TOPIC GUIDE:
Water Security and Economic Development

Tom Quick and James Winpenny
May 2014

EVIDENCE ON DEMAND
CLIMATE & ENVIRONMENT
INFRASTRUCTURE | LIVELIHOODS

About Evidence on Demand and Professional Development

Evidence on Demand supports the professional development of Climate, Environment, Infrastructure and Livelihoods Advisers at DFID. Technical Competency Frameworks for the advisory groups guide the support provided. Evidence on Demand also supports cross-cutting or development competencies which cover areas of technical knowledge and skills needed by advisers to effectively deploy their core technical skills and knowledge in development policy and operations.

The Evidence on Demand team is led by a HTSPE Limited and IMC Worldwide Limited Joint Venture. Both firms are established development consultancies with considerable experience in managing resource centres. The Joint Venture is backed by a core consortium of specialist organisations. The consortium provides technical support for developing quality assured resources, answering helpdesk enquiries and supporting consultancy services. Please go to the Evidence on Demand website (www.evidenceondemand.info) for further details.

Disclaimer

This Topic Guide has been produced by Evidence on Demand with the assistance of the UK Department for International Development (DFID) contracted through the Climate, Environment, Infrastructure and Livelihoods Professional Evidence and Applied Knowledge Services (CEIL PEAKS) programme, jointly managed by HTSPE Limited and IMC Worldwide Limited.

The views expressed in the Topic Guide are entirely those of the authors and do not necessarily represent DFID's own views or policies, or those of Evidence on Demand. Comments and discussion on items related to content and opinion should be addressed to the author, via enquiries@evidenceondemand.org.

All the figures in this publication have been accurately referenced; additionally, Figures 2, 4, and 6 have been given fair use permission for use in this publication in their original form by the original authors.

Your feedback helps us ensure the quality and usefulness of all knowledge products. Please email enquiries@evidenceondemand.org and let us know whether or not you have found this material useful; in what ways it has helped build your knowledge base and informed your work; or how it could be improved.

DOI: http://dx.doi.org/10.12774/eod_tg.may2014.quickwinpenny

First published May 2014

EVIDENCE ON DEMAND
CLIMATE & ENVIRONMENT
INFRASTRUCTURE | LIVELIHOODS

Contents

List of Boxes

List of Figures

List of Tables

About Topic Guides

Welcome to the Evidence on Demand series of Topic Guides. The guides are being produced for Climate, Environment, Infrastructure and Livelihoods Advisers in the UK Department for International Development (DFID). There will be up to 30 Topic Guides produced 2013-2014.

The purpose of the Topic Guides is to provide resources to support professional development. Each Topic Guide is written by an expert in the field. Topic Guides:

- Provide an overview of a topic;
- Present the issues and arguments relating to a topic;
- Are illustrated with examples and case studies;
- Stimulate thinking and questioning;
- Provide links to current best ‘reads’ in an annotated reading list;
- Provide signposts to detailed evidence and further information;
- Provide a glossary of terms for a topic.

Topic Guides are intended to get you started on a subject with which you are not familiar. If you already know about a topic then you may still find it useful to take a look. Authors and editors of the guides have put together the best of current thinking and the main issues of debate.

Topic Guides are, above all, designed to be useful to development professionals. You may want to get up to speed on a particular topic in preparation for taking up a new position, or you may want to learn about a topic that has cropped up in your work. Whether you are a DFID Climate, Environment, Infrastructure or Livelihoods Adviser, an adviser in another professional group, a member of a development agency or non-governmental organisation, a student, or a researcher we hope that you will find Topic Guides useful.

Tips for using Topic Guides

I am going to be under the spotlight. How can a Topic Guide help?

The Topic Guides, and key texts referred to in the guides, cover the latest thinking on subject areas. If you think that a specific issue might be raised when you are under the spotlight, you can scan a Topic Guide dealing with that issue to get up to speed.

I have just joined as an adviser. Where should I start?

