to detect
FOOD SOVEREIGNTY
The right to define one's own food system (small farmers)
Support for the small farmers and the rural infrastructure against perceived threats to existence by agribusiness
FOOD WELFARE
Safety nets for availability
Food donations or welfare benefits to enable poor to buy

Over 20 per cent of the undernourished population live in South and South-West Asia (UNESCAP, 2009), with the most acute problems in Afghanistan (Figure 11). Even the most dynamic country in the region, India, has more food-insecure people (231 million) than the whole of sub-Saharan Africa does. Across the region, around 3.8 million children die each year before reaching the age of 5 years, with half these deaths from inter alia causes related to malnutrition. In its 2009 report, Sustainable Agriculture and Food Security in Asia and the Pacific, UNESCAP listed 26 countries that it has identified as food insecurity hotspots, namely Afghanistan, Armenia, Azerbaijan, Bangladesh, Cambodia, Republic of Korea, Georgia, India, Indonesia, Lao People's Democratic Republic, Maldives, Mongolia, Myanmar, Nepal, New Caledonia, Pakistan, Papua New Guinea, Philippines, Solomon Islands, Sri Lanka, Tajikistan, Thailand, Timor-Leste, Uzbekistan, Vanuatu and Viet Nam. It can be noted that for food security assessment, national-level figure is not as useful for decision-making as subnational data are because food insecurity often occurs in specific provinces such as Madhya Pradesh in India and Ningxia in China.

Figure 11. Global Hunger Index in Asia and the Pacific.





Source: UNESCAP (2009).

The 2007–2008 food crisis (and the recent high food price rebounds in 2011) has revealed deep structural problems in the global food system. The global economic and food crises in 2006–2008 have deprived more people of access to adequate food. The food crisis has pushed 100 million people into poverty in

2007–2008 and nearly 50 million in the latter half of 2010 (World Bank, 2011, cited in United Nations, 201 1). These episodes seriously affected countries in Asia and the Pacific region. Malaysia, for instance, shambled into panic when its food supply was disrupted following Viet Nam's export restrictions on rice.

As the population grows in the coming decades, more and more crop production will be needed for human and animal consumption. The demand for food and animal feed crops is p rojected to grow by 70 to 100 per cent in the next 50 years (ADB, 201 3). This will escalate the pressure on water for food, as agriculture already accounts for 79 per cent of annual average water withdrawals in Asia and the Pacific.

4.3.2 Nexus challenges

The older debate on food policy concerns how to tailor food systems to respond to industrialization and urbanization and how to enable people to be fed from a natural and a biological world (Lang and Barling, 2012). Both challenges are still relevant in the region until today. UNESCAP (2009) estimates that to provide each consumer with 1,800 calories per day, by 2050, Asia and the Pacific region would need an additional 2.4 billion m^3 of water per day. Not only that the challenges to food production in Asia and the Pacific region are still underpinned by the old debate of supply-driven food security, but also, other new concerns will be more distinct in the near future, as listed below:

- **_Aging irrigation system_ – A prolonged period of low public investments in irrigation has resulted in poor service to farmers, which demotivates farmers from making their own investments in agricultural inputs.**
- **_Productivity of agriculture_ – By 2050, if farmers**

cannot increase productivity, South Asia will need to divert up to 57 per cent more water to agriculture, and in East Asia this will account for up to 70 per cent.

- *Environmental stress* – The lack of water is not the only problem affecting socio-economic development. Salinization induced by irrigation reduces productivity. Saline soils are already affecting almost 20 per cent of irrigated areas in Pakistan, 23 per cent in China and 50 per cent in Turkmenistan (ADB, 2013).
- *Land-grab* – As a response to the food insecurity concern, investments in agricultural and forest lands in many parts of the world (not only in developing countries) have increased significantly. Also known as "land grabs", this phenomenon presents one of the most contemporary and visible measures to safeguard long-term national food security.
- *Climate change* – The IPCC suggests that a 2°C increase in mean air temperature could

decrease rain-fed rice yields by 5–12 per cent in China. Under one scenario, net cereal production in South Asian countries is projected to decline by 4 to 10 per cent by the end of this century. In Bangladesh, by the year 2050, production of rice may fall by just under 10 per cent, and wheat, by a third.

Given Asia and the Pacific region's high and volatile food prices and increasingly scarce resources, ensuring a secure supply of food is essential. An agenda for food security should begin immediately. This agenda should promote sustainable agriculture and social protection against supply and price shocks in the region (UNESCAP, 2009).

The Interdependence of Water, Energy and Food

Resources

Water, food and energy are strategic resources sharing many comparable attributes. The current literature only presents rudimentary understanding of the complex and pervasive connections between water, food and energy security issues. This section exemplifies Asia and the Pacific region's experiences with the interlocking effects of the WFE nexus, which results in challenges that cross two or even all three of the domains. This section also identifies geographical "flashpoints" in the region.

5.1 Biofuels

Asia's currently largest biofuel-producing countries are Indonesia, Malaysia, Thailand, Philippines, China and India. Energy security, climate change mitigation, foreign exchange savings and rural development are commonly identified as justifications for biofuel expansion. Energy security is especially the key reason for the involvement of majority of Asian countries in biofuels. There is considerable urgency to implement policies aimed at bringing biofuels into Asian countries' energy mix. Biofuels are seen as a credible option because they can be blended easily with fossil fuels and hence have an immediate impact by reducing the quantity of fossil fuel imports. In order to further promote the production and use of biofuels, a range of countries have established targets for blending biofuel components in the overall fuel mix (see Table 4).

Table 4. Targets for largest biofuel-producing countries in Asia and the Pacific region.

