The Status of the Water-Food-Energy Security Nexus

in Asia and the Pacific region

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Position Paper on the Status of the Water-Food-Energy Nexus in Asia and the Pacific region

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1. EXECUTIVE SUMMARY

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2. BACKGROUND

2.1. *The debate on resources scarcity*

Scholars have debated the central role of natural resources for economic development and human survival for more than two centuries. The general argument goes: as extraction rates of resources increase, the horizon of scarcity shortens (see Norgaard 1990). In the last decades the concern over resource depletion not only continues but seems 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, hence, posing a threat to sustainable development. The famous book *The Limits to Growth* produced a scenario analysis of 12 possible futures from 1972 to 2100, and concluded that continued growth in the global economy would lead to significant resource scarcities in the first decades of the 21st century (Meadows et al 1972). Committed conservationists then demanded a lowering of the environmental impact per unit of gross domestic product.

However, in the 1980s real energy and mineral prices fall, producing little evidence of looming shortages (Tilton 1996). This vindicated the position of those unconcerned about resource depletion, who claimed with equal conviction 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 1980s. The "roaring" 1990s saw a further increase 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 is reignited. According to a study by the McKinsey Global Institute there has been 147% increase in real commodity prices 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 sink strength. Many indicators point to the unprecedented planetary changes such as biodiversity loss, climate change and nitrogen removal from the atmosphere (Rockstrom et al 2009). Consequently, the 21st century has been hailed as the century of the environment. Humanity is now considered as a geological force that has ushered in a new epoch called the Anthropocene. Today, an estimated 60 per cent of the world's ecosystem services have been degraded since the mid-20th century.

Resource problem was mainly a local (or national), 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 strategic resources of energy, water and food (EWF) are considered to be inextricably linked. The Asia Pacific region is considered to be an important site for this contest.

2.2. New resource realism

Five attributes characterize the recent perception of resources scarcity. *First*, a 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: 15). This realization has also encouraged countries to 'dematerialize' their economic development by reducing and circulating resource usage. Examples are the policies of *Circular Economy* in China and Japan's *Low Material Society* policy.

The *second attribute* has to do with technical, social and environmental challenges on the exploitation 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). Another case is shown in 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 are subject to a higher risk of supply disruption. In addition, planetary global warming is set to amplify the existing environmental 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 GDP annually as a result of existing climate patterns.

The unprecedented demand for more and new natural resources makes the *third attribute*. It is powered by the sudden emergence of insatiable new consumers as a result of surging economic growth in China, India and other Asian economic powerhouses. Up to three billion middle-class consumers will emerge in the next 20 years compared to 1.8 billion today (Dobbs et al 2011). The market distortion of resource pricing for populist reasons is deepening the scarcity crisis. According to McKinsey up to $1.1 trillion is spent annually on resource subsidies.

As opposed to only confronted with the physical scarcity of single natural resources, the world is now grappling with multiple resources scarcities. The dwindling natural resource stocks began to send shocks to the global economic system as reflected in the market. From 2007 to 2008, food prices rose sharply. Their persistence and high volatility since then have resulted in far reaching implications. The World Bank stated that 44 million people were driven into poverty by rising food prices in the second half of 2010. 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. In July 2008, oil prices reached US$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 interconnectedness (of price volatilities) underlines the *fourth attribute*, with energy, water and food 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* whereby leading corporations asked governments to assert more control on water resources. Similarly in the food sector, the Sustainable Agriculture Initiative (SAI) which includes big businesses such as Danone, Nestle, Unilever, Kellog's Kraft, McDonalds and PepsiCola has been engaging other stakeholders involved in influencing food policies (Lang and Barling 2012). However, the presence of state prevails. Recent years saw the rise of resource nationalism as a strategic response to the perceived resource exhaustion (e.g. state-owned petroleum companies).

2.3. Rationale to integrate water-energy-food

The idea of 'limits' as propagated 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: 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 acceptable socially and politically?

Of all natural resources, energy, water and food are most needed to sustain life on earth. These three strategic resources share many comparable characteristics: billions of people without access to them; they are rapidly growing global demand; all face resource constraints; all three are 'global goods' 'involving international trade with global implications; each have different regional availability and variations in supply and demand; and all operate in heavily regulated markets (Bazillian et al 2011). 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-Energy-Food Nexus and Its Drivers

The three resources are tightly interconnected, forming a policy nexus. A macro argument is in order here. Food production is the largest user of water globally. It is responsible for 80-90% of consumptive water use from surface- and ground-water. Water, however, is also used to generate electricity and about 8% of global water withdrawal is for this purpose. Energy, in turn, is needed to transport and fertilise crops. Food production and supply chains are responsible for around 30% 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 there will be a 70% increase in demand for food and a 40% rise in demand for energy. Yet by 2030, the world has to confront a water supply shortage of about 40%. Therefore, our economy cannot run on the same finite energy, water and food resources far into the future.

Water, energy and food are inextricably linked. Water for energy currently amounts to about 8% of global water withdrawals. Food production and supply chain is responsible for around 30% of total global energy demand.

Food production is the largest user of water at the global level, responsible for 80–90% of consumptive blue water use. Food production is the largest user of water at the global level, responsible for 80–90% of consumptive blue water use. However, in 2050, with 9.2 billion people sharing the planet, it is expected that there will be a 70% increase in agricultural demand for food and 40% energy demand increase. Yet by 2030, the world will confronts water supply shortage of approximately 40%.

2.4. *Benefits of the Nexus approach*

The Nexus perspective focuses on the interdependence of water, energy, food (W-E-F) by understanding the challenges and finding opportunities. The Nexus approach recognizes the interconnectedness of W-E-F across space and time. Its objectives are:

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

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) below. 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".

