ADB

Thinking about Water Differently

Managing the Water-Food-Energy Nexus

Asian Development Bank

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Abbreviations

ADB	–	Asian Development Bank
PRC	–	People’s Republic of China
DMC	–	developing member country
m^3	–	cubic meter

Executive Summary

Concerns about water security have reached the mainstream media, highlighting a significant threat to water availability at the global and regional level, particularly in certain parts of Asia and the Pacific. In fact, economic growth in the region will soon be constrained by water shortages, affecting the reliable production of food and energy. Part of the discussion is in terms of the water–food–energy nexus, that is, the links between the businesses of supplying water, food, and energy.

The evidence for existing and emerging water scarcity has been presented by a wide range of organizations. The 2030 Water Resources Group stated that with the total annual sustainable freshwater supply remaining static at 4,200 billion cubic meters (m^3), the annual deficit for 2030 is forecasted to be 2,765 billion m^3, or 40% of unconstrained demand, assuming that present trends continue. India and the People's Republic of China (PRC) are forecasted to have a combined shortfall of 1,000 billion m^3—reflecting shortfalls of 50% and 25%, respectively. There is little evidence of changing trends. Signals of scarcity and stress have had little impact on policies, demand, or the market.

On the supply side, there is little room for finding and abstracting more water. In areas with physical water scarcity (including north PRC, south and northwest India, and Pakistan), demand needs to lessen. Elsewhere in Asia, with economic water scarcity (Bangladesh, Cambodia, north and northeast India, Lao People's Democratic Republic, Myanmar, Nepal, and Viet Nam), new investment may still be aimed at improving supply-side infrastructure.

However, throughout the region, solutions have to be found mainly on the demand-side. Demand-management studies, conducted at a global level, illustrate the impact and costs for a wide spectrum of measures to reduce demand, whether in agriculture, industry, or municipal water use.

Water for food. The highest social and political significance is the water–food link. Rising food prices, food price spikes, shortages, adverse market interventions, social instability, and food riots are already a reality, and may make governments finally take decisive action on water security. All of South Asia, Cambodia, the Lao People's Democratic Republic, Papua New Guinea, and the Philippines have been classified as "high food security risks"; Afghanistan as "extreme risk"; and the rest of the region as "medium food security risk."

Water for agriculture uses at least 70% of available freshwater, through either rain-fed or irrigated systems. As much as 50% of this water may be used more productively, however, through elimination of irrigation or production inefficiencies. In particular, in South Asia, irrigation efficiencies have been allowed to remain low through energy subsidies, although there are encouraging signs with the uptake of new technology. Water efficiencies in agriculture increased by only about 1% per year between 1990 and 2004. Of the food produced, up to 40% is often wasted. Despite these inefficiencies, investment in agricultural research has declined in the past decades, and basic interventions to improve and drive efficiency improvements and productivity enhancements at scale have been absent.

Water for energy. Increasing access to energy is a priority for many countries in the region, as nearly 1 billion people lack access to electricity. Yet expanding energy production requires greater access to freshwater, making future energy production dependent on water access. Seventy-five percent of the expected increase in energy use to 2030 will be met from fossil fuels, especially coal. One of the most challenging aspects of the water–energy link is that the low-carbon growth target for energy generation is particularly hard to meet, as many alternative low-carbon sources consume more water.

Energy in water. In urban water supply, wastewater and sanitation systems, energy is often the main operational cost component. The process of distributing water and collecting wastewater is energy-intensive. The associated large-scale pipe networks are costly to operate, as they have high levels of power consumption to drive pressurized or pumped systems. Many of these systems are inefficient, but more importantly, any water losses are readily translated to energy losses. This contributes adversely to carbon and water footprints.

The region is short of water at a time when it is making some of its most impressive gains in reducing poverty. Historic levels of economic development have put huge burdens on the environment, with water resources paying a high price. The risk of water scarcity is already threatening the region's development ambitions, and water scarcity in many countries has implications for food production and industry. Both rely on unsustainable levels of water consumption. Most countries in the region, particularly the PRC and India, need to take urgent steps to improve water efficiencies in food production, energy generation, industrial production, and municipal water services.

Further, environmental degradation and inequitable access to water, both in urban and rural settings, will always affect the poor and vulnerable first and worst, without access to affordable alternatives or cost-effective means of coping. Failure to address these key issues will result in increasing ill health for children and the elderly, and growing inequity and further marginalization of the poor and vulnerable, particularly women and girls.

The facts on the water–food–energy nexus point to the ineffectiveness in the existing management of water as a finite resource and to the inability to recognize water as an economic as well as a social good. The reason for the apparently irrational behavior on the use and allocation of water must be the absence of a true market for water. The information that is available is not leading to sustainable decisions about changing the value that is assigned to water. The present set of incentives does not lead to actions that are essential for an equitable and secure supply of food and inclusive and sustainable growth. The issue is, therefore, a combination of accessible information and the incentives that should follow from such information.

Governments must be encouraged to take a longer-term view, that is, to accept short-term investment or higher costs for long-term benefits. This requires a clear mandate from a broad constituency to facilitate these trade-offs. Such a constituency is gaining ground in Asia and the Pacific, among informed citizenry as well as businesses. Investors now demand intelligence on the water risks facing their prospective investment targets. Evidence of concerns by international and local financial markets on water security will help inform the priority that governments will attach to dealing with water scarcity. The introduction of new metrics, such as the water footprint, provides consumers a sense of the impact of their choices on water scarcity. Likewise, the concept of virtual (embedded) water in commodities allows a reassessment of international and regional trade practices.

The complexity of the interlinkages affecting water puts new demands on water governance. In the past, global society believed that it could afford to let water abstractions take their course, assuming unlimited resources; this is no longer sustainable. New modes of interaction and collaboration are required, using existing institutions with new mandates or creating new institutions. Such new institutions will need access to accurate data and analytical tools, supported by new forms of economic modeling to reflect the complexity of the nexus.

For the Asian Development Bank (ADB), the challenge is how to respond in this environment. In planning for a future approach to water, it must establish (i) why past national water policies and strategies have not been effective in the face of clear, imminent shortages and thereby allowed a crisis situation to develop and (ii) what impact ADB interventions in water (e.g., agriculture, urban, energy, and natural resources) can realistically achieve.

Actual and forecast water scarcity will compel project design to place the search for efficiencies in all water uses at its center. Similarly, water resources constraints have put renewed urgency on promoting investment and technologies toward wastewater management, including reuse. The private sector, already recognizing the risks related to water shortages in investment planning, will equally embrace the opportunities offered by the need for innovation and investment, provided clear and unambiguous messages emerge from governments and financial markets.

The critical role for ADB in securing future water for the region, and guiding the international water community in this, is to encourage its developing member countries (DMCs) to respond proactively to the prospect of water stress by adopting radically new ways of managing water, introducing good water governance, and recognizing the irreplaceable value of a limited resource. In other words—starting to think differently about water.

The new ADB country water assessments will assist DMCs in recognizing the need for water governance and management, based on accurate facts about the balance between current supply and demand for water, and on a realistic forecast.

Ultimately, the country water assessments will lead to a vision of how national water security may be achieved or maintained, balancing competing needs for food and energy. Based on this vision, options and scenarios can be described for a full unconstrained program of action designed to deal with any future water scarcity or water stress.

From such an unconstrained program, an outline can be selected of what should constitute government response to working toward water security for the future. Using planning horizons of 10 and 20 years, and based on an outline of what a new national water policy should contain, a coherent and rational national program of action needs to be designed, underpinned by a set of proposals for water governance structures aimed at effective water management and allocation.

Consistent with the proposed government program, an ADB program of funding and technical support can be proposed for a 10-year period. The suggested ADB country water program should be in support of ADB's Water Operational Plan as well as the latest country partnership strategy. ADB country water assessments are also anticipated to have relevance beyond ADB water operations, providing key guidance on ways to drive efficiency of water use in the power generation sector and to highlight the critical importance of reducing food waste through better storage, handling, and transport infrastructure at the farm-to-market level.

Some strategic thrusts likely to be promoted by ADB in the water sector include the following:

(i) **Reforming water governance.** Through advocacy at global, regional, and national levels, demonstrate convincingly to DMCs the critical need to manage water differently, assigning its strategic and vital value in allocation and trade-offs, and to amend governance structures and procedures accordingly.

(ii) **Data and information.** Support DMCs in generating reliable data on the availability and behavior of water resources, in particular, groundwater. Make information on all aspects of water security accessible and place them into the public domain, including possible measures to deal with water scarcity.

(iii) Resource protection. Support DMCs in more effective reduction of wastewater and other waste discharging into freshwater supplies through regulation, investment, and innovation.

(iv) Water for food. Stimulate research into improving the use of water in agriculture, increasing food production on the same area of land, and using less water.

(v) Increasing storage. Promote increases in strategic storage, including aquifer recharge, in response to uncertainties in supply, aggravated by climate change.

Background

This report was conducted under a technical assistance project[1] that aims to assist the Asian Development Bank (ADB) in understanding the water–food–energy nexus in the context of water security issues, both at the policy and project levels.

This report is in line with the ADB Water Operational Plan.[2] In addition, ADB has started to embrace the concept of the water footprint for products, processes, and people to introduce a metric for embedded water use and water trade. This should allow for a better-informed position on the formulation of policies on water governance.

Box 1. **The Writing on the Wall**

A few books have set the scene for the current concerns on the limitations of water to sustain humankind's activities. *Silent Spring*, by Rachel Carson, brought environmental concerns from academia to the broader public and stoked interest in ecology and environmental sciences. Published in 1962, its main message concerned the accumulation of DDT in the environment, and birds in particular, as a result of its uncontrolled application as a general biocide.

Limits to Growth (1972) by Donella and Dennis Meadows modeled the consequences of a rapidly growing human population and finite resource supplies. It cautioned that there were limits to sustainable growth. Many have since claimed that "the green revolution," which lifted millions out of hunger and poverty in the decades that followed, proved these predictions wrong. Others point out that *Limits to Growth* was ultimately shown to be correct, as limits to sustainable growth have been breached. Growth and spending has been at the incalculable expense of irreversible damage to environment and depletion of nonrenewable resources.

The March of Folly: From Troy to Vietnam by the historian Barbara Tuchman (1985) does not deal with natural resources; however, its theme of ill-advised leaders guiding their people to self-destruction in the pursuit of irrational goals or "follies," despite the availability of feasible alternatives, was picked up by Jared Diamond (see below). To be classified as a folly, a choice had to be clearly contrary to the self-interest of the group pursuing them; conducted over a period of time, by a number of individuals; and, importantly, there had to be people alive at the time who pointed out correctly how the act in question was self-destructive.

Collapse: How Societies Choose to Fail or Survive by Jared Diamond (2005) relates directly to the current debate on security of water, food, and energy. Analyzing the reasons for the collapse of human civilizations in history, Diamond recognizes the common patterns of human action (including population growth) causing the natural carrying capacity of systems to be exceeded. His concluding list of the 12 environmental factors that will determine our future include those of water and soil management, deforestation, and energy.

When the Rivers Run Dry by Fred Pearce (2006) is a terrifying, but measured, account of the damage caused by humankind to its rivers. Despite the very bleak tales, the book maintains a message of hope—providing that the world begins to think about water differently.

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1 ADB. 2008. *Technical Assistance for Knowledge and Innovation Support for ADB's Water Financing Program*. Manila.

2 ADB. 2011a. *ADB Water Operational Plan, 2011–2020.* Manila.

Water Security in the Face of Water Scarcity

Evidence

The ADB Water Operational Plan summarizes the status of knowledge and data on the emerging water crisis for Asia and the Pacific. The discussions in this Plan base some key data on the analysis published by the 2030 Water Resources Group of the World Economic Forum Water Initiative (Box 2).[3] In addition, many of the data and arguments on the relationship between water and agriculture, and the ability to meet future food demand, originate from a seminal comprehensive assessment,[4] which aimed to define the options for improving water productivity in agriculture. To indicate current urgency, the plan also acknowledged a recent report focused exclusively on food price volatility and food security.[5]

Box 2. Twelve Economic and Geopolitical Water Issues for the Next Two Decades

1. Water scarcity will increase dramatically in many parts of the world. This will have significant social and economic repercussions. Global grain harvests will be threatened, more countries will rely on food imports, and the livelihoods of many people will be threatened. This is on top of the billion or so people who do not have access to improved water supply today.
2. Meanwhile, global demand for food, especially meat, will rise sharply, placing more pressure on water for agriculture. Unless we change how we manage agricultural water, we will not be able to provide the food for tomorrow's consumer demands.
3. At the same time, and compounding the problem, fast-growing economies, especially in the Middle East and Asia, will likely allocate less water to agriculture over the next 2 decades and more to the growing demands of their urban, energy, and industrial sectors.
4. Domestic reform of water for agriculture is, therefore, urgently required in many water-stressed countries, in order to produce "more crops with fewer drops." But there is currently little political interest in this.
5. The over-extraction of freshwater is also compromising the environment severely in many parts of the world. Climate change adds to the urgency; its impacts play out most prominently in water resources.
6. Engaging in global trade can also help countries to manage water security issues, but the global trade system for agriculture is outdated and in urgent need of reform.

continued on next page

[3] World Economic Forum Water Initiative. 2011. *Water Security: The Water–Food–Energy–Climate Nexus.* Geneva; 2030 Water Resources Group. 2009. *Charting Our Water Future: Economic Frameworks to Inform Decision-Making.* Washington, DC: World Bank.