Country	Biofuel targets
Australia	350 million liters of biofuels by 2010
China	12 million metric tons of biodiesel by the year 2020

India	E5 blending mandates by 2008, E20 by 2020, E10 in 13 states
Japan	20 per cent of the total oil demand met with biofuels by 2030
Thailand	3 per cent biodiesel share by 2011; 8.5 million liters of biodiesel production by 2012

Source: Adapted from Timilisina and Shrestha (2010).

The promotion of energy from biomass (first-generation biofuels) for reducing greenhouse gas emissions has led to increased usage of fresh water, especially during the cultivation of biomass. The same can be said about ligno-cellulosic (second-generation biofuels). However, much hope lies with the algae technology as third-generation biofuels because it lessens the competition with food production for land and water.

Water-intensive biofuels have raised concerns about the increase in water stress that biomass production brings, particularly in countries that are already facing water shortages. In China, the current level of bioethanol production consumes 3.5–4 per cent of the total maize production of the country, reducing the market availability of maize for other uses by about 6 per cent (Yang et al., 2009). It is projected that depending on the types of feedstock, 5–10 per cent of the total cultivated land in China would need to be devoted to meet the biofuel production target of 12 million metric tons for the year 2020. The associated water requirement would amount to 32–72 km^3 per year, approximately equivalent to the annual discharge of the Yellow River. There are also a number of environmental concerns related to first-generation biofuel production, which depend on feedstock type, production location and agronomical practices.

In the study carried out between 2000 and 2007, the International Food Policy Research Institute found that biofuel demand resulted in a 30 per cent increase in the weighted average grain price. The biofuel share of the totally supplied global energy in 2006, however, was only 0.2 per cent, and the share of the fuel for the transport sector was about 1 per cent. If the share of biofuels in the energy mix is to increase significantly, very strong effects on food prices can be expected.

5.2 Hydropower

Water is not merely an environmental issue. It is also a strategic issue. A major cause of diplomatic anxiety between neighbors in Asia is the construction of dams on international rivers to generate electricity. Hydropower generation meets 16 per cent of the world's electricity needs. It has been one of the main driving forces behind the construction of 45,000 large dams worldwide. By 2030, it will be the world's dominant renewable energy source, with 170 GW worth of power capacity under construction. It is also fast growing in Asia, with 76 per cent more hydropower planned across the region (IEA, 2010).

China's Great Water Diversion Plan alarms countries in South and Southeast Asia. The plan entails the construction of mega-dams and inter-basin transfer plan on interstate rivers to meet China's thirst for water and energy (Chellaney, 2011). It involves the upper reaches of the Brahmaputra, Mekong, Salween and Arun rivers, unmistakably the water lifeblood of countries in the region. This plan is likely to dry up several streams in North-East India and Bangladesh. It may also affect rice paddy cultivation on the Assam floodplain and worsen Bangladesh's food insecurity problem.

The Mekong River flows from the headwaters in the Tibetan Plateau for 4,880 km through China, Myanmar, Laos, Thailand, Cambodia and

Viet Nam. It drains to 805,604 km^2 of land known as the Mekong Basin, a major granary for Asia. Today, 60 million people live in the Lower Mekong Basin (LMB), and 80 per cent rely directly on the river system for their food and livelihoods.

In the Greater Mekong, 12 hydropower dams will be built during 2011–2025. The estimated total peaking capacity is 12,980 megawatts. By 2030, the dams in the Mekong tributaries will have a substantial impact on water security because the mainstream river flows and the hydrological regime of the entire Mekong river basin will be altered. It will also result in significant changes in the ecology of Tonle Sap, affecting ecosystem and farming productivity as well as fish migration and, by extension, compromising food security in the region (Orr et al., 2012). If all the dams were built according to plan, the total loss in fish resources would be between 26 and 42 per cent, amounting to a devastating economic loss of around USD 476 million per year.

There is also a plan to build a 1,800 megawatts dam in Papua New Guinea (Pearce, 2012). A 500-km cable across the Coral Sea to Weipa, Mt. Isa and Townsville in Queensland, Australia, will send the generated power. The plan to construct a dam in this area would flood much of the valley of River Purari, a sacred ancestral land.

5.3 Thermoelectric production and water security

Energy security does not only revolve around oil security but also the security of electricity supply. Electricity generation includes thermal plants from fossil fuels such as coal, oil and gas, as well as from biomass, nuclear plants, solar and wind (Carrillo and Frei, 2009).[9] Electricity production is a large user of water resources.

In the United States of America, cooling for thermoelectric power already withdraws more water than any other water demand does (Faeth, 2013). In Asia and the Pacific region, where agricultural demand dominates overall demand for water, the demand for water from the energy sector can be a major competitor. Figure 12 illustrates the landscape of water-energy nexus as measured by the indicator of water consumption for energy production (see Spang, 2012).

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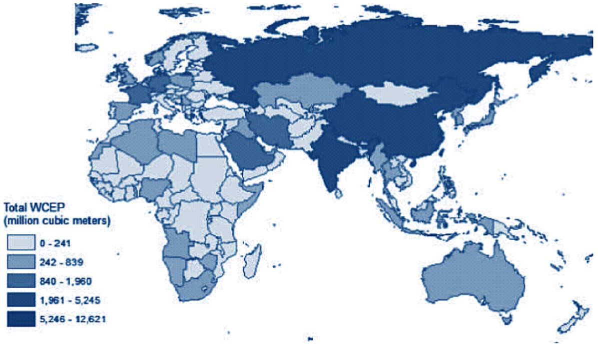
9 In thermal power plants, water is heated, turns into steam and spins a steam turbine, which drives an electrical generator. The water requirements of energy-generation systems differ depending on the energy source. Thermal plants use fossil fuels to generate electricity or heat, and their water needs can vary significantly depending on the type of plant and fuel and the form of refrigeration system they employ. Energy generated from renewable resources also consumes water.

Figure 12. Water consumption for energy production indicator.



Source: Spang (2012).