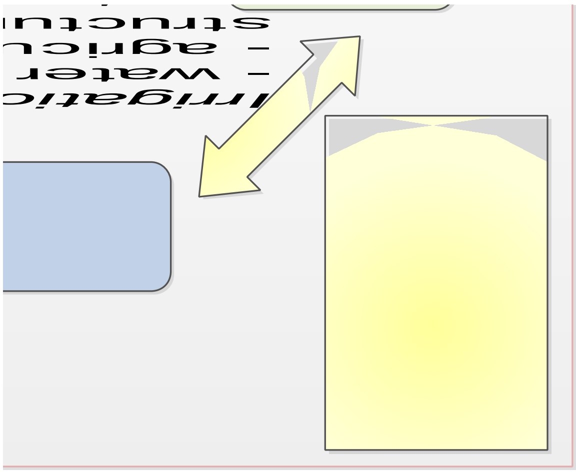

Figure 2: Schematic of water-energy-food nexus and its constituent issues

Currently despite the close relationship of energy and water, the funding, policymaking, and oversight of these resources are typically performed by different people in separate agencies. 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 for not integrating concerns over water and energy simultaneously (Hussey and Pittock 2011):

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

The development of first generation biofuels represent another layer of complexity by imposing trade-offs on all food, water and energy resources concomitantly. Recognising the WEF connection is necessary as the three resources are traditionally managed as separate issues across the spectrum of policy, planning, design and operation.

2.5. Report overview

Section 3 discusses the emergence of the WEF Nexus in the policy and academic debates internationally. It stems from the global concern with the security of strategic resources such as water, energy and food. Section 4 reviews the literature on the Nexus focusing on its assessments, institutional arrangements and the proposed policy options. Next, Section 5 analyses the looming resource challenge in the Asia Pacific region. Based on the region's peculiarity, Section 6 illustrates eight types of WEF interconnectedness with examples from within Asia Pacific. Section 7 delves deeper into the meaning of the Nexus by using three case studies, namely Central Asia, Mekong Basin and the Indo-Malaysia archipelago. Not surprisingly, in existing policy frameworks, energy and water policies are developed largely in isolation from one another. Before concluding, Section 8 outlines four key areas of policy interventions needed to mainstream the Nexus concept in the Asia Pacific region.

3. NEXUS AT THE FOREFRONT OF POLICY AND SCIENTIFIC DEBATE

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

Similarly, the emerging fear of energy, water and food 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 food, energy and water second only to terrorism as a foreign policy priority in Britain.

The nexus of water, energy and food is currently gaining attention from strategic circles in the policy and academic domain.

3.1. Policy conferences

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

- the World Economic Forum, regularly held in Davos;
- The Bonn Perspective on Rio+20, 2011 organized by the German government;
- Ministerial Roundtable 'W-E-F Security Nexus', Marseilles;
- World Water Week in Stockholm 2012 (theme: water and food security); and
- Mekong2Rio International Conference on Transboundary River Basin Management, held in Vientianne, Lao PDR.
- South African Water, Energy and Food Forum: "Managing the mega-nexus", held in Sandton.
- The Water Summit 2013 Abu Dhabi: Bringing WEF Nexus to Life.
- Managing Water, Energy, & Food in an Uncertain World (Universities Council on Water Resources UCOWR) held in Santa Fe, USA
- Corporate Sustainability in Africa 2012: "Living in the water, food and energy nexus", Johannesburg.
- Water, Energy, Environment and Food Nexus: Solutions and adaptation under changing climate, held in Lahore, Pakistan.

The meeting in Bonn gave birth to an active and informative website covering the latest issues and events on water, energy and food nexus. Its URL is http://www.water-energy-food.org . Its goal is to create (Bonn2011 Nexus Conference, 2011: 3):

> "…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 interlinkages between water, energy and food sectors as well as the influence of trade, investment and climate policies".

The Bonn2011 nexus approach emphasizes the guiding principles of: investing to sustain ecosystem services; creating more with less; and accelerating access, integrating the poorest.

The World Economic Forum brings the WEF security nexus to full political attention at the Davos Summit through the Global Risks 2011 report. It described the interconnected security problem as (World Economic Forum, 2011):

> "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."

3.2. 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. The meeting which was hosted by His Majesty King Carl XVI Gustaf of Sweden was joined by 19 renowned international scholars 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 R&D in relevant areas and
- to rethink policy and to focus on actions that address not just climate change, but a wide spectre of fundamental human needs for development.”

(Anonymous, 2010: 199)

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

- 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 20th 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, 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 other 160 breakout discussions and plenaries.

Together, all these high profile meetings send a clear message to decision-makers in governments, business and civil society. The message is that the ways in which countries deal with water, energy and food security will heavily influence economic growth, human well-being and the environment we live in and rely on. These fora also provided platforms for international dialogue and for suggesting investment and policy recommendations.

3.3. Nexus elements in major documents and initiatives

The WEF security nexus is now a part of international development canon and a recognized policy paradigm. The list below shows a number of

	Organization/Body	Documents/Meeting	Position on Nexus or its Elements
1	Food and Agriculture Organization (FAO) of the United Nations	The Energy and Agriculture Nexus. Rome. 2000. Energy and Natural Resources Working Paper No. 4 [p]	Energy-agriculture nexus is a coherent system. Bioenergy could boost agricultural productivity for rural development. Link between energy, biomass and carbon flows
2	UNESCAP	Low Carbon Green Growth Roadmap for Asia and the Pacific. 2012. [p]	Energy, water and food 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 [p]	Embrace 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 [p]	Broadens the debate on WEF 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 (IFPRI)	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[p]	Examines water for energy relationships and estimates total freshwater needs by energy source and region
8	The World Bank	Overcoming Barriers to	A report on the

		International Cooperation of River Basins Critical for Food, Water, Energy Security [p]	importance of river resources for the Nexus
9	United Nations Conference on Sustainable Development (UNCSD)	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	Establish a regional program on R&D on WEF security	Collaborating with ADB to publish the Third Water Development Outlook for Asia and the Pacific

4. UNDERSTANDING OF THE NEXUS

The academic and policy literature on current and future challenges in water, energy and food security explores three main themes. First, the nature of the relationships among the three elements (through input-output analysis). Second, the consequences of their changes and changes in other sectors including geopolitical implications. Third, their implications for policy development and actions for addressing the three securities (Bizikova et al 2013).