[4] Comprehensive Assessment of Water Management in Agriculture. 2007. *Water for Food, Water for Life: A Comprehensive Assessment of Water Management in Agriculture.* London: Earthscan and Colombo: International Water Management Institute.

[5] High Level Panel of Experts on Food Security and Nutrition of the Committee of World Food Security. 2011. *Price Volatility and Food Security: A Report by the High Level Panel of Experts on Food Security and Nutrition of the Committee on World Food Security.* Rome.

Box 2 *continued*

7. With agriculture remaining a thinly traded good, gains from trading so-called "virtual" water are limited. Changes in the geopolitical landscape will start to occur, as water-scarce countries seek their own water solutions.

8. Simultaneously, the United States and European Union will also seek to improve energy security. Energy policy decisions have strong connections to water, climate, and food security policy, which can spin negatively or positively. Energy policy must take into account these interlinkages. Domestic energy security should be seen as a decision to switch from relying on foreign oil to relying on domestic water.

9. Improving water infrastructure for cities, energy, and industry will become urgent across all economies, especially in Asia. Poor quality and inefficient water supply services will be seen as a brake on economic growth. Private finance will be required, as public funds will not be able to fill the water investment gap. Governments that introduce reforms in water supply management will attract private finance. This does not mean taking water supply out of public ownership, but undertaking reforms to ensure private investor risks are reduced and rates of return become more desirable. International aid for water will be increasingly used to access credit for private investments into public infrastructure on the back of these reforms.

10. The raw economics of water are both compelling and challenging: water security, economic development, and gross domestic product are interlinked. Business and capital will be attracted to those economies in water-scarce regions with sound water management. New technologies, new markets, and new financing ideas will be attracted to solving the water challenge. Water will become a mainstream theme for investors. Governments in water-scarce regions that undertake water reforms will strengthen and position their economies well. Global financial regulators will have to develop clear rules to manage the inevitable appearance of innovative water funds.

11. The overall conclusion is clear: governments in water-scarce regions will be in a weaker position if they choose not to engage in water management reforms, whether in their agricultural, energy, and municipal sectors, or through multi-country discussions on trans-boundary issues, international trade, and investment flows. The global water forecast for the next 2 decades, if no reform actions are taken, is chilling; water scarcity will have a profound effect on global and regional systems, whether from an economic growth, human security, environmental, or geopolitical stability perspective.

12. The current economic downturn offers an opportunity to start addressing the emerging water crisis. Management of future water needs stands out as an urgent, tangible, and fully resolvable issue, which can only be improved by a multi-stakeholder effort led by government. Governments can bring business and civil society together to help address a commonly (and often locally) felt challenge. While some trade-offs will be inevitable, all can benefit from improvements in how water is managed. Now, when a suite of reforms is required to fix systemic problems in the economic system, is the perfect time to start the water reform dialogue.

Source: World Economic Forum Water Initiative. 2009. *The Bubble Is Close to Bursting: A Forecast of the Main Economic and Geopolitical Water Issues Likely to Arise in the World During the Next Two Decades*. Geneva.

The Supply–Demand Gap

At a global level, the evidence for water scarcity—the reason to be concerned about water security—has been made eloquently. As stated, much is based on the groundbreaking work done for the 2030 Water Resources Group that was spawned by the World Economic Forum Water Initiative. This work detailed annual demands in 2005 with projections for 2030, which are summarized as follows:

(i) Globally, agriculture accounted for about 3,100 billion cubic meters (m^3), or 71%, of water withdrawals in 2005. If there are no efficiency gains, this will increase to 4,500 billion m^3 by 2030.

(ii) Industrial withdrawals accounted for 16% of current global demand, growing by 91%, to take 22% of withdrawals in 2030. This growth will mainly come from the PRC, which alone will account for 40% of the additional industrial demand worldwide.

(iii) Demand for domestic use will increase from some 600 billion to 840 billion m^3 per year, representing a relative decrease by 2030 as a percentage of total water withdrawal, from 14% to 12%.

Underlying these projections is the trajectory of trends, that is, the growth of average per capita demand for food, energy, and consumer goods compounding a still continuing growth in population. These projections are especially significant in the region because of the sheer number of people living in it, who are reflecting the aspirations of the population in the developing world toward the lifestyles and thereby the spending patterns of the developed world. Many forecasts have pointed out that the planet cannot sustain the call on resources if the entire population spent resources at the present rate of an average North American citizen.

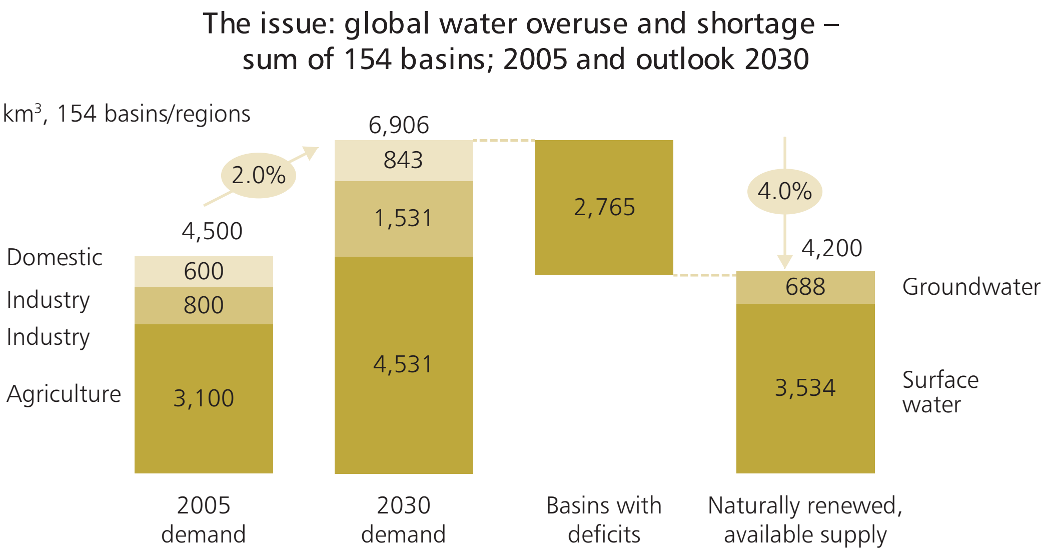
The gap exhibit (Figure 1) has become the starting point for much of the water security debate. It shows a 40% gap between sustainable supply from global river catchments and the projected demand in 2030. In certain catchments, this gap is already real, at least during below-average rainfall years. What is not yet clear—and where the biggest challenge lies—is how changes can be put in place on the demand-side to most effectively reduce global demands for water. Affordable options on the supply-side are all but exhausted. Thus, the issue has become how to transform the water sector for sustainability.

The warnings about a water crisis and water scarcity are based on forecasts by economists, farmers, scientists, water managers, and chief executives in global corporations. By 2030, there will be a significant supply–demand gap if the same trend continues. Unfortunately, the present level of preparedness, under existing conditions, makes it unlikely that the projected gaps will be closed effectively and efficiently without intervention.

This is the global setting, presented in a manner to cause impact, to call attention to an imminent crisis. However, it is important to note that the measure and the nature of the gap clearly varies between regions and catchments. The necessary actions, therefore, vary as well. In many parts of the region, water stress is caused or aggravated by avoidable inefficiencies, in ineffective and uncoordinated management of water resources, in failing or inadequate infrastructure. In these circumstances, strategic improvements can still be achieved on the supply-side.

ADB recognizes that a water crisis in the region is not inevitable. Even if supplies are limited, trends can be changed, demands can be modified, and productivity can be increased. Above all, water governance can be improved.

Figure 1: **Gap between Supply and Demand of Water** (forecast for 2030)



km^3 = cubic kilometer.

Source: Water 2030 Global Water Supply and Demand model; agricultural production based on IFPRI IMPACT-WATER base case. Cited in World Economic Forum Water Initiative. 2011. *Water Security: The Water–Food–Energy–Climate Nexus*. p. 206. Geneva.

The challenge in formulating a response by ADB to water scarcity is in identifying and broadcasting the right mix of motivation and incentive for change. The water–food–energy nexus is complex and multidisciplinary by its very nature. The principles that bind it together are likely to be interpreted as being of an environmental nature, which has rarely proved to be a decisive incentive for politicians to take immediate and drastic action. The crucial motivators for change that ADB must highlight in its dialogue with its developing member countries (DMCs) are, therefore, those of food security, energy security, and economic advantage.

Momentum for Change

The facts that are now being put into the public domain about an emerging water crisis are leading to considerable debate on food and water security issues at global affairs forums and in the media. The main challenge now becomes how to bring out the facts and the options for change more convincingly, using arguments that can be easily understood by decision makers and that can be supported by a popular constituency. Broad-based understanding and support are vital, as measures must be taken that in the short-term may lead to higher costs or to a curtailing of rights for the long-term sustainable protection of resources and the equitable sharing of access to these resources. Three converging goals must be recognized as the guiding themes: (i) ensuring food security, (ii) reducing poverty, and (iii) conserving ecosystems.

The Water–Food–Energy Nexus

Context

The global debate is not about water security or water scarcity in isolation. Instead, it is about the nexus, that is, the links among water, food, and energy. For instance, in Asia, the extraordinary growth of industrialization and urbanization pushes the demands for energy, but expanding power production will be limited by water availability. But it is the growing demand for food, with its high water requirement, superimposed on population growth, which crucially turns an abstract crisis into a critical and immediate one.

The real threat is food scarcity, the ever-present risk of food price instability and the still-existing scourge of widespread poverty in the region. Over 568 million people, or 15% of the population, remain undernourished today.[6] These issues are much more visible than a future, abstract problem with water, which is largely invisible. Concerns about water security are shared globally. But Asia has its unique features in this: it has enormous opportunities, but equally some very real threats. The contrast is striking. The water crisis has been brought into this urgent focus partly because of the increasing wealth in newly industrializing PRC and India, with the resulting changes in lifestyle and consumption and aspirations of a growing urban middle class. At the same time, the Asia region (with about 58% of the world's population) holds 67% of the total global undernourished population (Table 1).

Decision makers and constituencies cannot be convinced of the need to act on water security if its urgency are not supported by indisputable and clearly accessible facts that show how many

Table 1. **Population Undernourished in Asia's Largest Countries**

Country	Undernourished, 2006–2008 (million)	Total Population, 2006–2008 (million)	Undernourished in Total Population (%)
People's Republic of China	129.6	1,336.5	9.7
India	224.6	1,164.6	19.3
Indonesia	29.7	224.7	13.2
Pakistan	42.8	173.2	24.7
Bangladesh	41.4	157.7	26.3
Total for 5 Largest Countries in Asia	**468.1**	**3,056.7**	**15.3**
Global Population	**850.0**	**6,652.5**	**12.8**

Source: FAO. 2011. *The State of Food Insecurity in the World 2011*. Rome.

[6] FAO. 2011. *The State of Food Insecurity in the World*. Rome. The FAO measure of food deprivation, which is referred to as the prevalence of undernourishment, is based on a comparison of usual food consumption expressed in terms of dietary energy (kcal) with certain energy requirement norms. The part of the population with food consumption below the energy requirement norm is considered undernourished ("underfed"). Energy requirement norms differ per country.

issues are linked and thus have similar solutions.[7] The focus, therefore, must be on putting such facts and information into the public domain. Decision makers must acknowledge that

(i) food security will only worsen unless agricultural productivity is improved and the waste in the water used for agriculture is reduced;

(ii) food prices will continue to be subject to fluctuation, with causes on both the demand- and supply-side, including increasing frequency of weather shocks; and

(iii) poverty in rural and urban Asia will only worsen if strategic groundwater reserves continue to be mined and consumed, and if aquatic ecosystems continue to be destroyed by failing to account for their real value in stabilizing and storage.