Topic Guides are peer reviewed and formally approved by DFID. They are a good starting point for getting an overview of topics that concern DFID. You can opt to be alerted to new Topic Guides posted on the Evidence on Demand website through Facebook, Twitter or LinkedIn. New publications of interest to advisers will also be announced in Evidence on Demand quarterly ebulletins.

I don't have much time. How long should I set aside for reading a Topic Guide?

The main text of a Topic Guide takes around three hours to read. To get a good understanding of the topic allow up to three hours to get to grips with the main points. Allow additional time to follow links and read some of the resources.

I need to keep up my professional development. How can Topic Guides help with this?

Topic Guides, while providing an overview and making key resources easy to access, are also meant to be stretching and stimulating. The annotated reading lists point to material that you can draw on to get a more in-depth understanding of issues. The Topic Guides can also be useful as aides-mémoires because they highlight the key issues in a subject area. The guides also include a glossary of key words and phrases.

I would like to read items in the reading list. Where can I access them?

Most resources mentioned in the Topic Guides are readily available in the public domain. Where subscriptions to journals or permissions to access to specialist libraries are required these are highlighted.

I have a comment on a guide. How can I provide feedback?

Evidence on Demand is keen to hear your thoughts and impressions on the Topic Guides. Your feedback is very welcome and will be used to improve new and future editions of Topic Guides. There are a number of ways you can provide feedback:

- Use the Have Your Say section on the Evidence on Demand website (www.evidenceondemand.info). Here you can email our team with your thoughts on a guide. You can also submit documents that you think may enhance a Topic Guide. If you find Topic Guides useful for your professional development, please share your experiences here.
- Send an email to the Evidence on Demand Editor at enquiries@evidenceondemand.org with your recommendations for other Topic Guides.

Acknowledgements

The Topic Guide was coordinated within DFID by Jean-Paul Penrose with additional inputs from Alan Hall, Guy Howard, Simon Lucas, Martin Walshe and John Carstensen.

Executive summary

There is a dual relationship between water resources and economic growth. On the one hand, water can stall and reverse economic growth through the destructive power of floods, droughts and pollution; on the other hand, it can drive production and economic growth across key sectors, including agriculture, energy and industry.

Too little water (scarcity), too much water (flooding) and poor quality water (pollution) represent a risk to sustained economic growth. Evidence suggests that inter- and intra-annual variability in water availability, coupled with poor water resource management, can reduce GDP by up to a third (Grey & Sadoff, 2006) and impinge upon human wellbeing and the environment. Under conditions of increasing water demand and more erratic water supply due to the impacts of climate change, the costs could be even greater.

By contrast, well-managed water resources can underpin economic growth and support pro-poor development. Historical narratives show the importance of major water infrastructure in driving social and economic development in both developed and developing countries. Water is a critical input to agriculture, energy and industry; it drives hydropower turbines and cools thermal power stations; it supports vast swathes of rainfed and irrigated agriculture; it is filtered and purified for use in the electronics industry and it is used in bulk in the steel industry.

However, water is difficult to manage: it is a cyclical medium rather than a sector, and consuming water at one time and point in the system can reduce its availability for a different use. For example, a decision to release water through hydropower turbines to generate power in winter is likely to be at the expense of the availability of stored water for irrigation in summer. In addition, excessive abstraction of water upstream by farmers for crops and livestock may very well be at the expense of other farmers and city users downstream.

The cross-cutting nature of water and its interdependency with other vital domains is acknowledged in the call for ‘integrated management’ and in the increasing use of the term ‘nexus’. The nexus is demonstrated by the power outages in India in 2012 (see box below).

How water and energy security are inextricably linked with agriculture in India

In July 2012, power failure in India left over 600 million people without power for up to two days. Water is a critical factor in India’s power challenge. Weak monsoons reduced rainfall by 18% in many states, causing farmers to increase abstraction of groundwater using electric pumps. Low rainfall also reduced water storage behind key dams, reducing hydropower production by 19% and forced some nuclear and coal powered plants to close down or reduce energy production due to insufficient water for cooling.

Too little rain in some areas was matched by too much in others – two hydropower plants in Himachal Pradesh were forced to close due to high silt levels. Water insecurity was, therefore, a significant factor contributing to the power outages.