The declining water availability has emerged as a major problem for the energy sector, which uses one fifth of China's water consumption (Ivanova, 2011). Specifically, its mining, processing and combustion of coal account for 22 per cent of domestic water consumption (REN21, 2012). Because freshwater resources will be more constrained in the future as it limits electricity and energy supply, there is a need to consider water efficiency in energy planning. Strategies to promote increased water productivity may include the following (ADB, 2013):

- **control pumping by charging appropriate tariffs for electricity used to pump groundwater for irrigation or investing in separate grids to enable power rationing for agricultural uses, and**
- **provision of incentives to encourage investment in reducing leaks in water delivery infrastructure as well as promote installation of energy-efficient pumps.**

5.4 Irrigation and food security

Water is essential for food production. Irrigation has helped boost agricultural yields in arid environments and has stabilized food systems (Rosegrant and Cline, 2003). It helps provide approximately 40 per cent of the world's food (FAO, 2003). However, irrigation may result in

unwanted environmental consequences. In Asia, it is estimated that by 2025, 17 million ha of the irrigated rice area may experience "physical-water scarcity," and 22 million ha, m aybe
subject to "economic-water scarcity" (Tuong and Bouman, 2001).

Many highly productive irrigated areas currently rely on water pumped from underground aquifers that are being exploited at rates far in excess of those at which they are replenished. The availability of low-cost pump sets and electricity subsidies has led to high extraction rates (Mukherji, 2007). Khan and colleagues (2006) described three irrigated rice regions with sustainability challenges:

- **Rechna Doab, Pakistan;**
- **the Liuyuankou irrigation system, China; and**
- **Murrumbidgee irrigation area in New South Wales, Australia.**

Soil salinity, low water-use inefficiency issues and groundwater management are major concerns in these areas with differing climatic and hydrogeological conditions. Khan and colleagues (2006) proposed a radical rethinking of the sustainability of food production, rational pricing and sharing of water and commodities to maintain ecosystem services within irrigated catchments.

Collectively, India, Pakistan, Bangladesh and North China use 380–400 km^3 of groundwater per year, an amount approaching half of the world's total annual groundwater withdrawals (Shah et al., 2003). Irrigated agriculture consumes over half of this water, and much of this agriculture is concentrated in parts of the Asian continent, including the entire Indo-Gangetic plains that are arid or semi-arid. Millions of farmers with small land holdings depend on groundwater for their livelihood.

To address irrigation and food security, there is a need to revitalize irrigation. This strategy will help unlock productivity gains. The use of smarter technologies would require investment in the upgrading of irrigation infrastructure.

5.5 Irrigation and energy security

Energy and irrigation are closely linked. To produce food, most types of agriculture require energy. Apart from food security, irrigation also exerts pressure on energy security. A case in point is India, where the provision of power for irrigation pumping has been an important policy since the 1960s (Kumar, 2005). Electricity and diesel are commonly used to meet the irrigation energy demand in the country. Irrigation accounts for about 15–20 per cent of India's total electricity use. In India, electricity utilization in agriculture is almost entirely dedicated to groundwater pumping through individual pump sets and larger pump lift-irrigation schemes. Especially in rural India, the low electrification situation has forced majority of farmers to depend on diesel for groundwater (Mukherji, 2007).

Subsidized electric power provision in Indian agriculture has had a tremendous impact on the diffusion of groundwater-based irrigation. Flat-rate electricity has encouraged farmers to pump aquifers faster than they can be replenished. Such an extensive irrigation system has led to groundwater overdraft, with critical conditions in several regions, causing major losses to the state electricity boards and leading to heavy fiscal burdens for states such as Gujarat, Haryana, Punjab and Uttar Pradesh (Kumar, 2005; Mukherji, 2007).

The benefits that may accrue from if the WFE nexus perspective is applied include the following:

- **Options available to manage groundwater** irrigation, to meet food security and to achieve energy security, may be identified.

- A nexus assessment may also assist in scenario building with an integrated vision for socio-economic development and costing.
- The nexus can help in preventing intra- and inter-state conflicts and may increase the pace of track-one diplomacy in places such as the Ganges-Brahmaputra Basin.

5.6 Food trade and virtual water

Some countries indirectly consume more freshwater resources than they have access to within their boundaries by relying on food imports from other nations. This results in the globalization of water impacts as noted by Chapagain and Hoekstra, (2008, p. 19):

"In the world of today, people in Japan indirectly affect the hydrological system in the United States and people in the Netherlands indirectly impact on

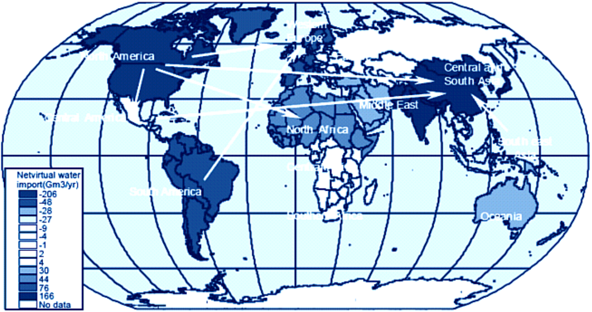
the regional water systems in Brazil."

Almost all food products consume water as part of their production process. The amount of water required per unit of production, however, depends largely on the type of food product. By trading food, national economies "trade" virtual water, from the producing and exporting countries to the importing and consuming countries. Some argue that virtual water import can be used as a policy option for food and water security.

The nexus of water and food security raises the question of whether trade harms the poor and disenfranchised in the developing world. In a study on food trade and water scarcity in Southern and Eastern Mediterranean, Yang and colleagues (2007) found that most countries there are so dependent on imports of water-intensive product. Countries in this region simply could not sustain the population without these imports.