4.1. Input-output relationship analysis

A major proportion of the scientific literature on the Nexus focuses on the analysis of input-output relationships. The Nexus is mainly characterized in resource efficiency terms.

A country-level analysis of water input into energy production:

- In the United States, the energy sector is the single biggest user of water in the economy (Carter 2010).

An industry-based assessment of water use in energy production:

- Pan et al (2011) calculated information about water withdrawal, consumption and wastewater drainage at each stage of coal supply chain in China. It is shown that without effective regulations or water saving measures, China's demand in the coal industry could surpass China's near future water supply capacity.

A comparative analysis of comparison of water-for-energy and energy-for-water:

- In Texas, USA, approximately 595000 megalitres of water annually (enough for 3 million people for a year) are consumed by cooling the state's thermoelectric power plants (Stillwell et al, 2011). Each year Texas uses 2.1-2.7

terrawatt-hours of electricity for water systems and 1.8 to 2.0 terrawatt-hours for wastewater systems. This value is enough to cover the electricity need for 100,000 people for a year. The article suggests that that increased efficiency advances both the sustainability of water and energy systems, and by extension reducing the costs to water and power consumers.

An analysis of energy for food production:

- Cuellar and Webber (2010) argue that the practice of intensive agriculture today is energy hungry. Contributions are through mechanized land preparation, fertilizer, irrigation and other inputs. Almost 8% of all energy consumed in US is for food production. About 27% of food is wasted and 2% of energy is wasted in unconsumed food.

An analysis of energy requirement in the production of biofuels:

- Murphy and Allen (2011) analyze 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 are calculated for each of the 48 states within the continental U.S. 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.

An analysis of water for energy and its impact on climate mitigation:

- Li et al (2012) reports that China's wind energy consumes 0.64l/kWh of water and produces 69.9g/kWh of CO_2 emission. Wind power could contribute to 23% of carbon intensity reduction, saving 800 million m^3, sufficient for use by 11.2 million households.

An analysis of environmental footprints of water and energy use in food production systems:

- Using the case study of the southern Murray Darling Basin in Australia, Khan et al (2009)present an empirical application of the WEF nexus by identifying the main pathways to reducing the environmental footprints in the agricultural system of rice, wheat, and barley production on selected farms The analysis indicates that boosting water productivity 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.

4.2. Analysis of institutional and policy dimensions of resource

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.

- 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 (Mukherje, 2007).

- Dramatic increase in costs of energy led to decreased domestic water access in Alaska's Northwest, with adverse effects on household hygiene practices (Eichelberger 2010).

- The literature also show 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)

- Malik (2010) examines the nature of water–energy nexus at the level of end users (as opposed to sector-based analysis) and their coping strategies. He uses the case study of India where the demand for both water and energy exceeds the available supplies of these resources. The paper also examines the nature of policy interventions that could help in moving towards bridging the gap between the demand and supply of water and energy, especially in inter-linked activities

- The findings of Henrikson (2011) and his co-authors suggest that in Europe there is much scope to encourage soil-management strategies that would mitigate greenhouse gas emissions and increase energy and water efficiency.

- Siddiqi and Anadon (2011) perform a country-level quantitative assessment of energy-water nexus in the 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 case of Saudi Arabia it is estimated that up to 9% of the total annual electrical energy consumption may be attributed to ground water pumping and desalination. Other countries in the Arabian Gulf may be consuming 5-12% or more of total electricity consumption for desalination. The results suggest: policy makers should explicitly consider energy implications in water intensive food imports and future restructuring of water demand; and an integrated decision may involve water reuse and changes in the agricultural sector and not the expansion of desalination systems that are energy intensive and financially expensive.

4.3. Nexus policy options

There are examples of policy options that could strengthen the nexus directly or indirectly. Although the interconnected nature of WEF 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 2013: 3). An exception is the case of water-energy nexus in the United States. As of November 2009, at least nine states had statutes recognizing the nexus between water and energy (Siddiqi and Anadon 2011). The important role of research to deepen our understanding of the nexus is duly recognized by universities in the United States, Spain and Australia. For instance there was a proposal in the United States to create institutions to administer and research nexus issues and share the findings *viz* the *Energy and Water Research Integration Act*, USA. However, although it was formulated it was never approved.

Other options to target synergies and avoid potential tensions include:
- enforce legislation linking groundwater extraction to power use;
- develop technologies to build water, energy, and food infrastructure;
- promote technologies that exploit the potential for more efficient, cost-effective, and local close-loop solutions based on lifecycle analysis;
- create incentives (and sanctions) to private, public, and civil society to accelerate the Nexus goals;
- increase agricultural power tariffs; and
- limit new power connections for groundwater wells.

The Bonn2011 meeting offered the following policy recommendations to address the three sustainable development pillars:
- accelerating access and integrating the bottom of the pyramid (society),
- creating more with less (economy), and
- investing to sustain ecosystem services (environment).

Its specific policy interventions are detailed below (Hoff 2011):
- increasing resource productivity;
- using waste as a resource in multi-use systems;
- stimulating development through economic incentives;
- governance, institutions and policy coherence;
- benefiting from productive ecosystems;
- integrated poverty alleviation and green growth; and
- capacity building and raising awareness.