Old water economics has failed to protect the resource. Market mechanisms have failed. Nonrenewable resources have been mined; water has been given away for free, often through blanket energy subsidies. Strategic future resources have been polluted as a cheap, convenient method of waste disposal. Such actions were possible largely because the underlying data were obscure; that is, the economics were not transparent.

Further, the competing calls on constrained water resources have become too great to permit arbitrary and unconstrained withdrawals without making rational allocations, based on agreed systems of trade-offs. In other words, what is called for is good water governance.

Water Resources

Throughout history, the development of water systems has enabled economic growth and productivity, with natural aquatic systems being transformed through changes in land use, urbanization, industrialization, large-scale agriculture, and as a convenient recipient of waste. Growth has been made possible through massive investment in water development on the supply-side—pumping, transfer, treatment, and distribution—during what has been termed "the hydraulic century."[8]

However, biodiversity of aquatic systems has rarely been awarded any economic value, resulting in their often-irreversible degradation. Recent global-scale analyses of threats to freshwater have considered water security and biodiversity simultaneously within a spatial accounting framework.[9] The graphic displays of river catchments under immediate threat have caught the attention of the media and contribute to an increasing concern among the public, which, in turn, may put greater pressure on global industries, international agencies, and governments to act more responsibly. The developing world—in particular, highly populated parts of Asia—show the tandem threats to human water security and biodiversity.

One of the key comparisons in the body of evidence on global water scarcity distinguishes between physical water scarcity and economic water scarcity (Box 3). Physical scarcity occurs where there is not enough water to meet demand. Usually associated with arid regions (e.g., West Asia and the Arabian Peninsula), physical scarcity can also occur when water resources are

[7] The same conclusion was formulated slightly differently in a recent article in *Nature* on modeling the nexus: "[w]hile environmental issues are normally the 'cohesive principle' from which the three areas are considered jointly, the enormous inequalities arising from a lack of access suggest that economic and security-related issues may be stronger motivators of change." See M. Bazilian et al. 2011. Considering the Energy, Water and Food Nexus: Towards an Integrated Modelling Approach. *Energy Policy.* 39 (12). pp. 7,896–7,906.

[8] T. Allan. 2011. *Virtual Water: Tackling the Threat to Our Planet's Most Precious Resource.* London: I. B. Tauris.

[9] C. Vörösmarty et al. 2010. Global Threats to Human Water Security and River Biodiversity. *Nature.* 467. pp. 555–561.

overcommitted. In such cases, remedial measures must include reducing demand, improving production efficiencies, and instituting trade measures to substitute homegrown commodities with a large water footprint. Other examples in Asia are south and northwest India, most of Pakistan, and the northern part of PRC. Economic scarcity, however, is caused by a lack of investment—and should, therefore, be a focus of possible intervention on the supply-side and improved management. Examples in Asia include Bangladesh, Cambodia, north and northeast India, the Lao People's Democratic Republic, Myanmar, Nepal, and Viet Nam.

Box 3. **Levels of Economic and Physical Water Scarcity**

Little or no water scarcity indicates abundant water resources relative to use, with less than 25% of water from rivers withdrawn for human purposes.

Physical water scarcity (water resources development is approaching or has exceeded sustainable limits) indicates that more than 75% of river flows are withdrawn for agriculture, industry, and domestic purposes (accounting for recycling of return flows). This definition—relating water availability to water demand—implies that dry areas are not necessarily water-scarce.

Approaching physical water scarcity means that more than 60% of river flows are withdrawn. These basins will experience physical water scarcity in the near future.

Economic water scarcity (human, institutional, and financial capital limit access to water although water in nature is available locally to meet human demands) indicates that water resources are abundant relative to water use, with less than 25% of water from rivers withdrawn for human purposes, but malnutrition exists.

Source: Comprehensive Assessment of Water Management in Agriculture. 2007. *Water for Food, Water for Life: A Comprehensive Assessment of Water Management in Agriculture*. London: Earthscan and Colombo: International Water Management Institute.

Water for Food

Water for food production accounts for about 70% of water withdrawals.[10] Combining increases in overall population, urbanization, and prosperity with changes in dietary demands, the demand for food will further increase considerably. For example, changing lifestyles and diets in Asia will increase demand for water-intensive products such as dairy and meat products. Estimates for the rise in the demand for meat globally cite an increase of 50% by 2025.[11] In addition, the emergence of subsidized biofuels for transport has led to greater competition for land and water use. A proportional increase in water withdrawals cannot be met without major shifts in production patterns.

Globally, 80% of water for agriculture comes directly from rain, and about 20% comes from irrigation. In Asia, the proportion using irrigation is much larger, predominantly in South Asia and southern portions of the PRC.[12]

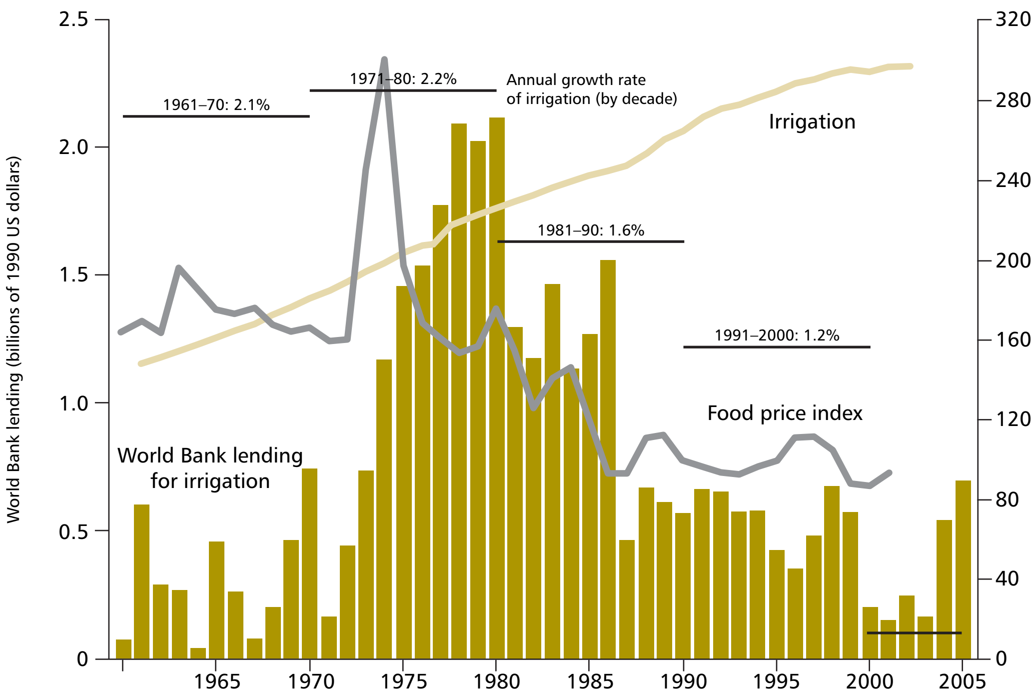
[10] World Economic Forum Water Initiative. 2011. *Water Security: The Water–Food–Energy–Climate Nexus.* Geneva.

[11] Footnote 10.

[12] Footnote 4.

The global food price index has steadily declined since 1975 (Figure 2).[13] Agricultural production has grown, backed by new crop varieties, fertilizers, investment in irrigation infrastructure, expansion of agricultural land, and subsidized access to easy-to-reach groundwater. Although world food production outstripped population growth, food price volatility reappeared in 2007/2008 and 2010/2011, possibly signaling the end of low food prices and the new prospect of long-lasting scarcity.[14] This could be recognized as the end of a period of structural overproduction in international agricultural markets, made possible by the extensive use of cheap natural resources backed by farm subsidies (i.e., a reliance on an unsustainable mining of nonrenewable resources, like water). Groundwater has been abstracted beyond recharge potential, and soil and aquatic ecosystems have been loaded with waste products and residues beyond their natural absorptive and self-cleansing capacity, often causing irreversible damage. No economic or financial value was attached to the use of these nonrenewable resources that could have influenced a choice of alternatives, thereby remaining "negative externalities," in economic terms.

Figure 2. **Irrigation Expanding, Food Prices Falling**



Source: Comprehensive Assessment of Water Management in Agriculture. 2007. *Water for Food, Water for Life: A Comprehensive Assessment of Water Management in Agriculture*. London: Earthscan and Colombo: International Water Management Institute.

[13] The food crisis of the early to mid-1970s, then triggered by the 1973 Organization of the Petroleum Exporting Countries (OPEC) oil price increases.

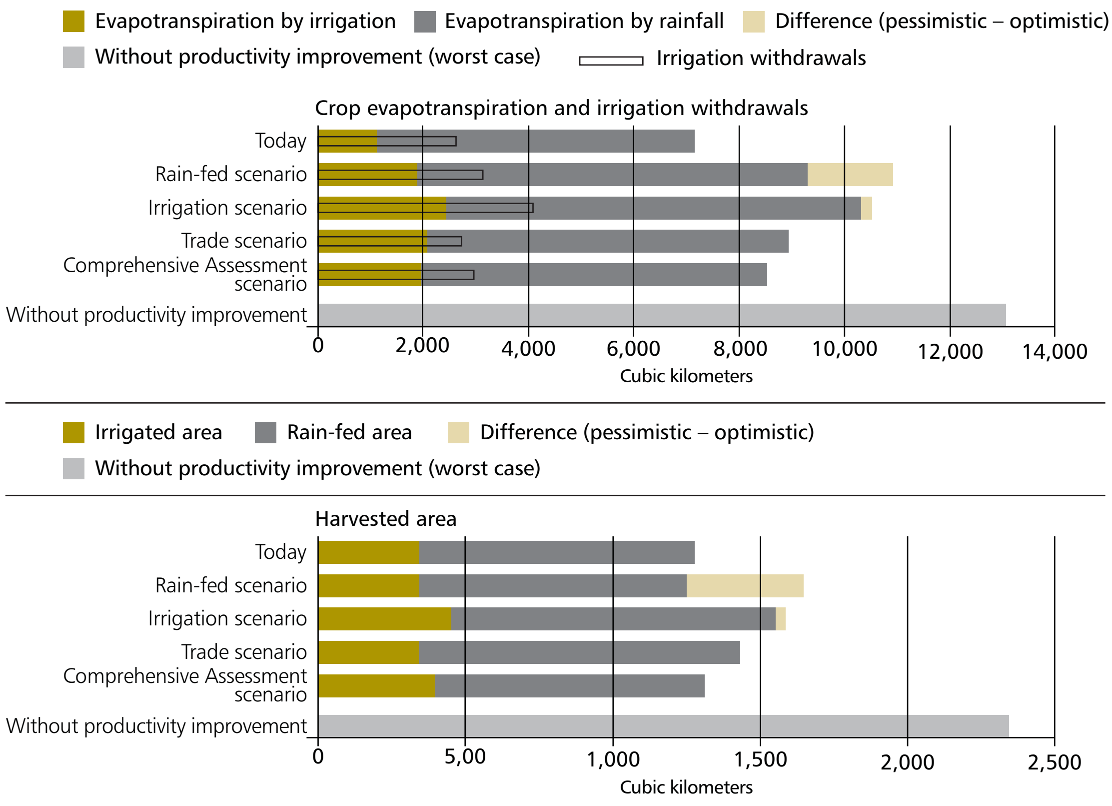
[14] A contributing (and some have argued, controlling) factor in food price volatility is the impact of momentum-based speculation on futures markets for staple crops. See, for instance, O. de Schutter. 2010. Food Commodities Speculation and Food Price Crises. Briefing note by the Special Rapporteur on the Right to Food. No. 2. New York. Mr. de Schutter wrote that "a significant portion of the increases in price and volatility of essential food commodities can only be explained by the emergence of a speculative bubble."

However, future food demands can be met by the world's available land and water resources in several ways.[15] Appropriate combinations of the four scenarios summarized below (and presented in Figure 3) will depend on local settings, and all will require considerable changes in policies, institutions, and skills.

(i) **Rain-fed scenario.** Investment to increase production in rain-fed agriculture through enhanced management of soil moisture, supplemental irrigation with small water storage, improvement of soil fertility management, and reversal of land degradation. The range displayed under this scenario reflects the uncertainty of the impact of climate change on future rainfall patterns.