Hoekstra and Hung (2005) quantified the volumes of virtual water flows between nations that are related to global crop trade. They found that the countries in Asia and the Pacific region with the largest net virtual water export are Thailand and India, whereas the largest net import appears to be in Japan, Republic of Korea, China and Indonesia (Figure 1 3). Another analysis revealed that Central Asia is one of the regions exporting water-intensive products despite its relatively stressed freshwater resources (Chapagain and Hoekstra, 2008). The challenge in the region is not the quantity of water available but its uneven distribution and excessive local use (Porkka, 201 2). It was found that those areas that are currently using too much of their water resources are also exporting large amounts of virtual water.

Figure 13. Virtual water balances of 13 world regions over the period 1995–1999.



Source: Hoekstra and Hung (2005).

Land and food security

Land is now the focus of intensified competition from a variety of uses, prominently represented by the term land grabbing. When increased demand for water, food and energy is combined, pressure on land conversion is concomitantly increased. Scheidel and Sorman (2012, p. 588) define land grabbing as follows:

"...The current processes of large-scale and long-term land acquisitions through private and governmental actors and is associated with vast and rapid changes in land use patterns and land use rights."

Specifically, the resurgence of agriculture to ensure food security has resulted in the rise of large-scale farms in land-abundant countries (Deininger and Byerlee, 2012). For example, between 2004 and 2009, Saudi Arabia leased 376,000 ha of land in Sudan to grow wheat and rice (Ananthaswamy, 201 1). Korea Times reported that in 2009, 73 Republic of Korean companies were growing grain on 23,000 ha of land in 18 countries (Pearce, 2012). It was also reported that the food giant Daesang grows 13,000 ha of maize in Cambodia for shipping back to Republic of Korea.

Such large-scale agricultural investments are not limited to land in the developing world. Droughts in the past decade have left big farmers in Australia insolvent, resulting in the sale of 45 million ha of Australian land (Pearce, 2012). The ensuing acquisitions are examples of moves to ensure food security by businesses outside Australia:

- **Dubai's food and fat giant IFFCO[10] and Malaysia's Federal Land Development Authority (FELDA) bought over controlling interest in the Australian Agricultural Company;**
- **Consolidated Pastures, with 5.7 million ha of Northern Territory grassland, was sold to a private equity firm British Terra Firma;**
- **The Australian Wheat Board is now owned by the Canadian company Agrium (re-named Agrium Asia-Pacific limited); and**
- **Singapore's Wilmar is buying into Queensland's**

sugar. Similarly, Olam International bought 9,000 ha of almond orchards, which produces half of Australia's almond harvest.

The Australian public has received these acquisitions negatively. The Sydney Morning Herald ran a headline that says "Australians are in danger of becoming servants and not masters of their own food resources" (Pearce, 2012). Such a public outcry reflected a sense of siege with what is perceived as land grabbing.

5.8 Water production and energy security

Energy is a concern in every stage of the water production and supply chain processes. It is required for the production, transportation, purification and distribution of water. Singapore is currently consuming a lot of energy to overcome its water scarcity challenge. Water security issue is one of the most crucial problems for Singapore's sustainability. It uses 1 .73 million m^3 of water a day. Although endowed with high rainfall (2,400 mm/year), Singapore is considered to be a water-scarce country because of the limited amount of land area where rainfall can be stored (Tortajada, 2006).

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10 IFFCO is a United Arab Emirates based conglomerate which was established in 1975. It manufactures and markets a well-integrated range of consumer products.

Currently, Singapore is dependent on 40 per cent imported water while increasing local catchment and using desalination and recycling water technologies (Table 5). Singapore aims for water self-sufficiency by 2060 and has leveraged this option to develop NEWater (recycled water) by innovation (Prakash, 2011). To boost up water availability from desalination process, in late 2005, the Singapore government opened up the Tuas Desalination Plant, the first municipal-scale seawater desalination plant, at a cost of SGD 200 million (Tortajada, 2006).

Table 5. Current water sources and 2060 targets for Singapore.

	Current reliance (per cent)	2060 Targets (per cent)
Seawater salination	10	30
Rainfall collected in reservoirs or water catchment areas	20	20
Reclaimed water by NEWater	30	50
Imported from Malaysia	40	–

Source: Prakash (2011).

Singapore's progress toward water self-sufficien cy is exemplary. Institutionally, the autonomy given to the Public Utilities Board to plan and implement the whole water cycle of Singapore h as enabled the country to put in place effective pol icy reforms to address the water insecurity challenge (World Bank, 2006). However, current desalination and membrane technologies (for NEWater) require large amounts of energy, which is costly both in environmental pollution and in financial terms. The current technologies of thermal and membrane processes are reaching their limits for reducing energy usage. With rising global energy costs, there is a dire need for new low-energy approaches in desalting seawater. The government of Singapore responds to this challenge by building its economy as a global hub for water technology and, in so doing, turns a crisis into an economic opportunity (Caballero-Anthony and Pau, 2013).

Case Studies of the Water, Food and Energy Nexus Challenges and Solutions

6.1 Water resources, irrigation and

energy in Central Asia

With an area of more than 5,000,000 km^2, Central Asia is the world's largest closed drainage basin. Water management in Central Asia is facing tremendous challenges. These challenges are rooted in past and present environmental degradation, socio-economic transition after the breakup of the Soviet Union and impacts of climate change. The period under the Union of Soviet Socialist Republics saw a complex scheme of water and energy exchange among the riverine countries developed to irrigate cotton production. Irrigation expansion resulted in large-scale environmental degradation, including the disappearance of parts of the Aral Sea, which was once the world's fourth largest lake, with a surface area of 68,000 km.[2]

6.1.1 Institutional arrangements

Since the break-up of the Soviet Union, water resources from the Amu Darya (which rises in Kyrgyzstan basin) and Syr Darya (which originates in Tajikistan basins) rivers have become the subject of competing interests and demands by the independent states. The states affirmed in 1990 their rights to control land, water and other natural resources within their territories, not only for agriculture production but also for energy purposes, resulting in unilateral development paths. The current legal framework for transboundary cooperation includes both binding instruments and various semi-formal agreements and documents:

- **Central Asian head of states created the Interstate Commission for Water Coordination (ICWC) of Central Asia on 18 February 1992 as an agreement on co-operation in shared management of international water resource use and protection. The ICWC is a technical authority, regulating and** supervising the allocation of water resources and related infrastructure.