Definition of water security

The concept of water security takes account of sectoral interdependencies and requires sufficient water to support the full range of uses. UN-Water (2013a) defines water security as:

The capacity of a population to safeguard sustainable access to adequate quantities of acceptable quality water for sustaining livelihoods, human wellbeing and socio-economic development, for ensuring protection against water-borne pollution and water-related disasters, and for preserving ecosystems in a climate of peace and political stability.

About 1 billion people in the industrialised world live in a water-secure world. This has been brought about by large and sustained investment in water infrastructure, often coupled with good governance systems and in some cases a 'favourable' hydrology, which made achieving water security easier. Not all water-related risks have disappeared, but the number of deaths from water-related diseases, floods and droughts is relatively low and has remained stable in the OECD since the 1990s (UNESCO, 2012). Insurance can mitigate residual risk to a degree, although this is not always sufficient; in addition, there is evidence that the economic costs of water-related disasters in the industrialised world have risen sharply since 1990 (largely due to the increase in the value of exposed assets) (Bouwer, 2011). Furthermore, climate change may also reintroduce water security challenges for countries that have benefited from a benign hydrology and relative water security (World Bank, 2014).

Outside of the industrialised world, water insecurity is widespread and the human and economic costs are high. This is captured in the following headline statistics:

- About 1.2 billion people reside in regions where water is physically scarce (WHO, 2009)
- Another 1.6 billion people face economic water shortage, a condition where countries lack the necessary infrastructure and financial capacity to take water from rivers and aquifers and deliver it to households (UN-Water , 2014b)
- The number of people at risk from floods is projected to rise from 1.2 billion today to around 1.6 billion in 2050 (OECD, 2012)
- Despite improvements in some regions, water pollution is on the rise globally (UN-Water, 2014a)
- 783 million people are still without access to improved sources of drinking water (WHO, 2014)
- 2.5 billion people, including almost one billion children, live without even basic sanitation (ibid)
- Half of the world's wetlands have been lost since 1900 (UN-Water, 2014a)
- Over 40% of the world's population live in transboundary river basins (ibid). Weak coordination regarding international waters can result in political tensions and has reduced the benefits (e.g. energy production) which can arise from cooperative management of shared waters.

Moving towards water security, where risks are mitigated and managed, and where water is efficiently and equitably distributed among the many and competing demands for it, is already a huge challenge. Three global trends threaten to make this even harder:

i) An increase in water demand from agricultural intensification and major expansion of industry and energy production (resulting, in part, from economic growth);
ii) Rapid population growth, especially in urban areas, coupled with a burgeoning middle class with new dietary preferences;
iii) Large-scale changes to the timing, intensity and distribution of precipitation due to climate change.

The challenge is therefore daunting, and the economic and social risks of inaction are large. However, the evidence suggests that the potential economic benefits of moving towards water security are equally as great. A selection of costs and benefits are presented in Table 1.