(ii) **Irrigation scenario.** Investment in irrigation by increasing irrigation water supplies (e.g., through innovations in system management, new surface water storage facilities, and using wastewater) and increasing water productivity in irrigated areas and value

Figure 3. **Land and Water Use Today**



Note: The figure shows projected amounts of water and land requirements under different scenarios. The Comprehensive Assessment scenario combines elements of the other approaches. The purple segments of the bars show the difference between the optimistic and pessimistic assumptions for the two rain-fed and the two irrigated scenarios. The brown bar shows the worst-case scenario of no improvement in productivity.

Source: Comprehensive Assessment of Water Management in Agriculture. 2007. *Water for Food, Water for Life: A Comprehensive Assessment of Water Management in Agriculture*. London: Earthscan and Colombo: International Water Management Institute.

[15] Arguments and data in this paragraph are from Comprehensive Assessment of Water Management in Agriculture. 2007. *Water for Food, Water for Life: A Comprehensive Assessment of Water Management in Agriculture.* London: Earthscan and Colombo: International Water Management Institute.

per unit of water (this is specifically valid for South Asia, where 50% of cropped area is irrigated and where productivity is low).

(iii) **Trade scenario.** Conducting agricultural trade within and between countries.

(iv) **Other.** Reducing gross food demand by influencing diets and reducing postharvest losses, including industrial and household waste.

The sector must aim to ensure that water is consumed productively, i.e. ensuring water in agriculture is used to produce the maximum food, fiber, and fuel with the minimum water consumption. In many cases, agricultural water diversions in irrigation are currently considered to be inefficient uses of water resources. However, while diversions are large, water considered not-consumed returns to the water system and may be used downstream. Increasing the "efficiency" of the irrigation system would reduce the return flows, possibly resulting in reduced water availability downstream. Improving the water performance of agricultural production systems requires a detailed understanding of water system in the context of the river basin in order to capture the impacts of reuse of return flows.

The challenge for global agriculture is to grow more food on not much more land, using less water, fertilizer, and pesticides than historical trends. In addition, water for agriculture must be managed on an integrated basis with other water uses. The preservation of ecosystems has to be considered essential and not merely as a marginal benefit. Food and Agriculture Organization estimates suggest that there is ample scope to increase the area under crops in Asia, with the exception of South Asia (Table 2). However, some of the potential areas may be forested or protected.

Table 2. **Potential Land Suitable for Agricultural Expansion**

Region	Area Currently Cropped (million hectares)	Total Area Suitable for Rain-Fed Production (million hectares)
Central Asia	265	497
South Asia	207	220
East Asia	232	366

Source: Based on FAO. 2002. *World Agriculture: Towards 2015/2030. Summary Report*. Rome; quoted in C. de Fraiture et al. 2007. Looking Ahead to 2050: Scenarios of Alternative Investment Approaches. In Comprehensive Assessment of Water Management in Agriculture. *Water for Food, Water for Life: A Comprehensive Assessment of Water Management in Agriculture*. London: Earthscan and Colombo: International Water Management Institute.

Summarizing the outcome of the various scenarios, Table 3 presents the potential for expanding food production in the main regions in Asia.

Table 3. **Scope for Productivity Improvement and Area Expansion**

Region	Scope for Improved Productivity in Rain-Fed Areas	Scope for Improved Productivity in Irrigated Areas	Scope for Expansion in Irrigated Area
Central Asia	Some	Good	Some
South Asia	Good	High	Some
East Asia	Good	High	Some

Source: C. de Fraiture et al. 2007. Looking Ahead to 2050: Scenarios of Alternative Investment Approaches. In Comprehensive Assessment of Water Management in Agriculture. *Water for Food, Water for Life: A Comprehensive Assessment of Water Management in Agriculture*. London: Earthscan and Colombo: International Water Management Institute.

Groundwater has lifted millions of farmers in Asia and Africa out of food poverty since the 1970s. Small-scale groundwater irrigation has promoted greater equity between groups of populations than large surface water irrigation. Groundwater is a resource that is often easily accessible—and increasingly so with the advent of cheap pumps—with usually good-quality water, provided that it is abstracted in a sustainable manner, not mined, and not used for low-value uses. Large areas of Asia still provide opportunities for smallholders to benefit from easily accessible groundwater to expand their agricultural production with irrigation, within the limits of recharge potential.

Yet the growth of land under cultivation, and, in particular, the intensive use of fertilizers and biocides in agriculture, has a profound impact on water quality. Analysis of global application of nutrients[16] demonstrates the large excesses of nitrogen and phosphorus applied, notably in the PRC and India.

Water for Energy

Energy and water are linked in two ways: (i) water is used in the production of nearly all types of energy, and (ii) energy is the dominant cost factor in the provision of water and wastewater services. Tables 4 and 5 give an overview of the amounts of water involved in fuel production and electricity generation. Table 6 presents typical energy consumption values in the domestic water industry.

Table 4. **Gas and Liquid Fuels Value Chain—Water Consumption (liters per gigajoule)**

Source	Raw Materials	Transformation	Delivery
Oil		25–65	Minimal
Traditional oil	3–7		
Enhanced oil recovery	50–9,000		
Oil sands	70–1,800		
Biofuels		Ethanol: 47–50	Minimal
Corn	9,000–100,000	Biodiesel: 14	
Soy	50,000–270,000		
Coal	5–70	Coal to liquid: 140–220	Minimal
Gas		Natural gas processing: 7	Minimal
Traditional	Minimal		
Shale gas	36–54		

Source: World Economic Forum with Cambridge Energy Research Associates. 2008. *Energy Vision Update 2009. Thirsty Energy: Water and Energy in the 21st Century*. Geneva.

Energy production is dependent on water, but it does not consume a considerable amount of water.[17] However, its use in production often affects the quality of water. Tailings and drainage of coal or uranium mining can affect surface water and groundwater. Oil and gas exploration can affect groundwater aquifers and impact marine and mangrove environments. The emergence of shale gas as an energy source has added to the concern of aquifer contamination.

[16] J. Foley et al. 2011. Solutions for a Cultivated Planet. *Nature*. 478. pp. 337–342.

[17] In traditional drilling for oil and gas, water is a by-product, usually with salinity exceeding that of seawater.

Table 5. **Electricity Industry Value Chain—Water Consumption (liters per megawatt-hour)**

Source	Raw Materials	Transformation	Delivery
Coal Oil or natural gas Uranium	20–270 See Table 4 170–570	Thermoelectric generation with closed loop cooling: 720–2,700	Minimal
Hydroelectric		Evaporation losses: 17,000	Minimal
Geothermal		5,300	Minimal
Solar		Concentrating solar: 2,800–3,500	Minimal
Wind		Minimal	Minimal

Source: World Economic Forum with Cambridge Energy Research Associates. 2008. *Energy Vision Update 2009. Thirsty Energy: Water and Energy in the 21st Century*. Geneva.

Table 6. **Domestic Water Industry Value Chain—Energy Consumption (kilowatt-hour per 1,000 cubic meters)**

Source	Raw Materials	Transformation	Delivery
Surface water	0–2,400	Treatment: varies with raw water quality	Depends on distance and elevation: 290
Groundwater	40 meters: 150 120 meters: 520	High-quality groundwater: 26 Brackish water: 300–1,400 Seawater desalinization: 3,600–4,500	
Municipal wastewater		660	

Source: World Economic Forum with Cambridge Energy Research Associates. 2008. *Energy Vision Update 2009. Thirsty Energy: Water and Energy in the 21st Century*. Geneva.

Increasing access to energy is a priority for many countries in Asia, as about 700 million people lack access to electricity, and 1.8 billion rely on biomass (e.g., wood) for heating and cooking.[18] Expanding energy production, however, requires greater access to freshwater. Energy generators will generally have de facto priority for water abstraction rights through asymmetrical access and influence. For instance, in the United States, where energy generation accounts for 40% of all freshwater withdrawals, water use for energy would need to increase by 165% to meet the needs for 2025.[19]

Operation of energy facilities are at times curtailed due to water concerns, such as a physical shortage of water or when the ecology of receiving water can no longer accept cooling water discharge during high temperatures. In other instances, the siting and operation of new energy facilities must take into account the availability or the value of water resources.

[18] ADB. 2013. *Asia Development Outlook*. Manila. Excessive use of firewood throughout history has been a major reason for deforestation and watershed destruction.

[19] Footnote 10.

Options for cooling thermal plants require varying degrees of water use. Traditional once-through systems withdraw the most water, but many power plants built since the 1980s use closed-loop systems, which consume more water mainly through evaporative cooling. Dry cooling is one of the rare examples in which there is an alternative to water use, as it relies on air rather than water for cooling. However, dry cooling has a lower fuel efficiency and, as a result, a higher carbon impact.

Despite attempts at creating alternative energy sources, 75% of the expected increase in energy use to 2030 is still expected to be met from fossil fuels, especially coal. The resulting carbon emissions will interfere with meeting international climate change mitigation targets. Resulting global warming will again exacerbate water scarcity and affect food production.

One of the most challenging aspects of the water–energy link is that the low-carbon growth targets for energy generation is doubly hard to meet. Pressure on the energy industry to develop low-carbon sources at scale, under a climate change mitigation agenda, puts even greater pressure on water availability. In other words, climate change policies may have considerable negative impacts on freshwater resources and ecosystems, and may thus result in maladaptation.

Among renewable energy sources, hydropower may become dominant in the future. However, even hydropower actually consumes water through evaporation from open surfaces of reservoirs, at an average rate of 17 m^3 per megawatt-hour. The International Energy Agency estimates that about 170 gigawatts of hydropower are under construction, 77% in Asia (i.e., 55% in PRC, 9% in India, and 13% elsewhere in Asia). The volumes of water thus consumed will be significant. As another growing renewable technology, concentrated solar power also uses relatively large quantities of water to generate steam, which drives turbines, and its use in some locations is already curtailed by water availability. Wind power, on the other hand, consumes little or no water.

Carbon capture and storage technology (i.e., carbon sequestration) also causes increases in water consumption. Coal-to-liquid technologies are being considered to generate transport fuels as an alternative to crude oil. However, such fuels are both carbon- and water-intensive: their manufacture and use emit about twice the amount of greenhouse gas as conventionally produced petrol or diesel, and a considerable amount of water is used to cool process streams, to feed steam-producing boilers, and for liquefaction.[20] Shale gas production is seen by some as a promising major source of natural gas, with important deposits in the PRC, India, and the United States. Yet there is growing evidence that the extraction and use of shale gas results in the release of more greenhouse gases than conventional natural gas, and may lead to emissions greater than those of oil or coal. In addition, the available technology for shale gas extraction risks contamination of groundwater aquifers and may cause earthquakes.

The increase in water use in energy production will outpace that of municipal uses. The challenges will be how water markets can modify the economics of different energy technologies; how energy companies can be influenced to reduce their water use; and how the energy industry can become better integrated with other industry, agricultural, and municipal water use. The lack of reliable provision of stable power is often the limiting factor in achieving equitable growth in many parts of Asia.

[20] World Economic Forum with Cambridge Energy Research Associates. 2008. *Energy Vision Update 2009. Thirsty Energy: Water and Energy in the 21st Century*. Geneva.

Energy in Water and Wastewater

Water is heavy and bulky, and its transport requires considerable energy. Thus, in urban water supply and wastewater management, the energy component of the cost of providing such services should be the dominant force in motivating planners and managers to rethink their strategies. Pricing policies and the promotion of water-saving devices are not yet actively practiced in Asia at a scale to keep down per capita water use as a means to reduce pumping costs. Many authorities responsible for urban supplies are still charging a negligible price for their product, leading to an undervaluing of treated water with considerable energy content and widespread waste. Instead, used water should be treated and rendered suitable for further purposes, as locally as possible, to avoid the additional transport cost of used water.

Mixing human waste with clean water for disposal purposes requires a subsequent separation of these constituents through physical, chemical, and biological processes, all of which require energy. The principles of these infrastructure solutions were designed for circumstances in late 19th-century cities, funded by municipal taxation, with public health concerns as the main policy driver. Asian cities in the 21st century, changing in unpredictable directions at great speed against the specter of water shortages, require other solutions. Choices will be determined by energy considerations, as well as land availability.

Creating energy from wastewater—and in particular through the anaerobic digestion of high-carbon sewage sludge—has been part of treatment plant design since the early 20th century. Much of this experience can be reapplied, with 21st-century technology, when urban wastewater treatment finally becomes a priority in Asian cities.