- The agreement on Joint Activities for Addressing the Crisis of the Aral Sea and the Zone around the Sea, Improving the Environment and Ensuring the Social and Economic Development of the Aral Sea Region, signed on 26 March 1993, instituted a policy organ, the Interstate Council for the Aral Sea, and an executive organ, the International Fund for Saving the Aral Sea (IFAS). Subsequently, the Interstate Council for the Aral Sea and IFAS were united into a newly defined IFAS as the region's supreme policy organization on water resource management. IFAS is the political authority that guides and sanctions the work of the ICWC via principles and policies agreed upon among the member states. In 2004, ICWC and its executive bodies were annexed to the IFAS and were ranked as an international organization. Other regional bodies established by Central Asian countries include the Basin Water Associations, the

Scientific-Information Centre, the Training Centre and the Coordination Metrological Centre.

These arrangements are increasingly considered to have become outdated. In addition, new agreements were made only in basins with large-scale water-control infrastructure. A study by Wegerich (2008) concluded that the riparian states are engaged in strategies of resource capture by increasing their water demand without renegotiating agreements. Uzbekistan, in particular, demonstrates control over data, current discourses and over provision infrastructure. From 2003 onwards, countries such as Uzbekistan shifted from administrative to hydrological boundaries for water management. The future is uncertain as the interest of the international community in Central Asian water issues seems to be decreasing, partly because of the difficulty of achieving sustainable results (Libert and Lipponen, 2012).

6.1.2 Nexus challenges

Water, food and energy security forms a complicated nexus in Central Asia because of the need to balance domestic, regional and international interests. Central Asia is confronted with conflicts between upstream (hydropower) and downstream (cotton irrigation) uses. For instance, tension arises when Kyrgyzstan needs to release water in the winter time to generate electricity, while Uzbekistan and South Kazakhstan need water in the summer for their irrigation schemes.

The move by Kyrgyzstan to construct its Kambarata Dam has strained regional relations in Central Asia, and so has Tajikistan's plan to rebuild its Rogun Dam. This is because the Syr Darya and Amu Darya rivers, which originate in the mountains of these two countries, flow through Uzbekistan, Turkmenistan and

Kazakhstan . These th ree downstream countries are well endowed with energy resources that the upstream states are reliant on (World Bank, 2004).

There are essentially two views on climate change impact in Central Asia. The pessimistic view is that a warming climate will reduce available water and, particularly if combined with rising water demand, increase the propensity for water-related conflicts among the riparian countries. The optimistic view is that increasing temperatures cause depletion in snow and glacier storage in higher altitude regions, which translates into additional runoff. This will avoid a deterioration of the supply-demand ratio.

6.1.3 Nexus solutions

The nexus challenge is much studied in Central Asia (World Bank, 2004; Granit et al., 2012; Stucki and Sojamo, 2012), particularly in the context of water and energy nexus. Water is a central element in the nexus. Therefore, collaboration on water issues is of utmost importance for reaching development outcomes in these three interlinked sectors. In this regard, a nexus approach offers the following:

- **Cooperation with international donor community, particularly in raising the Aral Sea as a global issue;**
- **New windows of opportunities for new financial facility, capacity building and knowledge networks; and**
- **Opportunities to learn from the experience of other transnational river basins (e.g., Mekong River Commission [MRC]) using the nexus approach.**

Granit and colleagues (2012, p. 420) argue that the WFE nexus framework provides policy-relevant questions to stimulate collaborative action in the light of uneven spatial distribution of assets and their inter-connectedness in Central

Asia:

- Which parts of the benefit-sharing approach used during the Soviet times could be viable in the political economy of today?
- How do sovereign agendas influence development along the interconnected WFE nexus?
- Is there a scope and interest for increased collaboration in the WFE nexus among the Central Asian countries through a regional integration and collaboration approach?

Apart from offering a policy framework for cooperation, other opportunities include

- the introduction of new technologies in different sectors (such as water saving, recycling and alternative sources of energy);
- improvement of the legal bases and standards for transboundary cooperation for the nexus; and
- the development of a unified information

database.

These benefits apply at regional, national and local levels.

6.2 Water, energy and food security in the Mekong River Basin

The world's ninth largest river, the Mekong River, traverses six nations along its approximately 5,000-km pathway from its source on the Qinghai Tibet Plateau to the South China Sea. Its basin covers more than 800,000 km². Geographically, it is divided into the Lower Mekong Basin (comprising Cambodia, Lao People's Democratic Republic, Thailand and Viet Nam) and the Upper Mekong Basin (comprising Myanmar and China). The riparian population within the basin comprises over 72 million inhabitants.

6.2.1 Institutional arrangements

As the South-East Asian economic community improves, these countries have an interest on enhancing sub-regional energy-economic cooperation. As in most international river basins, the relationship between the upstream and downstream states in the Mekong River system is politicized and controversial. Each of the six Mekong riparian countries has a complex history of power relations with its neighbors, which still influences their perceptions and dialogue.

At present, there exists various power relations based on the present water utilization and the future needs of different member states. Lao People's Democratic Republic favors to realize its hydropower-generating potential, whereas Thailand seeks cheap energy (hydropower), more water for its modernized agriculture sector and enhanced flows in the Chao Phraya

Basin. Viet Nam wishes to protect its efficient agriculture and aquaculture production in the Delta from saltwater intrusion. Cambodia, on the other hand, prefers the conservation of the current hydrological regime, including the seasonal flooding, which gives rise to its significant fishery.