The 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 (IISD) also proposes its very own 'Water-Energy-Food Security Analysis Framework', focusing on operationalizing the Nexus concept (see Figure 3 below).

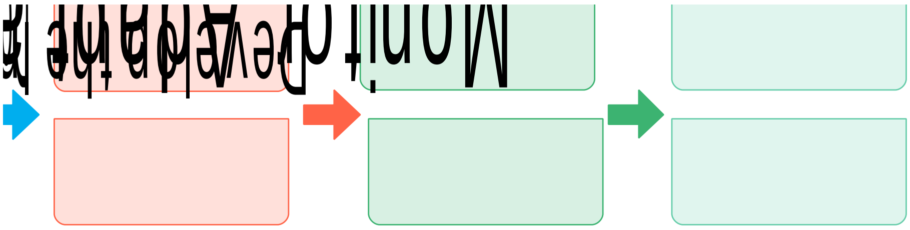

Figure 3: The IISD framework on the stages of WEF Nexus implementation
Source: Bizikova et al 2013

4.4. Geopolitical implications of the Nexus

There are many areas in which the nexus presents situations of tension and conflict due to the finite nature of many natural resources combined with a soaring increase in demand (Homer-Dixon 1991). This is true for even non-conventional security issues like water-energy-food are rapidly which are rapidly acquiring the status of full-fledged security threats. The security literature is replete with case studies of regions and country with existing or emerging risks. Figure 4 illustrates the potential flashpoints in Southeast Asia, Gujarat in India, the Nile Basin, Saudi Arabia, the Arctic Pole and South China Sea.

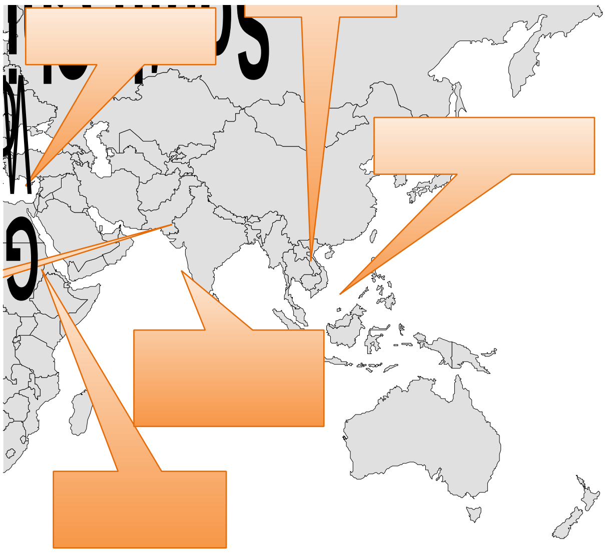

Figure 4: Examples of Nexus geopolitical flashpoints

4.5. *The Nexus as an economic and environmental strategy*

The preceding review of Nexus approaches essentially point to the combination of a utilitarian objective to use resources for economic development but guided by the principle of sustaining ecosystem services rather than presiding over their continuing degradation. It goes without saying that 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 centre-stage, with attention given to ecosystem services. Figure 5 illustrates a conceptual framework.

Figure 5: Water, energy, and food security nexus as an environmental strategy

5. THE LOOMING RESOURCE CHALLENGE IN ASIA AND THE PACIFIC

Since the 1990s, many of the Asia–Pacific region's developing economies have been characterised by rapid urbanization, large investments in infrastructure development, and by the emergence of new consumers. The increase in resource use in Asia and the Pacific between 1970 to 2005 has been above the world average (see Table 1). Domestic materials consumption (DMC) by the Asia–Pacific region grew more than fourfold from 7.6 billion tonnes in 1970 to 31.9 billion tonnes in 2005 (Schandl and West 2010). The per capita increase is equally astounding – in 1970 the per capita DMC stood at 3.2 tonnes (approximately 25% of the contemporary figure for the rest of the world) but by 2005 it had risen to more than 8.6 tonnes per capita (about 87% of the corresponding rest of the world figure).

Table 1: Average annual growth rate of material use

	Average annual growth rate of material consumption (% 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: UNESCAP 2012

The section discusses the trends, forecast and implications of water, energy and food resources security in Asia Pacific.

5.1. Water security

At the Second World Water Forum in 2000, the Global Water Partnership (GWP) 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 2012). Another related concept propagated by the same GWP is Integrated Water Resources Management (IWRM), which it defined as:

> ‘‘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.”

Both definitions accepts that human dependence on water is not a merely technical issue involving water-supply-use (e.g. irrigation) but much broader. Falkenmark (2001) strongly urges water to be recognized as water is acknowledged as the bloodstream of the biosphere, pointing to its environmental importance. Cook and Bakker (2012) argue that both concepts 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 (water rights, water allocation, inter-sectoral reallocation) that are based on complex amalgam of existing water uses and competing interests.

5.1.1. Water trends

The Asia-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. Invariably, water security throughout the developing countries of Asia and the Pacific is poor and under growing threat (Table 2). The fastest increase in water demand in Asia is now coming from the industry and urban households, and not agriculture anymore (ADB 2013). Already 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 requires further investments of US$59 billion for water supply and US$71 billion to provide access for improved sanitation (WHO 2010).

Table 2: 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

Vietnam	524,710	891,210	58.9

Source: Chellaney, 2011

However, annual average water availability has little meaning to measure water scarcity. Large parts of Monsoon Asia suffer from severe water scarcity while the average annual resource availability appears abundant.

5.1.2. Nexus challenges

Water is physically scarce in densely populated areas such as Central and West Asia. This scarcity relates to water for food production. Arguably, the countries in the region are not facing water scarcity because of physical scarcities of the resource alone, but because of poor management.