Energy for Food

Energy is used in the production and delivery of food, for pumping irrigation water, and for its transport, distribution, and cooling for storage. The cost and availability of energy in rural areas has had—and will continue to have—a decisive influence on the development of agriculture. The most prominent example is the dramatic growth of irrigation using groundwater, mainly in Bangladesh, northern PRC, India, and Viet Nam. Expansion of rural electrification, subsidized electricity, emergence of cheap pumps, and local well-drilling brought an explosion of the number of tube wells for irrigation. For example, in India, about 21 million wells were drilled in the past 20 years.[21] The volume of groundwater abstracted in India increased from 10–20 cubic kilometers before 1950 to 240–260 cubic kilometers by 2000.[22] These developments helped to lift scores of millions out of poverty and hunger. However, this supply is not sustainable everywhere—and the link with energy is crucial. Groundwater tables in Gujarat have lowered by more than 170 meters, are dropping at 6 meters per year, and are or soon will be beyond economic reach for most users.[23] The situation is similar in parts of the PRC. When subsidies are no longer politically sustainable, and when global electricity prices rise, farmers will receive a "double hit," necessitating a change in their production practices.

An additional significant component in the link between energy and food is the energy content of synthetic nitrogen fertilizer. Synthetic nitrogen is almost entirely produced using natural gas, and modern high-yield agriculture is almost entirely dependent on synthetic nitrogen.

[21] J. Drew. 2011. *The Protein Crunch: Civilisation on the Brink*. Vlaeberg, South Africa: Cheviot.

[22] Comprehensive Assessment of Water Management in Agriculture. *Water for Food, Water for Life: A Comprehensive Assessment of Water Management in Agriculture*. London: Earthscan and Colombo: International Water Management Institute.

[23] Footnote 21.

Food for Energy: Biofuels for Transport

The advent of liquid biofuels as a source of fuel for transport perhaps best symbolizes the complex interaction between energy, water, and therefore food, adding a new and complex dimension to the water–energy nexus.[24] The subsidized treatment for the growth of biofuels to gain greater security for energy for transport is at the cost of water for food. Many see a direct link between the subsidized growth of corn and soy for ethanol and the price volatility that caused the food crises in 2007/2008 and 2010/2011, and by consequence, food riots.[25] As the energy market—measured in calories—is about 20 times the size of the global food market, small percentages of substitution of traditional energy sources by biofuel will push up food prices by competing with limited water.

Biofuel is a type of fuel whose energy is derived from biological carbon fixation. Bioethanol, an alcohol made by fermentation of any feedstock containing significant amounts of sugar (e.g., sugar cane or sugar beet) or starch (e.g., maize and wheat), is widely used in Brazil and the United States. Biodiesel, made from vegetable oils (including rapeseed, soybean, palm, coconut, and jatropha oils) and animal fat, is the most common biofuel in Europe. Second-generation biofuels usually refer to more advanced technologies extracting fuel from cellulose and lignin, thereby increasing the volume and variety of sources that could be used for fuel production. Secondary biofuels refer to fuel produced from waste products, thereby reducing the call on resources.

The net impact or energy gain of the entire process of biofuel production is often marginal or negative.[26] Equally, the positive impact of biofuels on greenhouse gas emissions is uncertain, depending not only on production technology but also on assessment approaches.

At present, there is no biofuel production in Asia on a scale that is globally significant, with the exception of India and the growing use of palm oil grown in Indonesia and Malaysia.[27] The PRC contributed about 3.5% to global bioethanol production in 2007.[28] It has put a moratorium on the development of further biofuels for food security reasons.[29] However, whether the vast, untapped agricultural production potential of Brazil will be used for the production of food for global exports—which would contribute to food price stability—or for fuel production will impact Asia. The critical link with water security is ultimately whether growing crops for fuel competes for limited water and land with growing food for human consumption.

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[24] For one of the most comprehensive sources, see FAO. 2008. *The State of Food and Agriculture 2008: Biofuels—Prospects, Risks, and Opportunities.* Rome.

[25] A recent article examined the correlation between food crises and riots: M. Lagi, K. Bertrand, and Y. Bar-Yam. 2011. *The Food Crises and Political Instability in North Africa and the Middle East.* http://necsi.edu/ research/social/ foodcrises.html

[26] See FAO. 2008. *The State of Food and Agriculture 2008: Biofuels—Prospects, Risks, and Opportunities.* Rome. For a case study, see A. Dalla Marta et al. 2011. Energy and Water Use Related to the Cultivation of Energy Crops: A Case Study in the Tuscany Region. *Ecology and Society.* 16 (2).

[27] ADB. 2011. *Food Security, Energy Security, and Inclusive Growth in India: The Role of Biofuels.* Manila.

[28] FAO. 2008. *The State of Food and Agriculture 2008: Biofuels—Prospects, Risks, and Opportunities.* Rome.

[29] C. Ringler, Z. Karelina, and Rajul Pandya-Lorch. 2011. Emerging Country Strategies for Improving Food Security: Linkages and Trade-Offs for Water and Food Security. Background paper for the Bonn2011 Nexus Conference. 16–18 November. Stockholm.

Climate Change

Many countries are already experiencing water scarcity during dry years, dry seasons, and in certain catchments. Such occurrences will become more frequent with advancing climate change. Water usage, availability, and energy production have their impact on climate change; climate changes will affect water availability. An immediate, tangible impact of climate change will be the advent of an era of uncertainty, with a severe impact on the ability of the developing member countries (DMCs) to prepare prudent water management plans and to develop suitable responses to future drought or floods.

Climate change is likely to have a destabilizing effect on the world's water systems. Energy and water infrastructure, often assets with a long-term technical and economic life, were designed based on projections of historical hydrologic data and resulting probabilities. These probabilities are now significantly altered, as planners can no longer rely on past frequency distributions. Further, populations who rely on water from snow-fed river basins will have less reliable year-round supplies of water, assuming that present weather trends continue. Extreme weather events will be more frequent. Longer periods between rainfall can be expected, bringing greater urgency to create and maintain strategic water storage, both at local and regional levels, for surface water as well as groundwater. Megacities with vast populations require particular attention where large reserves of accessible freshwater must be held in readiness for periods of drought or other natural disasters. Energy production that relies on the steady availability of water will be jeopardized. Crop yields on rain-fed land are likely to decrease, and new crop varieties may need to be developed and introduced.

The Food and Agriculture Organization has proposed a typology of agricultural systems and climate impacts to help assess regions in which irrigation and other forms of agricultural water management are important, and how these regions will be affected by climate change:[30]

(i) Large surface irrigation systems fed by glaciers and snowmelt (e.g., the PRC, northern India, Indus River valley, Mekong River catchment).

(ii) Large deltas that may be submerged by rising sea levels, will increasingly be prone to flood and storm damage, and to saline intrusion (e.g., Bangladesh, the deltas of the Mekong and Red rivers in Viet Nam, and the Yellow River in northeast PRC).

(iii) Surface and groundwater systems in arid and semi-arid areas where rainfall will decrease and become more variable (e.g., large parts of India and Sri Lanka).

(iv) Humid tropics that experience seasonal storage systems in monsoon regions, where the proportion of storage yield will decline but peak flows are likely to increase (e.g., most of Southeast Asia).

(v) All supplemental irrigation areas where the consequences of irregular rainfall are mitigated by short-term interventions to capture and store more soil moisture or runoff.

Within Asia, the most vulnerable in terms of number of people affected is South Asia. The combination of high populations, heavily exploited natural resources, and climate risks create an especially threatening scenario for that area's poor.

[30] FAO. 2011. *Climate Change, Water, and Food Security.* Rome.

Population

Population growth is one of the determinant drivers for growth in water demand throughout the region. Growth rates in Asia have decreased, with the population forecasted to grow an average of 0.5% over the next 40 years. The share of global population of Asia and the Pacific is expected to decrease from 56% in 2010 to 50% in 2050. Because of India's higher net reproduction rate, India is expected to surpass the PRC to become the most populous country in the region—and the world—by 2020. The region's high fertility band includes other very populous countries, such as Pakistan and the Philippines. Other highly populated countries in the medium fertility group include Bangladesh, India, and Indonesia.[31]

Even more important for water demand than the population numbers is the demographic shift to urban middle-class lifestyles, with the accompanying changing expectations, consumption patterns, and diets. This is dominated by the PRC and India.

Urbanizing Asia

Asia is becoming an urban society, with compound effects on water withdrawals, consumption, and pollution. For instance, the more concentrated population puts greater stress on water and energy needs, and, in particular, on waste collection, treatment and disposal, or reuse. Increasing population density and waste production will exceed the natural assimilative capacity of natural water ecosystems that may still allow rural populations to discard their waste without excessive degradation impact. Despite dramatic advances in wealth and technology throughout Asia, the record of urban Asia in treating liquid waste is poor, as typically only about 10% of urban wastewater gets treated.[32] For industrial zones, often quoted as the driver of Asia's new wealth, data are conflicting, but the situation is likely similar with more severe long-term impacts. The constituents of industrial wastewater are more difficult and costly to remove, are likely to be toxic, and have a cumulative damaging effect on health and environment. Removal at the source, together with cleaner production mechanisms, provide critical opportunities for progress in this area. The benefits of improvements to the environment and to public health resulting from wastewater treatment have been too invisible, long-term, and indirect to create an incentive for local decision makers.

[31] United Nations. Population. Quoted in ADB. 2011. *Key Indicators for Asia and the Pacific 2011.* Manila. http://esa.un.org/wpp/unpp/panel_population.htm

[32] ADB. 2011. *Fast Facts: Urbanization in Asia*. Manila.

New Water Accounting

Water Economics

A Special Case

The water crisis is global, but the solutions are local, making the issue different from climate change and energy issues (i.e., saving carbon dioxide in one part of the globe has the same impact as elsewhere). To transport water for agricultural or domestic use costs energy—energy that will grow considerably more expensive. The upfront fixed investment, and the sustained consumption of consumables during operation (e.g., spares, chemicals, and power), have significant budgetary implications. Supplying a reasonable amount of water to an average middle-class urban family in Asia requires a mass of water equivalent to a small family car every day to be transported to that house—and to all the houses next door. Then, that water has to be carried away again, in a sullied condition, to prevent disease and environmental degradation. As the cost of both water and energy rises, the economics of water treatment and distribution options—centralized versus decentralized, to reuse or to discard—will change fundamentally.

Water Is Free Debate

Since the Dublin Statement on Water and Development in 1992, water has been recognized by the international community as an economic good.[33] The Dublin statement has often been attacked by those who believe that water is not an economic good but a human right. ADB recognized that water for all is indeed a human right—in fact, water for all was the guiding statement of the ADB water policy.[34] Yet food and shelter are also human rights, and neither of those are free.

It must be recognized that the assumption that water is free has led to a waste of water on an unsustainable scale as well as misappropriation and inefficiency in the use of a valuable and limited resource. The value of water, therefore, needs to be recognized. Pricing policies should keep water affordable to all, but its true value should never be undersold.

New Ways to Account for Water

When a valuable resource is constrained, new investment is usually drawn in, as shortages prompt a change in policies to augment supplies and to increase productivity of demand. For water, however, this did not occur. Between 1990 and 2004, the annual rate of efficiency improvement in agricultural water use, in rain-fed and irrigated areas, was only 1%. Compared with other infrastructure, such as in information and communication technology where

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[33] The Dublin Statement on Water and Sustainable Development (issued at the close of the International Conference on Water and the Environment, Dublin, Ireland, January 1992) recognizes the increasing scarcity of water as a result of the different conflicting uses and overuses of water. The declaration sets out recommendations for action to reduce the scarcity, through the following four guiding principles: (1) Fresh water is a finite and vulnerable resource, essential to sustain life, development and the environment; (2) Water development and management should be based on a participatory approach, involving users, planners, and policy makers at all levels; (3) Women play a central part in the provision, management, and safeguarding of water; and (4) Water has an economic value in all its competing uses and should be recognized as an economic good.

[34] ADB. 2001. *Water for All: The Water Policy of the Asian Development Bank*. Manila.

consumers have come to expect exponential rates of annual improvements in processing speed and data storage efficiency, water is conservative.