	Productive Activities			Health	Hazards		Ecosystems
	Agriculture	Energy	Industry		Floods	Drought	
Global	-	-	-	• The overall global benefits from meeting the MDGs for water supply and sanitation are estimated to be $84billion a year (WHO, 2004)	• Over the period 1950-2010 the average annual flood damage associated with property losses across the globe was US$11.6billion (2010 equivalent) (Whittington et al, 2013) • In 2011 the insured losses from floods was US$16.2 billion (Swiss Re, 2012)	• Over the period 1950-2010 the average annual damage from droughts was US$2.5 billion (in 2010 equivalent) (Whittington et al, 2013) • In 2011 the insured losses from drought were $2.4billion (Swiss Re, 2012)	• A global economic assessment of 63 million hectares of wetlands estimated their value at $3.4 billion per year (Brander & Schuyt, 2010)
Regional	• The expansion of irrigated agriculture in the 1950s and 1960s in Asia supported the 'green revolution', which doubled cereal production (IFPRI, 2002)	• The Diama and Manantali Dams in Senegal, Mali and Mauritania were estimated to have an internal rate of return of between 8-24% (KfW et al, 2009)	-	• Lack of safe WASH causes Sub-Saharan African countries annual losses equivalent to 5% of GDP (WaterAid, 2013)	• Under a temperature rise scenario of 2°C due to climate change, flooding could cause around US$50 billion worth of damage to coastal areas of Africa (Christian Aid, 2009)	• A drought in 2003 cost the European Union economy US$11.4 billion (Farmer et al, 2008)	• In the Caribbean, the shoreline protection services provided by coral reefs are valued between US$700 million and US$2.2 billion annually (WRI, 2010)
Country/Region	• In Madhya Pradesh (India), incomes of farmers who constructed on-farm ponds to irrigate pulses and wheat have risen by more than 70% (Giordano et al, 2012) • In Afghanistan, drought and armed conflict have reduced the level of surface water in canals by 70%, causing a 60% drop in irrigated land. It requested US$76 million in aid because 2.5 million people face 'imminent food crisis' due to water shortages (IRIN, 2006). This represents only a fraction of the full economic cost	• In Tanzania, reductions of hydroelectric power resulting from droughts and flooding are expected to cause losses of 0.7-1.7% of GDP by 2030 (World Bank, 2006) • In 2001 in Brazil, low river flow depressed hydropower production, leading to a government mandate to cut electricity use by 20%. The estimated impact was US$26 billion (2% of GDP) (Morrison et al, (2009)	• In Kenya, the loss of industrial production arising from inadequate water storage for hydropower generation between 1991 and 2001 was estimated at US$1.4 billion (around 8% of GDP) (Mogaka et al, 2006)	• In Bangladesh, the estimated total economic impacts of inadequate sanitation amount to a loss of US$4.2 billion each year, equivalent to 6.3% of gross national product in 2007 (UN-Water, 2013b)	• In Ethiopia, the historical levels of hydrological variability diminish economic growth projections by over one-third and raise poverty rates by 25%. A single drought event in a 12-year period will decrease GDP growth rates by 5-10% (Grey & Sadoff, 2007) • The flood in Thailand in 2011 triggered an estimated US$12 billion in insurance claims – the highest freshwater flood loss on record (Swiss Re, 2012). The World Bank estimates that the total economic damages and losses were US$46 billion (World Bank, 2012c)	• In Mexico, water shortages in 2011/2012 caused US$1.18 billion in lost harvests on farmland, killed 60,000 head of cattle and weakened 2 million more livestock, pushing food prices higher (Rosenberg & Torres, 2012) • Water shortages in the United States cost the agricultural sector US$4 billion a year (WEF, 2009)	• More than one third of the District of Pallisa in eastern Uganda is occupied by wetlands. The annual value of the goods and services these wetlands provide has been estimated to be US$34 million for the local economy, equivalent to $500/hectare (Emerton & Bos, 2004)

Table 1 Selected costs and benefits associated with water security (US$)

Despite compelling evidence that transitioning towards water security can drive economic growth, levels of investment are currently inadequate across the developing world. National governments, the private sector and donors must be prepared to support a step-change in the levels of investment in the institutional capacity, information and infrastructure required to manage water resources to support growth.

The poorest developing countries are particularly reliant on public expenditure for water supply, sanitation and water resources management, as the risks deter private investment. Donors have a crucial role to play in these countries and to help bridge the investment gap between identified need and current expenditure, which in Sub-Saharan Africa alone is judged to be US$93 billion per year (capital and maintenance costs), equivalent to 15% of GDP (Foster et al, 2010). Water infrastructure is a significant component of this cost, with US$21.9 billion needed for water supply and sanitation, US$9 billion for multipurpose water storage infrastructure, and US$3.4 billion for irrigation (ibid). The total identified funding need for water infrastructure is therefore approximately US$34 billion or 5.5% of GDP.

Investment in information (e.g. hydrological data), infrastructure (e.g. water storage) and institutions (e.g. integrating water policy across all relevant government departments) must go hand in hand. The balance and focus of investment will be driven by the country context with a gradual shift towards investing in better management systems and capacity once a minimum level of infrastructure has been put in place.