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

- *Climate change* - The IPCC predicts that freshwater availability in Central, South and East and Southeast Asia is likely to decrease due to climate change, along with population growth and rising standard of living, which 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 by reducing water availability in areas where irrigation is most needed or has comparative advantage (Turral et al 2008).

- *Water demand* - Water availability has become a serious constraint to sustainable food system 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, for example 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 sea (ADB 2013).

This insecurity poses risks for public health, political stability, and continued economic growth both within Asia and abroad.

5.2. Energy security

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

“access to clean, reliable and affordable energy services for cooking and heating, lighting, communications and productive uses”(AGECC 2010)

The objective of energy security, according to energy historian Daniel Yergin (1988: 11) “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 “[t]raditional thinking of energy security”, according to Downs (2004: 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. Fuelled 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.

5.2.1. Energy trends

Over the past 200 years, global energy use has grown by 25 to 530 exajoules (EJ) (United Nations 2011). The International Energy Agency projects world primary energy demand to reach between 14,850 Mtoe and 18,300 Mtoe by 2035, equivalent to an increase of between 23 and 51 per cent from 2009 (IEA 2010). In the past two decades, energy demand in China, India and other emerging economies has grown tremendously. By 2009, more than half of primary energy was consumed by developing countries, joining 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. This is a result of faster rate of population and economic growth as well as urbanization. Oil demand in Asia is expected to grow 44% (10.9Mbpd) between 2010 and 2015, accounting for some 86% of the global demand increase. With respect to natural gas, Asia’s demand will increase 143% (755 bcm), accounting for 45% of global demand increase. Asia’s coal demand, on the other hand, will increase 47% (1,379 Mtce), accounting for 119% of global demand increase, balanced only by declines in OECD countries.

Rapid economic growth to serve a large population base leads China to be the largest energy consumer in Asia. While 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 termed the ‘Chindia challenge’ by security experts (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 ASEAN, the Asia Pacific Energy Research Centre (APERC) projects energy demand to increase 170% between 2007 and 2030, from 375 Mtoe to 1019 Mtoe.

China’s and India’s energy demand has grown rapidly over the past decade and most projections suggest their voracious thirst for energy will further 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.

5.2.2. Nexus challenges

The future regional outlook is characterized by more energy demand but uncertainties in supply. Serious doubts have arisen 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 lead to long-term price increases which may in turn affect the security of other natural resources. Herein, geo-economics 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 geopolitical terms.

- *Energy scramble* - There is fear that petroleum availability, both in the near and long term, will become increasingly scarce as Asia Pacific countries absorb a growing global share of demand. This concern is not surprising given that the three major Chinese national oil companies — CNPC (China National Petroleum Corporation), Sinopec (China Petroleum and Chemical Corporation) and CNOOC (China National Offshore Oil Company) – have been pursuing ambitious internationalization strategies since the 1990s.

- *Alternative energy* - Leading options to respond to the need to increase energy security by increasing the domestic production of oil and oil substitutes and reducing greenhouse gas (GHG) emissions through non-conventionals and renewables may be limited because of water quantity or quality constraints. Hydraulic fracturing (fracking) and first generation biofuels for instance requires large volumes of water. This is especially a challenge in a semi-arid area where water is already scarce and groundwater tables are declining. The security of electricity supply is also a challenge with resources crunch.

- *Nuclear power plant proliferation* - Nuclear power generators use about 2.5 times the water per unit of electricity than gas and 25 percent more than coal. In Asia, as of 2008, the World Nuclear Association reported 111 nuclear reactors were in operation, 19 under construction, 63 planned, and 112 proposed (Symon 2008). The largest existing nuclear power industries are in Japan and South 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, Southeast Asian countries' interest in nuclear power reflects growing concern over the economic cost and environmental impact of other fuel sources. Vietnam, Indonesia, Thailand and Malaysia are examples of countries in the region with concrete plans for nuclear power implementation

5.3. Food insecurity

Securing future food availability is a top priority in most countries. At the 1996 World Food Summit, food security is defined as (FAO 2009: 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 at the Summit included the call for at least halving 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 the Asia Pacific region (see Figure 6). Arguably, accessibility to food is the only security concern in the region. Food security challenges in the Asia Pacific region are influenced by other related concepts such as food sustainability, resilience, defense, et cetera. Table X illustrates a set of overlapping social and policy-relevant meanings on food security that now compete for policy legitimacy and presence.

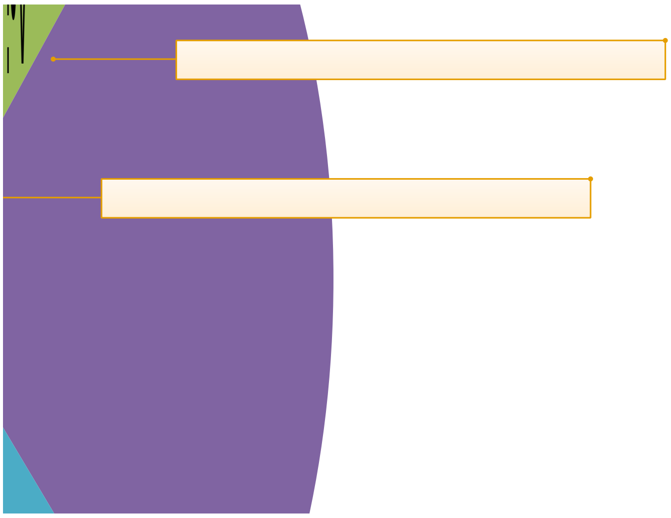

Figure 6: Undernourished population by region, 2010
Source: FAO, 2010

Figure 7: Ideas informing the food security discourse
Source: Adapted from Lang and Barling, 2012

5.3.1. The trends

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 crisis and the food crisis in 2006-08, have deprived more people of access to adequate food. The food crisis has pushed100 million people into poverty in 2007-2008 and nearly 50 million in the latter half of 2010 (World Bank 2011 cited in UN 2011). Countries in the Asia Pacific region were seriously affected by these episodes. Malaysia for instance shambled into panic when its food supply was disrupted following Vietnam's export restrictions on rice.