These varying demands were negotiated and codified in a framework agreement of MRC in April 1995 between the governments of Cambodia, Lao People's Democratic Republic, Thailand and Viet Nam. The Joint Committee and MRC Council governed the agreement. The role of MRC is to ensure the sustainable use and management of water and related resources of the Lower Mekong Basin.

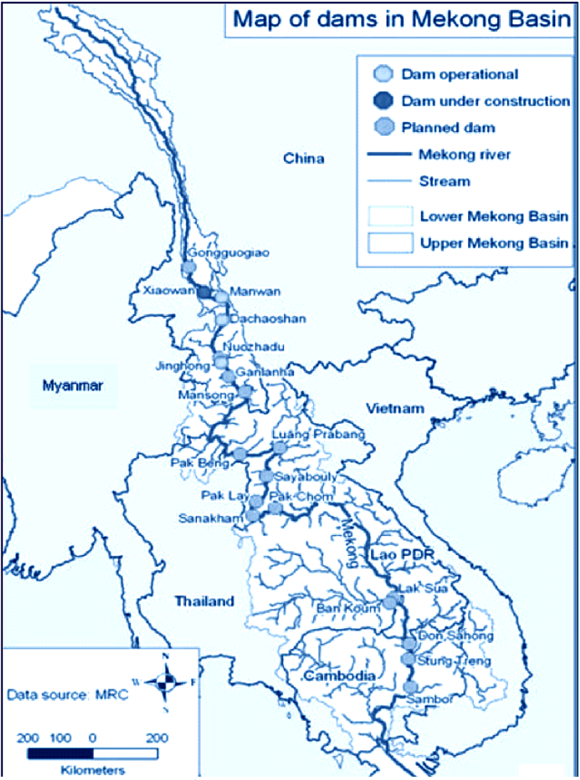
6.2.2 Nexus challenges

Unprecedented environmental change has accompanied rapid economic development within the basin in the past decades. Over 21 per cent of the basin is eroding, while only 31 per cent of its original forests left intact, but it continues to be under threat as only 5 per cent is currently placed under protection. Moreover, with the projected population growth of 2 per cent over the next 50 years, increasing environmental degradation will likely challenge the future of the basin.

The recent years saw a resurgence in global hydropower, driven by increasing demands for clean energy, cheap electricity and potential profits. There are eight existing or planned dams on the mainstream Upper Mekong, whereas the Lower Mekong is composed of 12 proposed d ams. In addition to the mainstream dams, hund reds of Mekong tributary dams exist or are in the planning stages (Figure 14). These tributary dams are located in Lao People's Democratic Republic, Thailand and Viet Nam. Hydropower

and irrigation expansion developments along the mainstream of the Mekong River and its tributaries may cause transboundary effects within the Mekong Basin region (Baker, 2012). The existing and planned dams and their diversions, together with irrigation expansion, could change the natural flow regime of the Mekong River and entail high risks to the riparian population. There are also potential impacts caused by unpredictable meteorological conditions, climate change and rising sea levels – all compromising the security of water, food and energy, which requires new consideration and
action by the Mekong River Commission.

Figure 14. Hydropower dams on the Mekong Basin.


Map of dams in Mekong Basin
Dam operational
Dam under construction
Planned dam
Mekong river
Stream
Lower Mekong Basin
Upper Mekong Basin
China
Myanmar
Vietnam
Thailand
Lao PDR
Cambodia
Mekong
Gongguoqiao
Xiaowan
Manwan
Dachaoshan
Nuozhadu
Jinghong
Ganlanba
Mansong
Luang Prabang
Pak Beng
Sayabouly
Pak Lay
Pak Chom
Sanakham
Lak Sua
Ban Koum
Don Sahong
Stung Treng
Sambor
Data source: MRC
200 100 0 200
Kilometers

Source: WWF (2013).

6.2.3 Nexus solutions

To reduce the risks identified in the previous sections, key ecosystems such as Tonle Sap in Cambodia and the Mekong Delta would benefit from multiple-scale WFE security nexus evaluation, from regional to basin and even from sub-basin to local impacts. Applying the nexus approach in the Mekong River Basin encourages synergy and informed trade-offs. By identifying energy as a key component, countries can begin to look at factors beyond nexus, such as economic policies that drive hydropower development. It may also maximize benefits in key areas for sustainability and equity.

The Mekong River Commission recognizes the importance of the nexus framework. In May 2012, the Commission organized the Mekong2Rio Conference, with the objective to understand how transboundary rivers can meet the water, food and energy needs of riparian populations while mi nimizing negative impacts (Bach, et al., 2012). With the participation of 350 participants from 14 river basin organizations, the Conference met the objective of sensitizing the decisionmakers and scientists in the region to the need of embracing a nexus perspective.

Since 2009, the Australian government has been funding the project Exploring Mekong Region Futures, which aims to improve the sustainability of the Mekong region. It does so by investigating the complex relationships among the production, distribution and use of water, food and energy of the region (Smajgl and Ward, 2013). The work revealed the dynamics of human migration, natural resource flows and financial investments, which influence a high level of connectivity between countries in the Mekong region.

To implement the nexus solution, the following barriers must be systematically removed:

- ***Sector-based approach*** **– unbalanced development among the three sectors, discordant responsibilities with a sector, fragmented management;**
- ***Governance*** **– geopolitics and international discord, political will and commitment, instability of internal politics, inflexible international legal frameworks, power of economic actors versus dispersed power of farmers; and**
- ***Science-policy interface*** **– lack of data, bad science, changing "goal posts" and jargon,**

insufficient capacity to evaluate complexities.

The dominant paradigm on economic development in the Mekong River Basin needs to embrace a more balanced nexus approach. This approach should recognize the importance of investment in and protection of natural capital. It also needs to acknowledge the need to maintain ecosystem functions and livelihoods (Bach et al., 2012).