The key question that needs to be answered is why the market has not responded, despite an imminent water crisis and a food crisis already real in many regions. Agriculture's 70% or 80% share of the water use is compounded by the high embedded inefficiency in farm water use at around 50%, and the poor global trend of a 1% annual productivity improvement. Quoting from the 2030 Water Resources Group: "An unfettered reliance on markets will not deliver the social, economic, and environmental outcomes needed. Good regulation in water is indispensable."[35]

There is unquestionably a lack of transparency on water economics. Much of the information required to make rational management decisions about water and water use is not obvious, easily accessible, quantifiable, or understandable. New ways are needed to provide clear, simple presentations of the costs of water—or rather the lack of water—to decision makers and their constituencies.

Virtual Water and Water Trade

New tools have been developed in water accounting that should help measure and thereby manage water. Since the early 1990s, the concept of virtual water has been developed,[36] quantifying the water that is embedded in goods, food, and livestock. It identifies how water gets traded across catchments and regions, enabling a more rational assessment of whether such trades are economically and environmentally sustainable.

The concept of virtual water trade is beginning to be accepted in specialist literature to aid in quantifying the impact of current practices. Strategic water planners and managers in the region need to examine how these new concepts in water accounting will assist in demonstrating the urgency to act in dealing with water security and if they provide the tools to develop a fact-based vision.

Currently, global water saving through trade in agricultural products is estimated to be equivalent to 6% of the global volume of water used in agricultural production.[37] The potential for greater food trade is obvious, guided by a more conscious realization of the benefit of importing embedded water. Water scarcity will prompt government to embrace more coherent approaches to food trade (and associated embedded water) as a means for water-short countries to reduce pressure on domestic water resources. Similarly, using similar concepts may help demonstrate the questionable value of interbasin linkages if water transfers can be achieved more effectively and less environmentally damaging through a virtual water trade.

Water Footprint

From the embedded water principle of virtual water, the concept of the water footprint is now emerging as one of the most promising tools in water accounting. At ADB, initiatives

[35] Footnote 2. p. 2.

[36] Mostly by Professor Tony Allan, of King's College London, in 1993. Dr. Allan is the recipient of the 2008 Stockholm Water Prize for "his unique, pioneering, and long-lasting work in education and raising the awareness internationally of interdisciplinary relationships between agricultural production, water use, economies, and political processes."

[37] A. Hoekstra and A. Chapagain. 2008. *Globalization of Water: Sharing the Planet's Freshwater Resources.* West Sussex, UK: Wiley-Blackwell.

have begun to incorporate this concept in water planning. The water footprint is a measure of humankind's appropriation of freshwater resources, measured in water consumed or polluted. It can be calculated for products consumed; for a process; or for a group of people in a city, a catchment, or a country. It can be used to make changes on the demand-side to make consumers globally aware of the water consequences of their choices in food and clothing, for example.[38] More strategically, at the level of a country or a water catchment, it can be used to determine whether a certain water use is economically and environmentally sustainable.

With virtual water, the water footprint concept adds a demand- and consumer-oriented indicator in a sector where policy tends to be angled toward supply and production.[39] This transition of management consideration will be a key challenge as the sector rebalances and improves its governance and rationale for infrastructure investment and water allocations.

As an example of the water footprint, Table 7 shows relative water scarcity and water import dependency of some DMCs for which such data are available.

The concepts of virtual water measures and the water footprint have been criticized, challenging their value in informing policy. Some point out that the value of water, in different spatial locations and being used for different purposes, cannot be considered to be comparable.[40] Others state that advocacy for virtual water trade does not account for any environmental impact of increasing agricultural trade or the costs of shipping.[41] While there are limitations, used prudently, these are effective tools in a sector that so far has failed to develop adequate methodologies to articulate water balance and choices.

The Cost Curve

One of the results of the analyses of the water–food–energy nexus is the water availability cost curve, sometimes referred to as the McKinsey Curve. Cost curves have been compiled as case studies for some regions, including the PRC, India, São Paolo State in Brazil, and South Africa. Figure 4, from left to right along the horizontal axis—expressed in incremental availability of water in billions of m^3—lists possible measures to reduce water use. It shows their quantitative impacts, both of supply- and demand-side measures, for agriculture, municipal, and industrial uses. The height of these blocks, the vertical axis, shows the cost or savings per unit, in US dollars per m^3 of water saved. Together, it recognizes that a combination of technical, institutional, and policy measures could deal with scarcity to improve water security.

In this form, the cost curve is a purely quantitative measure. Before it can be used in practice, it does require another important dimension or determinant for which further analysis is needed—that of political economy. Insight is required of what the effort will be and what sociopolitical obstacles can be expected when introducing certain measures. It may be argued that without the added dimension of political economy, the cost curve has little practical value. However, if well researched and reasonably accurate, its value lies in displaying the range of measures,

[38] One important breakthrough in the credibility of the water footprint was achieved when *National Geographic,* with a worldwide readership estimated at 40 million, featured the concept of the water footprint in a special edition on water in April 2010.

[39] Mathews, Ruth. 2011. Water Footprint Assessment. Presented at National Workshop on Water Accounting and Efficiency Measures. Nghe An, Viet Nam. August 2011.

[40] Frontier Economics Pty. 2008. *The concept of "virtual water"—a critical review.* A report prepared for the Victorian Department of Primary Industries. Melbourne.

[41] C. de Fraiture et al. 2007. Looking Ahead to 2050: Scenarios of Alternative Investment Approaches. In Comprehensive Assessment of Water Management in Agriculture. *Water for Food, Water for Life: A Comprehensive Assessment of Water Management in Agriculture.* London: Earthscan and Colombo: International Water Management Institute.

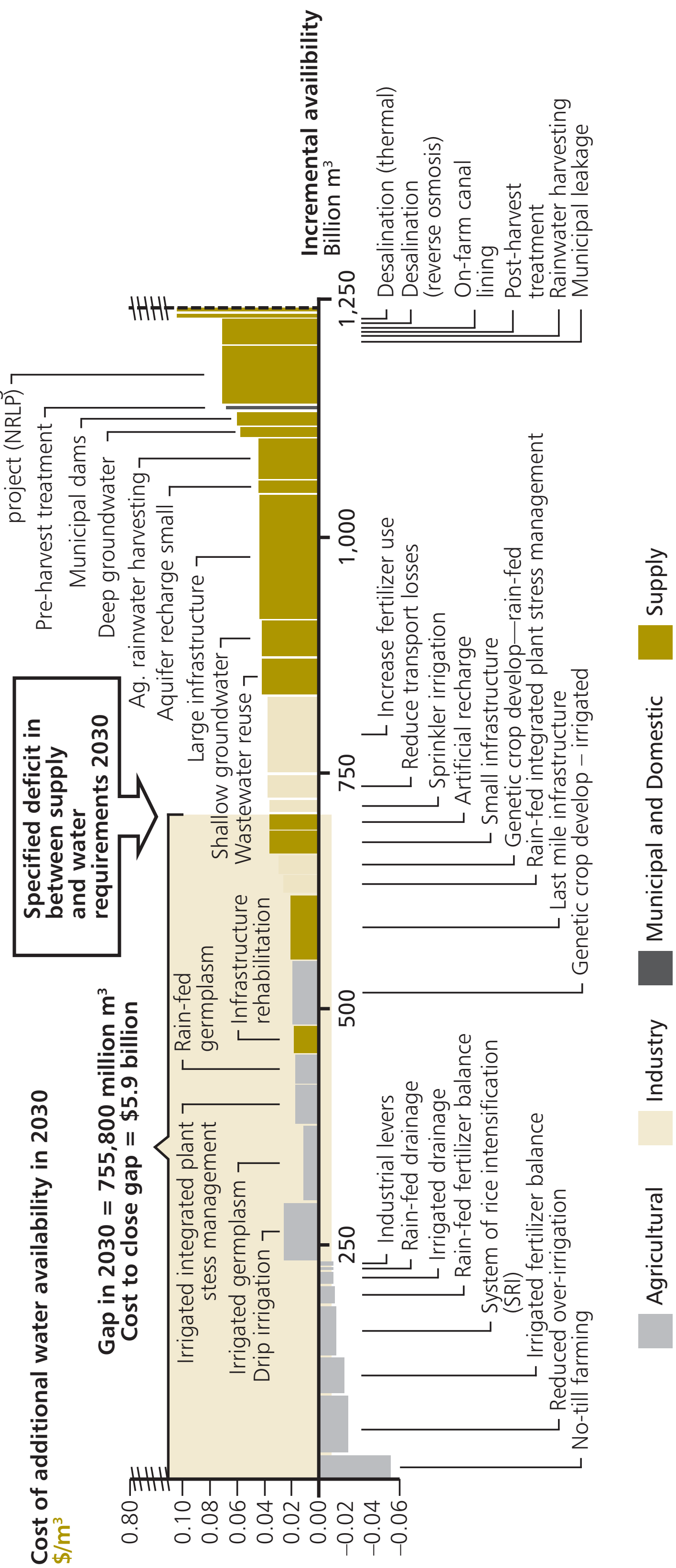
Table 7. **Water Footprint, Water Scarcity, and Water Dependency**

Country	Total Renewable Water Resources km³/year	Internal Water Footprint km³/year	External Water Footprint km³/year	Total Water Footprint km³/year	Water Scarcity %	Water Self-Sufficiency %	Water Import Dependency %
Afghanistan	65.0	16.8	0.5	17.3	27	97	3
Armenia	10.5	2.2	0.7	2.8	27	77	23
Australia	492.0	21.8	4.8	26.6	5	82	18
Azerbaijan	30.3	6.5	1.3	7.8	26	83	17
Bangladesh	1,210.6	112.4	4.1	116.5	10	97	3
Bhutan	95.0	0.7	0.1	0.8	1	88	12
Cambodia	476.1	20.5	0.5	21.0	4	97	3
China, People's Republic of	2,896.6	825.9	57.4	883.4	30	93	7
Fiji	28.6	1.0	0.1	1.0	4	95	5
Georgia	63.3	3.9	0.3	4.2	7	94	6
India	1,896.7	971.4	16.0	987.4	52	98	2
Indonesia	2,838.0	242.3	27.7	270.0	10	90	10
Japan	430.0	51.9	94.2	146.1	34	36	64
Kazakhstan	109.6	26.6	0.4	27.0	25	99	1
Korea, Republic of	69.7	21.0	34.2	55.2	79	38	62
Kyrgyz Republic	20.6	6.6	0.0	6.6	32	100	0
Lao People's Democratic Republic	333.6	7.4	0.2	7.7	2	97	3
Malaysia	580.0	38.9	15.0	53.9	9	72	28
Myanmar	1,045.6	74.4	1.1	75.5	7	99	1
Nepal	210.2	18.7	0.7	19.3	9	96	4
Pakistan	222.7	157.3	8.9	166.2	75	95	5
Papua New Guinea	801.0	5.1	5.1	10.2	1	50	50
Philippines	479.0	104.4	12.5	116.9	24	89	11
Sri Lanka	50.0	22.1	1.6	23.7	47	93	7
Thailand	409.9	123.2	11.2	134.5	33	92	8
Turkmenistan	24.7	8.8	0.2	9.0	36	98	2
Uzbekistan	50.4	22.8	1.3	24.1	48	95	5
Viet Nam	891.2	100.2	3.1	103.3	12	97	3

km³ = cubic kilometer.

Source: A. Hoekstra and A. Chapagain. 2008. *Globalization of Water: Sharing the Planet's Freshwater Resources*. West Sussex, UK: Wiley-Blackwell.

Figure 4. Sample Water Availability Cost Curve—India



Source: 2030 Water Resources Group. 2009. *Charting Our Water Future: Economic Frameworks to Inform Decision-Making*. Washington, DC: World Bank.

together with their respective financial costs, that are available to society and the economy to respond to the threat of future water scarcity.

An example of the importance of assessing the political economy is that of attempts to improve productivity on small farms throughout Asia. There are enormous water savings to be made by reducing the waste in irrigation water and in the produce that spoils before reaching markets. Yet reaching those millions of small individual farmers will involve convincing a cautious, traditional group of the population. This will require a long-term political commitment, from central ministries to state administrators to farmer associations and rural extension workers. Changes will not happen unless backed up by awareness raising and education, giving clear incentives and information reliably, transparently, and convincingly. It is crucial to build robust stakeholder platforms to allow development of effective leaders and strong advocates for change.

Minimum Freshwater Flows

In the discussion on new ways to account for water and to measure its supply and demand, reference should be made to a fundamental measure on the supply-side, a departure from common practice in water resources studies. When assessing the sustainably available abstraction from freshwater sources (mainly river flows), the minimum flows required for sustaining natural aquatic life must be considered to support biodiversity, fisheries, and aquatic ecosystems.