At the global level, the Millennium Development Goals (MDGs) have been important in setting out a framework, goals and targets to drive poverty reduction and improve the lives of poor people. In terms of water, they have focused exclusively on reducing the number of people without access to safe drinking water and basic sanitation, and not on broader water resources management or vulnerability to water-related disasters. The post-2015 development agenda is expected to build on the MDGs but also broaden the focus on water. The UK supports this and proposes targets around the following themes:

- ensuring universal access to safe drinking water, sanitation and hygiene;
- improving the sustainable use and development of water resources;
- reducing wastewater pollution and improving water quality by reducing the discharge of untreated domestic, agricultural and industrial wastewater, and increasing the safe reuse of wastewater;
- reducing the risk of mortality and economic loss from natural and human-induced floods and droughts;
- strengthening equitable, participatory and accountable water governance.

The post-2015 development agenda will be crucial in supporting a move towards greater water security and in complementing work done at the country level to achieve this. Overall, the barriers to achieving water security are well documented, as are many of the potential solutions. It is now time to scale up investment in what has historically been a forgotten 'sector'.

SECTION 1

Introduction

Structure of the guide

The Topic Guide is split into four parts:

- Part 1 provides an introduction to the topic of water security and its contribution to economic growth and especially pro-poor growth, as well as setting out the importance of various social, economic and institutional barriers to water security;
- Part 2 of the report is organised around the four pillars of water security: economic development; drinking water and human wellbeing, ecosystems, and water-related hazards. It presents the evidence around the economic benefits of improving water security for these four pillars;
- Part 3 of the guide discusses the need to scale up investment in information, infrastructure and institutions in order to deliver improved water security;
- Part 4 presents keys concepts and tools that can be used to assess water-security issues and the potential economic benefits of doing so in particular contexts.

Setting the scene

Too little water (scarcity), too much water (flooding) and poor quality water (pollution) represent a risk to sustained economic growth. Evidence suggests that inter and intra-annual variability in water availability, coupled with poor water resource management, can reduce GDP by up to a third (Grey & Sadoff, 2007). Under conditions of increasing water demand and more erratic water supply due to the impacts of climate change, the economic costs could be even greater.

At the same time, well-managed water resources can underpin economic growth and pro-poor development. Historical narratives show the importance of major water infrastructure in social and economic development in both developed and developing countries. For example, the construction of large-scale water storage and hydropower infrastructure in Sweden in the early 20th century powered the growing economic hubs in the south of the country and helped transform Sweden from a poverty-stricken country to one of the wealthiest countries in the world (Lindström & Granit, 2012). More recently, reforms to the Office du Niger in the Sahel are generally considered to have produced successful outcomes for agricultural output, livelihoods and poverty reduction through transforming the way in which water for agriculture is managed (Aw & Diemer, 2005).

The dual nature of water as both a destructive and productive agent is key to understanding how investments in water security can underpin economic growth. Reducing the negative economic costs associated with scarcity, flooding and pollution, and capitalising on the economic benefits of using water productively and sustainably, can drive long-term economic growth.

The opportunities associated with water are context and location specific, and will depend on the existing vulnerability and exposure of the population, as well as the nature of the water insecurity (which depends in part on the hydrology of the area). While this Topic Guide pulls out some of the key economic evidence, themes and issues, the context-specific nature of water security makes the rigorous calculations of the ‘universal value’ or even the national value of increased water security challenging to defend (Whittington et al, 2013). Further work at the country level is required to assess the potential strategies and economic benefit of moving towards greater water security.

At the same time, while water risks are location specific, the fallout from local water insecurity can reverberate across societies, destroying livelihoods and disrupting global supply chains. For example, the 2011 floods in Thailand damaged seven major industrial estates in the central region, which resulted in car manufacturers suspending production and major revenue losses in the electronics industry.