As 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 projected to grow by 70% to 100% in the next 50 years (ADB 2013). This will escalate the pressure on water-for-food as agriculture already accounts for 79% of annual average water withdrawals in Asia and the Pacific.

5.3.2. Nexus challenges

Lang and Barling (2012) argue that the older debate on food policy concerns how to tailor food systems to respond to industrialization and urbanisation, and how to enable people to be fed from a natural and a biological world. The challenges to food production in Asia-Pacific are still underpinned by this debate and other new concerns such as:

- *Aging irrigation system* - a prolonged period of low public investments in irrigation has resulted in poor service to farmers, which in turn is demotivating farmers from making their own investments in agricultural inputs.

- *Productivity of agriculture* - farmers in South Asia by 2050 will need to divert up to 57 per cent more water to agriculture and in East Asia up to 70 per cent if they cannot increase productivity,

- *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% of irrigated areas in Pakistan, 23% in China, and 50% in Turkmenistan (ADB 2013).

- *Land-grab* - As a response to the food insecurity concern, the investments in agricultural and forest lands in many parts of the world (not only developing) 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 Inter-governmental Panel on Climate Change suggests that a 2°C increase in mean air temperature could decrease rain-fed rice yields by 5-12% in China and under one scenario net cereal production in South Asian countries is projected to decline by 4 to 10% by the end of this century. In Bangladesh, production of rice may fall by just under ten per cent and wheat by a third by the year 2050.

Ensuring a secure supply of food is essential, given Asia Pacific's high and volatile food prices, and increasingly scarce resources.

6. THE INTERDEPENDENCE OF WATER, ENERGY AND FOOD RESOURCES

Water, energy and food are strategic resources sharing many comparable attributes. We have only rudimentary understanding of the complex and pervasive connections between water, energy and food security. This section exemplifies Asia Pacific experiences with the interlocking effects of the WEF Nexus which results in challenges that cross two or even all three of the domains. It also identifies its 'geographical hotspots' in region.

6.1. *Biofuels*

Asia's currently largest biofuel producing countries are Indonesia, Malaysia, Thailand, the 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 especially is the key reason for the majority of the Asian countries' involvement 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 3).

Table 3: Biofuel Targets for Selected Asia Pacific Countries

Country	Biofuel Targets
Australia	350 million litres of biofuels by 2010
China	12 million metric tons of biodiesel by year 2020
India	E5 blending mandates by 2008, E20 by 2020, E10 in 13 states
Japan	20% of the total oil demand met with biofuels by 2030;
Thailand	3% biodiesel share by 2011; 8.5 million litres of biodiesel production by 2012

Source: Adopted from Timilisina and Shrestha, 2011

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

Water intensive biofuels water has raised concerns about the increase in water stress, particularly in countries that are already facing water shortages. In China, the current level of bioethanol production consumes 3.5–4% of total maize production of the country, reducing market availability of maize for other uses by about 6% (Yang et al 2009). It is projected that depending on the types of feedstock, 5–10% 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 32–72km^3 per year, approximately equivalent to the annual discharge of the Yellow River. Not only that, there are a number of environmental concerns related to first-generation biofuel production, which depend on feedstock type, production location, agronomical practices.

The International Food Policy Research Institute (IFPRI), in its study carried out between 2000 and 2007, found that biofuel demand resulted in a 30% increase in the weighted average grain price. However, the biofuel share of the totally supplied global energy in 2006 was only 0.2% and the share of the fuel for the transport sector was about 1%. But if the share of biofuels in the energy mix is to be increased significantly, very strong effects on food prices would be expected.

6.2. Hydropower

Water is not merely an environmental issue, but also a strategic issue. A major cause of diplomatic anxiety between neighbours in Asia is the construction of dams on international rivers to generate electricity.

Hydropower generation meets 16% of the world's electricity needs and has been one of the main driving forces behind the construction of 45,000 large dams world-wide. By 2030 it will be the world's dominant renewable energy source with 170GW under construction. It is also fast growing in Asia with 76% more hydropower planned across the region (IEA, 2009).

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. It involves the upper reaches of 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 affects rice paddy cultivation on the Assam floodplain and worsen Bangladesh's food insecurity problem.

The Mekong Rive flows from the headwaters in the Tibetan Plateau for 4,880km through China, Myanmar, Laos, Thailand, Cambodia and Vietnam. It drains 805,604 square kilometres of land known as the Mekong basin, a major granary for Asia. Today, 60 million people live in the Lower Mekong Basin, 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 MW. 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, 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 devastating economic loss of around US$476 million (RM1.4 billion) per year.

There is also a plan to builld a dam in Papua New Guinea to construct giant 1800 MW. The power generated will be sent by 500km cable across the Coral Sea to

Weipa, Mt Isa and Townsville in Queensland, Australia. The plan to dam this area would flood much of the valley of River Purari, a sacred ancestral land and sago planting area. .

6.3. *Thermoelectric production and water security*

The requirement of water in thermal power plants is well recognized.

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).

In China, the mining, processing, and combustion of coal accounts for 22% of domestic water consumption (REN21 2012).

Energy production is a large user of water resources, and in turn, the water sector is a large user of energy. Strategies to promote increased water productivity may include those (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.