Emerging Opportunities

Responding to the Crisis

Facts about the water crisis demonstrate an incontestable reality as well as the crisis's underlying geophysical, socioeconomic, and political causes. These facts consist of data on supply and demand, constraints on expanding the supply-side, opportunity for influencing demand, new economic parameters that can demonstrate the economic case (e.g., protecting future water sources and abandoning subsidies), and use of embedded water concepts to monitor the case for working toward a global water trade. The water–food–energy nexus is being modeled to assist in describing and quantifying system responses.[42] These facts should now contribute to formulating global and national water policies.

Water Policies

National governments and international agencies should formulate and disseminate their water policies consistent with these facts on the water crisis. Understanding and accepting the reality and being prepared for difficult choices and trade-offs will help define the range of opportunities available to deal cost effectively and creatively with water shortages.

Water policies can be important public statements. They should be designed to create confidence among affected populations that their water future is safe. It is important to recognize that water policies, when formulated with vision and courage, can stimulate innovations and encourage interaction with the private sector by demonstrating a commitment to dealing with water security issues proactively. A sound water policy will provide confidence to prospective investors that their industries can rely on a continued supply of water and energy. In fact, investors' guides already analyze corporate exposure to water-related risks and advise their clients accordingly, demonstrating the importance attached to water as a critical factor in investment.[43] Simultaneously, those involved in any element of the water industry will be encouraged to invest in further innovation if governments send the right signals (e.g., innovation in advanced irrigation systems, decentralized wastewater treatment systems, and geographic information system technology to monitor and manage groundwater use).

Although water stress is a global issue, solutions in improved distribution, storage, treatment, and source protection must be implemented locally. A clear, explicit water policy is important to provide guidance and to demonstrate commitment to local efforts by subnational administrations and the private sector.

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[42] M. Bazilian et al. 2011. Considering the Energy, Water and Food Nexus: Towards an Integrated Modelling Approach. *Energy Policy.* 39 (12). pp. 7,896–7,906.

[43] See, for instance, B. Barton et al. 2011. *The Ceres Aqua Gauge: A Framework for 21st Century Water Risk Management*. http://www.ceres.org/resources/reports/aqua-gauge

Public Perception

Political Economy and Raising Awareness

An underlying reason for the water crisis in the region is the lack of awareness among decision makers and their constituencies of the real cost of using water. Many of the measures required to avert or manage the crisis will involve changes in cost and pricing structures for water and water services that will affect almost everyone in society. Decision makers, in particular those at a lower level who confront affected citizens directly, will be reluctant to advocate and introduce unpopular measures. The most obvious example is the need to raise the tariffs for urban water supply to more realistic levels. Explaining the broad context of the need to apply the real cost of water services to all users requires a long-term program of public education.

Good Water Governance

Governments must be aware of the need and benefits of having an explicit water policy that addresses water scarcity. Such an explicit statement will invite investment and provide reassurances to investors that action to achieving water security is occurring. Water governance, as a concept, may need to replace water management as the driving principle. Water governance includes awareness of the sociopolitical forces that shape decisions to improve water security. Management of resources needs to be improved by developing more efficient institutions which improve access to knowledge. All this will require combinations of investment, policy, and research. Food trade based on rational water-trade analysis needs to be encouraged.

Water Markets

An underlying reason for the emergence of a water crisis is the failure to value water as a market commodity. One response is to introduce concepts of water markets. Historical water markets and water-sharing systems have functioned for centuries in Asia (e.g., Indonesia's *subak* system, Persia's *qanats*, and Oman's *aflaj*) in relatively homogenous, well-established social settings. However, the introduction of new systems of water rights and water markets (such as in Australia) may be impractical for an immediate future in Asia.

Investment in Innovation and Technology

The low value attached to water has suppressed investment in water technology by the private sector, compared with investments in information, communication, and transport technology. Explicit statements of water policy, by international agencies and governments, that begin to respond to the urgent need to deal with water stress, may generate investments in new water technology and bring down the cost of technology options. Similarly, for the private sector, the emergence of explicit corporate water risk assessments will stimulate investment in processes that will help mitigate such risks. Advances in information technology may be expected to apply to the availability and behavior of water resources in all its forms, for more effective real-time resource management. It will help stimulate the uptake of new technology. Other promising initiatives that would benefit from enhancements in information technology include soil conservation and aquifer recharge, recycling of used water (for specific low-quality requirements, in particular for local re-use), semi-centralized wastewater treatment (to recover both water and energy, in combination with solid waste), rainwater harvesting in urban settings, localized storage, etc.

The Potential Response

Needs for Developing Asia

Water operations within ADB and how water programs and projects are planned need to be reshaped in response to the recognition of an emerging water crisis. The ADB Water Operational Plan as well as country water assessments are all a part of this.

ADB should work with its DMCs in developing a fact-based vision as a starting point for formulating its strategy. The facts may be consolidated in a water availability cost curve, or a comparable consolidation, as a convenient presentation of the options available and their impact, their cost, and consequences. These facts need to be complemented with the results of a thorough political economy analysis that focuses on the essential dimension of information on the barriers to adoption of potential measures (i.e., the sociopolitical and institutional effort required to implement the measures and to achieve results).

Making changes is about creating incentives and motivators. Societies, governments, consumers, and producers all need clear, relevant incentives that will make them change their behaviors and influence the way they make their choices. ADB should present these incentives for the policy changes that governments need adopt to protect their water and thereby their survival.

Thinking about Water Differently

The critical role for ADB in helping achieve water security for the region, and guiding the international water community in this endeavor, is to encourage its DMCs to respond proactively and constructively to the prospect of water stress by adopting new ways of managing water, introducing good water governance, and recognizing the irreplaceable value of a limited resource. In other words, by starting to think differently about water.

A gradual, but steady and consistent, introduction by ADB of new metrics for water economics will assist in bringing about a change in the thinking around water. The central theme of the dialogue on water policy should be on the immediate risk to food security, energy security, and economic growth and stability. The use of terms such as embedded water, water trade, and water footprint will assist DMCs in thinking differently about water before formal concepts such as water pricing and water rights can be established.

Preparing the Program

Assessing Future Scenarios

ADB country water assessments will assist DMCs in recognizing the need for water governance and management, based on accurate facts about the current balance between supply and demand for water and on a realistic forecast. A critical evaluation of DMCs' naturally renewable supply will be a starting point, including supplies from accessible, reliable, and environmentally sustainable supplies (i.e., not including one-off mining of groundwater or the use of surface water for receiving waste beyond self-cleansing capacities) and maintaining seasonal freshwater flows in rivers to sustain aquatic life. This will provide the baseline for any quantitative assessment of the shortfall between supply and demand, in terms of m^3 per year, for the whole DMC or by region or catchment, as appropriate.

Future trends must be evaluated in the preparation of forecasts for future freshwater supplies, taking into account a potential reduction in reliable supplies as a result of climate change (e.g., the impact of changing rainfall patterns and mountain snowmelt, retreat of glaciers, and rising sea levels). Forecasts will take into account that accessibility and availability of water may be impaired through quality limitations caused by continuing pollution, reducing the suitability for certain consumptive uses. Future trends in population, urbanization, industrialization, economic growth, and changes in lifestyle must be projected as a basis for formulating forecasts for future water demand in the main economic sectors. Recent international studies may be used as a framework for forecasts to achieve a basis for comparison and regional aggregation. The future water demand for agriculture, industry, energy, and municipal uses can be prepared either on an unconstrained basis or on actual projected (constrained) requirements. In most cases, demand will be defined as water consumption, rather than water withdrawal, assuming that any return flow remains available for subsequent downstream uses depending on time, place, and quality.

From such projections, the possible shortfall or gap between supply and demand by 2030 and 2050 can be assessed, based on continuation of current trends and processes. Where relevant, such analysis will be disaggregated geographically, identifying areas or river basins that are most likely to be subjected to water stress.

Managing Supply and Demand for Future Water Security

A comprehensive range of possible measures to reduce or otherwise modify water demand should be identified, with a quantitative assessment of their impact in m^3 per year, and the unit net costs or savings of introducing and applying such measures in US dollars per m^3. Similarly, measures that can still be taken to improve the sustainable supply of water should be identified and quantified, across all economic sectors, including the rehabilitation or new construction of supply infrastructure, improvement of storage, or recharge.

A quantitative consolidation of these supply- and demand-side measures should be complemented by a descriptive but fact-based assessment of the sociopolitical conditions that will determine the successful application of such measures, including the practical cultural or political barriers that may exist to the adoption of these measures.

Water Governance

The political economy assessment described above should be followed by an analysis and formulation of recommendations on a range of activities in response to conditions encountered, from policies to education, awareness, and investment. Trade-offs will be inevitable between conflicting objectives and areas of interest but will be essential to reach workable compromises in improving water, food, and energy security. Lessons should be learned from previous attempts to achieve reform and change. Measures to achieve trade-offs and support for these may include a combination of the following: (i) social action and public debate, (ii) development of better analytical tools (e.g., to assess the benefits of protection of ecosystems), and (iii) improved equitable access to critical information.

New approaches to good water governance should incorporate river basin management, analyzing the de facto allocation of water as a means to deliver good water governance. Much attention has been paid to the ideal organizational model for river basin management, in particular how to make river basin organizations work in concert with existing government administrative hierarchies of central and subnational governments. The key role of river basin management is at the heart of integrated water resources management—to provide a rational basis for allocation between competing water requirements, including those for sustaining ecosystems. Various models have been developed, usually working on consensual models, depending on the nature of the main problems as well as social and cultural backgrounds. A critical review of the real impact of past attempts at rational water management or water allocation should inform the design of water governance systems and procedures for the future, when water stress conditions will put greater demands on the efficiency of allocation processes.

Private Sector Participation

The potential for private sector involvement in the water sector should be described—distinguishing between the needs and expectations of a national and the international private sector—as an essential component of the response to a water security threat. Existing forms of private sector involvement should be reviewed, together with a critical assessment of the regulatory framework and the business climate in general, examining whether adequate incentives and safeguards are in place for the private sector to invest in, or to be involved in, the water sector.

Program Components

Options

Using the facts and analysis in the preceding sections, a vision should be formulated on how national water security may be achieved or maintained for the future, balancing the competing needs for food and energy. Based on this vision, options and scenarios should be described for a full, unconstrained program of action designed to deal with any future water scarcity or water stress at the local, regional, and national level. The consequences and impact of continuation of present trends should be illustrated in a business-as-usual scenario to provide a clear message and incentives to make decisions and trade-offs.

Program components should include initiatives on the collection, analysis, and dissemination of data and information as well as legislative, institutional, and regulatory changes to amend water governance structures. These should be responses to changing circumstances and the need to allocate priorities and make trade-offs, together with incentive measures for innovation and investment, aimed at both the public and the private sector.

A Government Program

From the above program, an outline should be created of a government response in working toward water security for the future. Using planning horizons of 10 and 20 years, and based on an outline of what a new national water policy should contain, a coherent and rational national program of action should be designed. Government responses should aim to maintain reasonable growth while safeguarding society's long-term interests and well-being. The response should protect the environment and preserve ecosystems to sustain growth and future survival. The program should be ambitious yet realistic, taking into account funding constraints as well as inevitable institutional inertia.

The program may include policy, legal, administrative and regulatory, fiscal, and budgetary components, as well as investment proposals. Sources of prospective funding—as well as principal actors—to realize the program should be identified from existing national budgets, new taxation and other internal revenues, private sector investment, and development partners. Strengthening awareness among decision makers as well as a broad popular constituency should be considered as an essential component of the program to enable the creation of a supportive environment in which difficult trade-offs can be accepted.

Structure of a Potential ADB Country Program

Consistent with the above program, an outline for a potential ADB program of funding and technical support should be defined for a 10-year horizon. The suggested ADB country water program should be in support of ADB's Water Operational Plan as well as the latest country partnership strategy.

Irrespective of the outcome of policy analysis and supply and demand management measures, certain water initiatives will be relevant and urgent for most DMCs and should be pursued consistently while awaiting the establishment of a reformulated policy base. Most of these potential initiatives will relate to (i) strengthening the knowledge base, (ii) demand-side management and efficiency improvement, and (iii) protection of resources.

Reforming Water Governance

At the core of the ADB country water program should be elements of water governance reform. The aim should be, through advocacy at national and local levels, to demonstrate to governments the critical need to manage water differently, assigning its strategic and vital value in allocation and trade-offs, and to amend governance structures and procedures accordingly. A national water policy may need to be formulated, consistent with the proposed reformed approach to water governance.