Conclusions and Recommendations

Natural resource management questions are multi-faceted in nature and complex in resolution. The current international interest on WFE nexus presents a policy window to put in place systemic changes that embolden integrated resource management. To do so, the cross-sectoral effects of policies should be accounted for at all levels of governance. The goals of integrated resource policy, however, must recognize the durable constraints of unequal resource distribution at different scales, uncertain resource markets, the limits of eco-efficiency, and environmental carrying capacity.

This section elucidates the institutional requirements and the policy frameworks that are needed to build on the security nexus among water, food and energy resources in Asia and the Pacific region.

7.1 Deepen understanding of WFE nexus in Asia and the Pacific

Except for a few (see section 7), there is a dearth of studies on the interconnections between water, food and energy in Asia and the Pacific region. Water-energy nexus and water-food nexus analyses are better represented than the WFE nexus. Specifically, Pacific Island countries are less represented in the literature. The following actions are important to break through the "cognitive hurdle" of mainstreaming the WFE nexus approach:

- **Analytical comprehensiveness – The nexus accounting of water, food and energy needs to be more fully understood in terms of three metrics – physical (resource intensity), monetary (price and cost dynamics) and distributive (implications of social allocations).**
- **Scale-specific assessment – To enable policy-makers to ask the right policy questions of the future, formulate policy goals and address the nexus challenge, researchers must systematically explore country- or regional-scale studies but must also pay attention to local scale consequences.**
- **Policy salience – Knowledge on the nexus should**

be co-produced with bodies and social forces such as relevant authorities, experts and stakeholders governing water, food and energy resources. Establishing national and regional data-hubs will enable social learning that can empower adaptive management.

- Ecosystem approach – Because ecosystems are the economy's life support system, the environmental dimension must be integral to any WFE nexus framing and modeling.

7.2 Adopt the green economy model as meta-policy

Asia and the Pacific region needs to find profitable market-oriented solutions to the nexus challenges. A nexus framework must embrace green economy as a new policy goal and pursue "low-carbon, resource-efficient and socially inclusive" development strategies as espoused in the United Nations Conference on Sustainable Development (UNCSD or Rio+20) in June 2012 and in the UNESCAP Green Growth

Roadmap.

The Mckinsey Global Institute projects a resource productivity revolution with the following opportunities (Dobbs, et al., 2011):

- **Building energy efficiency**
- **Increasing the penetration of electric and hybrid vehicles**
- **Reducing food wastage**
- **Increasing yields on large-scale farms**
- **Reducing land degradation**
- **Increasing yields on smallholder farms**
- **Improving oil and coal recovery**
- **Reducing municipal water leakage**
- **Improving irrigation techniques**
- **Urban densification**
- **Shifting road freight to rail**
- **Increasing transport fuel efficiency**
- **Improving power plant efficiency**

Other green growth measures include identifying a multi-purpose approach to dam development to provide water supply, energy, flood protection and economic development as well as enhancing the storage capacity of reservoirs and identifying investments needed to revitalize private and public sector programs.

7.3 Re-orientate government policy framework

Despite the close relationship of water, food and e nergy resources, their funding and decisionmaking are managed as separate issues across the spectrum of policy, planning, design and operation. Three actions are needed on the part of governments.

- **First, governments must strengthen price signal to ensure productive and efficient use of resources. They can do this by removing energy, agriculture and water subsidies. Placing an attractive price on carbon will encourage private** sectors to transition to a greener economy.

- Second, governments can remove market failures that are not related to price. This may include actions such as improving access to capital such as through loan guarantees. This will enable innovation and redesigning of property right regimes to empower co-management of common pool resources.
- Third, governments can address the challenge of supply-and-demand chain by forging stronger linkages between resources and global markets. They can do this by focusing on the weakest links of each of the three resources and as a whole.

Other measures to re-orientate government policy framework include an awareness-raising campaign to "socialize" the idea of the WFE nexus. A re-designing of the property rights regime is necessary to circumvent "lock-in" policy decisions regarding land. In cases involving the community, efforts must be put in place to consider the risks of security narratives on society such as on community rights issues.

7.4 Disruptive innovation

Investment in agricultural research has declined i n the face of over–production. New research is needed to introduce modern technology for water application, such as drip and sprinkler irrigation and the use of new biotechnical innovations, including the development of crops modified to better withstand moisture stress.

7.5 Empower policy processes toward "institutional thinking"

The WFE nexus approach should identify which kind of processes support a transformation of structural conditions to build the foundations for sustainable and adaptive resource governance. It should recognize the consequences of one sector on another to achieve efficiency using systems thinking in order to foster policy integration and harmonization. The relevant core ministries responsible for water, energy and agriculture portfolio need to work closely together. Wide collaboration, although difficult, is the only effective way to address a potential crisis.

A WFE nexus-sensitive policy requires a systemic perspective to embrace complexity and the wealth of interactions characterizing resource governance regimes. Long-term policy thinking should be institutionalized in the core ministries governing water, food and energy resources. The institutions should be equipped with horizon-scanning tools such as future studies modeling and foresight.

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APPENDICES Appendix 1A

Summary of key publications on water resources in Central Asia

No.	Authors	Source	Findings
1	Kure et al. (2012)	Hydrological Processes	Regional hydrological climate impacts in Pyanj and Vaksh River basins in Tajikistan
2	Sorg et al. (2012)	Nature Climate Change	Climate change impacts on glaciers and runoff in Central Asia. Glacier shrinkage is most pronounced in peripheral, lower elevation ranges near forelands.
3	Rahaman (2012)	International Journal of Water Resources Development	Analysis of Central Asia's two water-related agreements: Agreement on the Cooperation in Joint Management, Use and Protection of Inter-state Sources of Water Resources (1992) and the Statute of the Inter-state Commission for Water Coordination of Central Asia (2008).
4	Porkka (2012)	International Journal of Water Resources Development	Application of water stress index and water shortage index to assess the role of virtual water flows in physical water scarcity in Central Asia.