- provision of incentives to encourage investment in reducing leaks in water delivery infra- structure; promote installation of energy-efficient pumps

6.4. *Irrigation and food security*

Water is essential for food production. Irrigation has helped boost agricultural yields in arid environments and stabilized food systems (Rosegrant and Cline 2003). It provides approximately 40% of the world's food from less than 20% of its area (FAO 2003). Yet, irrigation may results in unwanted environmental consequences. In Asia, it is estimated that by 2025, 17 million hectares of the irrigated rice area may experience "physical-water scarcity", and 22 million hectares "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, taxing groundwater and not surface-water for irrigation (Mukherji 2007). Khan and colleagues (2006) describe three rice irrigated 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 issues in these areas although with different climatic and underlying hydrogeological conditions. The authors propose a radical rethink 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. 2007). 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 to help unlock productivity gains. The use of smarter technologies would require investment in the upgrading of irrigation infrastructure.

6.5. Irrigation and energy security

Energy and irrigation are closely linked. To produce our food most types of agriculture require energy. Apart from food security, irrigation also exerts pressure on energy security. Irrigation accounts for about 15–20% of India's total electricity use. Punjab has only 1.5% of India's land, but its output of rice and wheat accounts for 50% of the grain the government purchases and distributes to feed more than 400 million poor Indians. A significant problem is that farmers are pumping aquifers faster than they can be replenished, and, as water levels drop, increased pumping is sapping an already fragile and overtaxed electricity grid.

6.6. Food trade and virtual water

Through food trade there is a virtual flow of water from producing and exporting countries to importing and consuming countries.

6.7. Land and food security

As one of the world's biggest food importers, South Korea's foreign agricultural investment has been on a steady increase (Pearce 2012). In 2009, Korea Times reported 73 Korean companies were growing grain on 23,000 ha in 18 countries. It was also reported that the food giant Daesang grows 13,000 ha of maize in Cambodia for shipping back to Korea.

Droughts in the past decade have left big farmers in Australia bankrupt and selling up. 45 million ha of Australian land ceased production (Pearce 2012). New acquisition include:

- Australian Agricultural Company sold controlling interest to Dubai's food & fat giant IFFCO and Malaysia's FELDA
- Consolidated Pastures 5.7 million ha of NT grassland was sold to British Terra Firma, a private equity firm

- Canadian company Agrium owns the Australian Wheat Board now named Agrium Asia Pacific limited
- Singapore's Wilmar is buying into Queensland sugar; Olam bought 9,000 ha almond orchards , delivering half of Australia's almond harvest
- San Diego's Summit Global Management spent $20 million buying up water licences in Murray Basin

These acquisitions have been received negatively by the Australian public. The Sydney Morning Herald ran a headline that says "Australians are in danger of becoming servants and not masters of their own food resources". Such a public outcry reflected a sense of siege with what is perceived as land-grabbing.

6.8. Water production and energy security

Energy is of concern in every stage of the water production and supply chain. 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 cubic metres of water a day. Currently it is dependent on 40% imported water while increasing local catchment and using desalination and recycling water technologies (Table 4). Singapore aims for water self-sufficiency by 2060 and has leveraged this option to develop NEWater (recycled water) by innovation.

Table 4: Current water sources and 2060 targets for Singapore

	Current reliance (%)	**2060 Targets (%)**
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

However current desalination and membrane technologies (for NEWater) require large amounts of energy which is costly both in environmental pollution and in money terms based on 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.

7. CASE STUDIES OF THE WEF NEXUS CHALLENGE AND SOLUTION

7.1. 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. They are rooted in past and present environmental degradation, the socio-economic transition after the breakup of the Soviet Union, and the impacts of climate change. The Soviet period 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. It was once the world's fourth largest lake with a surface area of 68,000 km^2.

7.1.1. Institutional arrangements for inter-state resource management

Conflicts can also arise between hydropower and downstream uses, including irrigation, in-stream uses, and supporting ecosystems. For instance conflicts arises when the Kyrgyz Republic 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 three downstream countries are well endowed with energy resources that the upstream states are reliant on.

Since the break-up of the Soviet Union, water resources from the Amu Darya (which rises in Kyrgyztan) and Syr Darya (which originates in Tajikistan basins become subject to 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 trans-boundary cooperation includes both binding instruments and various semi-formal agreements and documents:

- The Interstate Commission for Water Coordination (ICWC) of Central Asia is created according to Agreement on co-operation in shared management of international water resources use and protection adopted by Heads of State on 18th February 1992. 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 (ICAS), and an executive organ, the International Fund for Saving the Aral Sea (IFAS). Subsequently, ICAS and IFAS were united into a newly defined IFAS as the region's supreme policy organization on water resource management. The IFAS is the political authority that guides and sanctions the work of the ICWC via principles and policies agreed among the member states. In 2004, ICWC and its executive bodies are annexed to the International Fund for Aral Sea Saving (IFAS) and rank as an international organization. Other regional bodies established by Central Asian countries include Basin Water Associations, Scientific-Information Centre, Training Centre, and Coordination Metrological Centre

One gap is that these arrangements are increasingly considered to have become outdated. In addition, new agreements were only made 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. Uzebekistan, in particular, demonstrates control over data, current discourses, and over provision infrastructure. From 2003 onwards, countries like 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 & Lipponen 2012).

7.1.2. Climate change

There are essentially two views about 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 a depletion of snow and glacier storage in higher altitude regions that translates into additional runoff, which at least in the next few decades, will avoid a deterioration of the supply-demand ratio.

7.1.3. Data challenges

Research organizations active in Central Asia's water resources management issues are: Tashkent Institute of Irrigation and Melioration; International Water Management Institute, Tashkent; International Centre for Agricultural Research in Dry Areas (ICARDA-CAC), Tashkent; American University of Central Asia. Kyrgyztan; 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:

- 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.
- UNDP's Central Asia water database presents these high-frequency data in terms of their trends relative to multi-year averages, in order to provide 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 these data in chart and indicator format.