Governments are likely to require support in generating reliable data on the availability and behavior of water resources, in particular on groundwater. Such information on all aspects of water security should be made accessible and placed into the public domain, including possible measures to deal with water scarcity.

Improving Agricultural Productivity and Expanding Agricultural Research

All analyses of global food and water security point to the (i) predominant use of water for agriculture and (ii) large waste in the process of growing, transporting, and storing food and food products. In Asia, this waste appears to be mainly in the farm-to-market part of the chain (as opposed to the developed world, where most food is wasted at the store and household level). These are likely to involve infrastructure measures (e.g., more efficient transport and storage) but also more accessible knowledge and financial networks to allow small farmers to benefit from global markets. The real feasibility for the private sector in stimulating such networks is in evidence.[44]

All case studies on the water availability shortfall highlight high-impact measures in the agriculture sector at the low unit-cost end of the scale. Improving agricultural productivity and

[44] See examples quoted in KPMG International. 2011. *Issues Monitor: Ensuring Food Security*. New York.

irrigation efficiency, therefore, should be considered a high-priority intervention in most DMCs, reducing water use while increasing food production and maintaining farmers' incomes. Under certain circumstances, incentives to save water by individual farmers are clear and immediate. In other conditions, achieving change in traditional farming techniques will demand long-term processes of education and creating incentives and targeted subsidies during transition phases.

Restoring Watersheds

Most DMCs have suffered from damage to watersheds through deforestation, "slash-and-burn" practices, urbanization, and the application of monocultures. Programs should include measures to improve water retention and storage, combined with reforestation, to reduce soil erosion and flash floods. These measures will have particular relevance as part of climate change mitigation policy and may, therefore, attract special funding.

Improving Knowledge of Groundwater

The importance of groundwater as a natural resource and strategic reserve needs to gain more common currency. More detailed knowledge is required of groundwater and its behavior, with results made accessible to decision makers. The use of groundwater to store water reserves deserves greater attention (i.e., restoring the groundwater as a strategic resource, in particular in with the prospect of greater periods of drought brought on by climate change). The potential to use remote sensing as a technology to assess, measure, and manage groundwater abstractions and reserves needs broader application.

Used Water

One of the activities most damaging to water security in the long term is the use of water resources, both surface water and groundwater, as a recipient of waste. Governments can undertake a wide range of regulatory initiatives to reduce this threat, mainly in the area of enforcing existing legislation. Wider application and better broadcasting of the economics that more realistically reflect the full, long-term costs of destruction of water resources for future use may demonstrate more convincingly to governments that more active enforcement of environment pollution legislation is imperative for sustainable growth. Other pressure on industry to include waste management and recycling as an integral part of the production process may be brought about through consumers and shareholders. In private sector industry, corporate water risk management may provide sufficient incentives to introduce water-saving and internal water reuse measures.

Urban Water Supply Efficiency and Nonrevenue Water

Reducing water loss (i.e., nonrevenue water) in urban water supply systems to acceptable levels (i.e., less than 20%) serves as more immediate water, energy, and cost savings. Low nonrevenue water is also an indicator of effective management of a water utility and may be used to set an example to consumers to extend water loss reduction to in-house losses. Throughout urban Asia, water tariffs should be increased to realistic levels to cover costs and to reduce water waste. To respond to consumer concerns, tariff increases should be accompanied by (i) visible improvements to the quality of service, ultimately leading to water being provided throughout the day and at drinking-water quality, thereby reducing the need to buy comparatively expensive bottled water; (ii) efficiency improvements by the utility company, such as nonrevenue water reduction; and (iii) consumer information about possible in-house water-saving devices to reduce water use and water bills.

Urban Wastewater Management

Improvements in dealing effectively with urban wastewater in Asia's cities are not materializing at a sufficient pace. Reasons are predictable: high capital costs; low tariffs, if any, for wastewater and no immediate financial returns; low visibility of benefits; economic payback of capital investments beyond the political horizon of elected local decision makers; and complex, prolonged construction processes, creating severe disruption to urban life. Breakthroughs are required in financial and economic systems as well as in technology. These will have to involve a new set of economic drivers that reflect the real cost of postponing decisions and to encourage investment from public as well as private sources and technological advances to lower costs and to simplify construction methodologies.

A considerable share of the investment in conventional systems is for large-diameter and often deep collection mains and pumping stations to transport wastewater to large centralized wastewater treatment plants. More decentralized treatment would bring benefits in reducing both the capital and operational costs of collecting and transporting water. Such benefits would be further enhanced if local use is created for treated effluent. Decentralized wastewater treatment requires a small footprint, important in densely populated Asian cities; therefore, it should focus on advanced technologies—for instance, membrane technology. However, it may be argued that developing the skills required to operate such plants is easier than using urban land for large centralized treatment plants or finding new sources of freshwater. If the urgency for treating urban wastewater creates a demand for affordable small-footprint localized treatment plants, then market forces are likely to ensure that new technologies will emerge to meet this demand.

References

2030 Water Resources Group. 2009. *Charting Our Water Future: Economic Frameworks to Inform Decision-Making*. Washington, DC: World Bank.

Allan, Tony. 2011. *Virtual Water: Tackling the Threat to Our Planet's Most Precious Resource*. London: I. B. Tauris.

Asian Development Bank (ADB). 2008. *Technical Assistance for Knowledge and Innovation Support for ADB's Water Financing Program*. Manila.

———. 2011a. *ADB Water Operational Plan, 2011–2020*. Manila.

———. 2011b. *Fast Facts: Urbanization in Asia*. Manila.

———. 2011c. *Food Security, Energy Security, and Inclusive Growth in India: The Role of Biofuels*. Manila.

———. 2011d. *Water for All: The Water Policy of the Asian Development Bank*. Manila.

Barton, Brooke et al. 2011. *The Ceres Aqua Gauge: A Framework for 21st Century Water Risk Management*. http://www.ceres.org/resources/reports/aqua-gauge

Bazilian, Morgan et al. 2011. Considering the Energy, Water and Food Nexus: Towards an Integrated Modelling Approach. *Energy Policy*. 39 (12). pp. 7,896–7, 906.

Carson, Rachel. 1962. *Silent Spring*. Houghton Mifflin. New York.

Chartres, Colin and Samyuktha Varma. 2010. *Out of Water: From Abundance to Scarcity and How to Solve the World's Water Problems*. Upper Saddle River, NJ: FT Press.

Comprehensive Assessment of Water Management in Agriculture. 2007. *Water for Food, Water for Life: A Comprehensive Assessment of Water Management in Agriculture*. London: Earthscan and Colombo: International Water Management Institute.

Anna Dalla Marta et al. 2011. Energy and Water Use Related to the Cultivation of Energy Crops: A Case Study in the Tuscany Region. *Ecology and Society*. 16 (2).

Diamond, Jared. 2005 *Collapse: How Societies Choose to Fail or Survive*. New York: Penguin.

Drew, Jason. 2011. *The Protein Crunch: Civilisation on the Brink*. Vlaeberg, South Africa: Cheviot.

Economist. 2010. Special Report: Water—To the Last Drop. 20 May.

Foley, Jonathan et al. 2011. Solutions for a Cultivated Planet. *Nature*. 478. pp. 337–342.

Food and Agriculture Organization. 2008. *The State of Food and Agriculture 2008: Biofuels—Prospects, Risks, and Opportunities*. Rome.

———. 2011. *Climate Change, Water and Food Security*. Rome.

———. 2011. *The State of Food Insecurity in the World 2011*. Rome.

Frontier Economics Pty. 2008. *The concept of "virtual water"—a critical review*. A report prepared for the Victorian Department of Primary Industries. Melbourne.

High Level Panel of Experts on Food Security and Nutrition of the Committee of World Food Security, 2011. Price volatility and food security: A Report by the High Level Panel of Experts on Food Security and Nutrition of the Committee on World Food Security. Rome.

Hoekstra, Arjen Y. and Ashok K. Chapagain. 2008. *Globalization of Water: Sharing the Planet's Freshwater Resources*. West Sussex, UK: Wiley-Blackwell.

Hoekstra, Arjen Y. et al. 2011. *The Water Footprint Assessment Manual: Setting the Global Standard*. London: Earthscan.

Hoff, H. 2011. Understanding the Nexus. Background paper for the Bonn2011 Nexus Conference. 16–18 November. Stockholm.

Hussey, Karen and Jamie Pittock. 2012. The Energy–Water Nexus: Managing the Links between Energy and Water for a Sustainable Future. *Ecology and Society*. 17 (1). p. 31.

International Energy Agency. 2011. *World Energy Outlook 2011*. Paris.

KPMG International. 2009. *Issues Monitor: Ensuring Food Security*. New York.

Lagi, M., K. Bertrand, and Y. Bar-Yam. 2011. *The Food Crises and Political Instability in North Africa and the Middle East*. http://necsi.edu/research/social/foodcrises.html

Mathews, Ruth. 2011. Water Footprint Assessment. Presented at National Workshop on Water Accounting and Efficiency Measures. Nghe An, Viet Nam. August 2011.

Meadows, Donella et al. 1972. *Limits to Growth*. Universe Books.

Organization for Economic Co-operation and Development (OECD), Working Party on Structural and Global Policies. 2010. *Coherence between Water and Energy Policies*. Paris.

Pearce, Fred. 2006. *When The Rivers Run Dry: What Happens When Our Water Runs Out?* Cornwall, UK: Eden Project Books.

Ringler, Claudia, Zhenya Karelina, and Rajul Pandya-Lorch. 2011. Emerging Country Strategies for Improving Food Security: Linkages and Trade-Offs for Water and Food Security. Background paper for the Bonn2011 Nexus Conference. 16–18 November. Stockholm.

de Schutter, Olivier. 2010. Food Commodities Speculation and Food Price Crises. Briefing note by the Special Rapporteur on the Right to Food. No. 2. New York.

Stockholm International Water Institute (SIWI), International Food Policy Research Institute (IFPRI), World Conservation Union (IUCN), and International Water Management Institute (IWMI). 2005. *Let It Reign: The New Water Paradigm for Global Food Security*. Stockholm: SIWI.

Tuchman, Barbara W. 1984. *The March of Folly: From Troy to Vietnam*. New York: Random House.

United Nations. Population. Quoted in ADB. 2011. *Key Indicators for Asia and the Pacific 2011*. Manila. http://esa.un.org/wpp/unpp/panel_population.htm

United Nations Environment Programme. 2011. *Water Footprint and Corporate Water Accounting for Resource Efficiency*. Nairobi.

Vörösmarty, C. J. et al. 2010. Global Threats to Human Water Security and River Biodiversity. *Nature*. 467. pp. 555–561.

World Economic Forum. 2009. *Energy Vision Update 2009. Thirsty Energy: Water and Energy in the 21st Century*. Geneva.

World Economic Forum Water Initiative. 2009. *The Bubble Is Close to Bursting: A Forecast of the Main Economic and Geopolitical Water Issues Likely to Arise in the World During the Next Two Decades*. Geneva.

————. 2011. *Water Security: The Water–Food–Energy–Climate Nexus*. Geneva: World Economic Forum.

Thinking about Water Differently
Managing the Water–Food–Energy Nexus

The water–food–energy nexus is emerging as a critical issue in Asia and the Pacific. It is clear that solutions must be found to assure water security, thereby eliminating the immediate—and increasing—risk to food security, energy security, and economic growth and stability: water must be recognized as an economic as well as a social good. Governments need to be encouraged to think differently about water, take the longer-term view, and be mindful of the strategic and economic value of this limited resource.

This publication is the result of a scoping study initiated by the Asian Development Bank to better understand the issues associated with the water–food–energy nexus in Asia and the Pacific. It provides high-level guidance on the choices available to address the region's water security issues.

About the Asian Development Bank

ADB's vision is an Asia and Pacific region free of poverty. Its mission is to help its developing member countries reduce poverty and improve the quality of life of their people. Despite the region's many successes, it remains home to two-thirds of the world's poor: 1.7 billion people who live on less than $2 a day, with 828 million struggling on less than $1.25 a day. ADB is committed to reducing poverty through inclusive economic growth, environmentally sustainable growth, and regional integration.

Based in Manila, ADB is owned by 67 members, including 48 from the region. Its main instruments for helping its developing member countries are policy dialogue, loans, equity investments, guarantees, grants, and technical assistance.

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