5	Varis and Kummu (2012)	International Journal of Water Resources Development	The vulnerability profile for Central Asia's major river basins placed in comparison with Asia-Pacific's 10 important river basins.
6	Rakhmatullaev et al. (2012)	Environmental Earth Sciences	Review of present and past conditions of water reservoirs, irrigation and sedimentation in Central Asia. Main rivers are already highly regulated—Syr Darya (78 per cent) and Amu Darya (94 per cent).
7	Kienzler et al. (2012)	Field Crops Research	The current status of conservation agriculture in Central Asia. Proposal for more participatory approach with farmers and context-specific application.
8	Siegfried et al. (2012)	Climatic Change	Coupled climate, land-ice and rainfall-runoff model for Syr Darya to quantify the potential impacts of climate change on water stress. The area most at risk is Fergana Valley.
9	Qi (2012)	Frontiers of Earth Science	Overview of global change challenges facing Central Asia, including regional and international efforts.
10	Karimov (2012)	Water Policy	Trade-off between hydropower and irrigation in Syr Darya.
11	Abdullaev (2012)	International Journal of Environmental Studies	Improving water governance in Central Asia through the application of data management tools such as geo-information and remote sensing.
12	Oberkircher (2011)	Society and Natural Resources	Technology adoption by farmers in response to water scarcity. Scientific research must acknowledge local realities.

13	Bai (2011)	Environmental Monitoring and Assessment	Changes in the area of inland lakes in arid regions of Central Asia during the past 30 years. Also showed that human activities had broken the balance of water cycles.
14	Wegerich (2011)	Central Asian Survey	New water agreements were made only in basins with large scale infrastructure. Inequitable water allocation continues.
15	Janes (2011)	Asia-Pacific Journal of Public Health	Failed development and vulnerability to climate change in Central Asia and implications for food security and health.
16	Laldjebaev (2010)	International Journal of Water Resources Development	Sources of the water-energy issues in Tajikistan and avenues for their resolutions.
17	Gunchinmaa and Yakubov (2010)	Water Policy	Institutional arrangements for the reform of on-farm irrigation systems through Water User Groups.
18	Ziganshina (2009)	Journal of Water Law	Commitments to and compliance with international water law in Central Asia
19	Liobimtseva and Henebry (2009)	Journal of Arid Environments	Assessment of the vulnerability, adaptation and mitigation in the context of climate change in Central Asia. Aridity will increase especially in western Turkmenistan. Development of indicators of human vulnerability-food security, water stress.
20	Barlow and Tippett (2008)	Journal of Hydrometeorology	Variability and predictability of Central Asia warm season river flows shown to be closely related to the regional-scale climate variability of the preceding cold season

Appendix1B

Reference list of key publications on water resources in Central Asia.

Kure, S. and others. 2012. Hydrologic impact of regional climate change for the snowfed and glacierfed river basins in the

Republic of Tajikistan: hydrological response of flow to climate change. *Hydrological Processes*, DOI: 10.1002/hyp.9535.
Sorg, A. and others. 2012. Climate change impacts on glaciers and runoff in Tien Shan (Central Asia). *Nature Climate Change*, vol. 2, pp. 725–731.
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Appendix 2

Data challenges in Central Asia.

Research organizations active in Central Asia's water resource management issues are Tashkent Institute of Irrigation and Melioration International Water Management Institute, Tash kent; International Centre for Agricultural Research in Dry Areas (ICARDA-CAC), Tashkent; American University of Central Asia, Kyrgyzstan; and Transboundary Water Management in Central Asia Programme (GIZ GmbH).

One key assessment is the United Nations Economic Commission for Europe's (UNECE) range of projects in Central Asia, called the Second Assessment of Rivers, Lakes and Groundwaters, published in 2011. Central Asia is an important sub-region for activities under the UNECE Convention on the Protection and Use of Transboundary Watercourses and International Lakes (UNECE Water Convention). For a synopsis of assessments and scientific studies, see Appendix 1.

Central Asian countries and regional initiatives have gathered a large quantity of information on practically all issues related to water sector and water use. The key databases are as follows:

- **The Scientific-Information Centre of Interstate Coordination Water Commission (SIC-CWC) of Central Asia runs the Central Asia Regional Water Information Base (CAWIB) project with funding from the Swiss government.**
- **The National Snow and Ice Data Center (NSIDC) runs Central Asia Temperature and**

Precipitation Data, 1879-2003. This data set updates and expands the NOAA Global Historical Climate Network (GHCN) of quality controlled meteorological records.

- The United Nations Development Program's (UNDP) Central Asia Water Database presents high-frequency data in terms of their trends relative to multi-year averages. The database provides a more user-friendly picture of the extent to which high- or low-water conditions are in fact present in the Aral Sea basin. In addition to providing the full data base of raw data, UNDP's Central Asia Water Database also provides data in chart and in indicator formats.

The key data gap and challenges are as follows:

- The use of these information is complicated because they are fragmented, sparse, complicated to use and inadaptable to computer technology usage.
- The capacity for collecting, managing and

quality-controlling regional information is generally low. Monitoring networks are not sufficiently developed and, in some cases, are even deteriorating.

- There is only limited decision-making taking place at the regional level, which would drive the demand for information and policies beyond well-established business-as-usual practices.

The key research gaps are as follows:

- Finer resolution studies on disputes and water management solutions are available for key basins such as the Ferghana Valley but are harder to find for other important areas.
- Water and energy security is frequently discussed in the context of Central Asia, but not for all three resources – water, food and energy. The exception is found in the work of Granit et al. (2012) in a work entitled *"Regional Options for Addressing the Water, Energy*

and Food Nexus in Central Asia and the Aral Sea Basin."