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 and monitoring networks are not sufficiently developed and in some cases are even deteriorating.
- At present 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 harder to find for other important areas
- Water and energy security are frequently discussed in the context of Central Asia, but not for all three water-energy-food. The exception is found in the work of Granit et al (2012) in a work titled "Regional Options for Addressing the Water, Energy and Food Nexus in Central Asia and the Aral Sea Basin".

7.2. Energy and water security in the Greater Mekong Sub-region

The Greater Mekong Sub-region (GMS) comprises of six countries i.e., Cambodia, China, Laos, Myanmar, Thailand and Vietnam located along the longest river in Southeast Asia called the ''Mekong River''. As a greater Southeast Asian economic community, these countries have an interest on enhancing sub- regional energy-economic cooperation.

Table 4: Irrigated area in the Lower Mekong Basin Countries until 2003

Country	**Irrigated Land: 1000ha**				**Share in arable land and permanent crops (%)**			
	1979-1981	1989-1991	1991-2001	2003	1979-1981	1989-1991	1991-2001	2003
Laos	107	135	174	175	13.3	15.7	18.2	17
Cambodia	120	240	270	270	5.8	6.3	7.1	7.1

Thailand	3007	4248	4973	4986	16.4	20.6	25.8	28.2
Vietnam	1685	2867	3000	3000	25.6	44.8	36.4	33.4
All LMB Countries	4919	7490	8417	8431	17.7	23.6	26.1	26.8

Source: Adapted from Hoanh et.al, 2010

7.3. Biofuels in the Malaysia-Indonesia archipelago

Although promoted as a solution for reducing GHG emissions, the production of some biofuels has turned to be unsustainable. This is especially true for feedstock producing areas in some developing countries. Indonesia and Malaysia are the leaders in biodiesel production. They provide an interesting case study of the intricate links cementing water, food and energy resources together (see annotation in 6.1).

[INCOMPLETE SECTION]

8. POLICY RECOMMENDATIONS

The increasing interdependence of the three strategic resources may raise security concerns and create geographical flashpoints for conflicts. Nevertheless, the current international interest on Nexus presents a policy window to put in place systemic and crosscutting changes that embolden integrated resource management. This begs the question about the institutional requirements and the policy frameworks that are needed to build on the nexus between water, energy and food.

8.1. Deepen the understanding of WEF nexus in Asia Pacific

In general there is a dearth of studies on the interconnections between water-food-energy in the Asia Pacific region. Water-energy nexus and water-food nexus are better represented than WEF nexus with case studies of water bubbles such as India, China and Central Asia.

- Specifically, the nexus of water, energy, and food needs to be more fully understood in terms of three metrics – physical, (resource intensity) monetory (price and cost dynamics) and distributive (implications of social allocations):

- To enable policy-makers to ask the right policy questions of the future, and formulate policy goals and address the nexus challenge, country- or regional-scale studies must be explored systematically.

- Knowledge on the nexus should be co-produced with bodies and social forces such as relevant authorities governing WEF resources

8.2. Adopt Green Economy (or Green Growth) model

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 where possible.

The world needs to find profitable market-oriented solutions to nexus challenges. The Mckinsey Global Institute projects a resource productivity revolution with the following opportunities:

- Building energy efficiency
- Reducing food wastage
- Increasing yields on large-scale farms
- Increasing yields on smallholder farms
- Reducing municipal water leakage
- Urban densification
- Increasing transport fuel efficiency
- Increasing the penetration of electric and hybrid vehicles

- Reducing land degradation
- Improving oil and coal recovery
- Improving irrigation techniques
- Shifting road freight to rail
- Improving power plant efficiency

Other eco-efficiency measures include:

- take a multipurpose approach to dam development to provide water supply, energy, flood protection and economic development;
- enhance the storage capacity of reservoirs and promoting transboundary data collection/sharing and governance; and
- identify investments needed to revitalize private and public sector programs.

8.3. Re-orientate government policy framework

Three actions are needed on the part of governments.

- First, strengthen price signal to ensure productive and efficient use of resources. This can be done by removing the energy, agriculture and water subsidies (amounting to more than US$ 1 trillion). 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 (through loan guarantees etc) to enable innovation and redesigning property right regimes to empower co-management of common pool resources.

- Third, address the challenge of supply-and-demand chain by forging stronger linkages between resources and global markets. This can be done by focusing on the weakest links of each of three resources and *in toto*.

8.4. Disruptive innovation

Investment in agricultural research has declined in the face of over–production. New research is therefore needed:

- introduce modern technology for water application, such as drip and sprinkler irrigation; and use new biotechnical innovations, including development of crops modified to better withstand moisture stress.

8.5. Empower policy processes toward 'institutional thinking'

The Nexus approach 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, even though difficult is the only effective way to address a potential crisis.

9. CONCLUDING REMARKS

Distillation of key points will set the scene for policy recommendations.

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1. APPENDIX 1

Summary of key publications on Central Asia water resources

No.	Authors	Source	Findings	Nexus		
				W	E	F
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 Interstate Sources of Water Resources* (1992) and *the Statute of the Interstate 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 & 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%) and Amu Darya (94%).	■	■	
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 if Fergana Valley	■		■
9	Qi, J. et al 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, J. et al 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 only made in basins with large scale infrastructure. Inequitable water allocation continues	■		
15	Janes,C.R. 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, M 2010	Int. J. of Water Resources Develop.	Sources of the water-energy issues in Tajikistan and avenues for their resolutions	■	■	
17	Gunchinma et al 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 & 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 & Tippett 2008	Journal of Hydrometeorology	Variability and predictability of Central Asia warm season river flows are shown to be closely related to the regional-	■		

			scale climate variability of the preceding cold season			