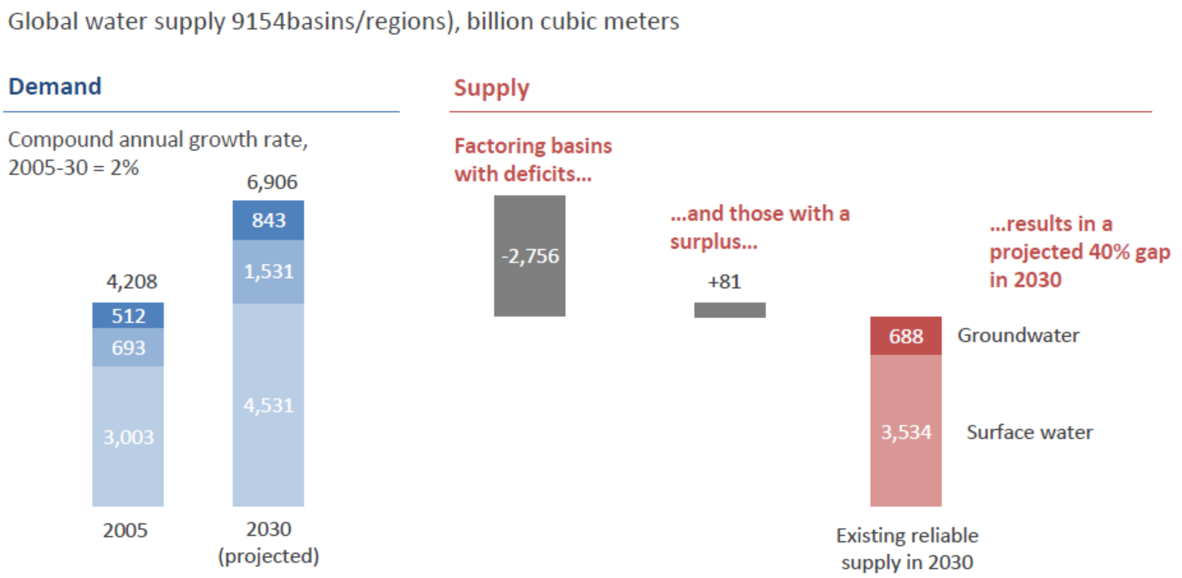
In an increasingly connected and inter-dependent world, the risk of water insecurity concerns us all.

Too little water

Most scenarios of future global water paint an alarming picture of rapid growth in demand overtaking available supply in many countries over the next two decades:

> *...Between 1990 and 2000, the world’s population grew by a factor of four but freshwater withdrawals grew by a factor of nine. This means that withdrawals of water through 2030 will increase much more quickly than global population, as people get wealthier and consumption patterns rise. ...the world could face a 40% shortfall between water demand and available freshwater supply by 2030. Many countries are already extracting groundwater faster than it can be replenished (Mexico by 20%, China by 25%, and India by 56%). If current trends continue, by 2030 two-thirds of the world’s population will live in areas of high water stress* (Waughray, 2013).

Figure 1 Global water stress by 2030 (adapted from McKinsey et al, 2009a, p44)



In its *Environmental Outlook to 2050* the OECD (2012, p208) strikes a similar sombre note:

> *Many people are suffering from inadequate quantity and quality of water, as well as stress from floods and droughts. This has implications for health, the environment*

and economic development. Without major policy changes and considerable improvements in water management processes and techniques, by 2050 the situation is likely to deteriorate, and will be compounded by increasing competition for water and increasing uncertainty about water availability.

When the supply of and demand for water are on such a collision course, something must give way, since water is finite and there are limits on the amounts that can be made available for human use. 'Business as usual' is by definition impossible – there cannot be a '40% shortfall'. If these trends continue, whole sections of the economy and society will have to go short, with significant economic and social consequences. Often ecosystems such as wetlands are the first casualties of water scarcity. While they can tolerate water scarcity for a while, eventually they become degraded and unable to support the population that depends on them (e.g. wetlands no longer provide a buffer against flood risk) (ten Brink et al, 2013).

Understanding of the risks posed by water scarcity has grown significantly. In 2014 the CEOs of global businesses identified 'water supply crises' as the third highest global risk (WEF, 2014). Businesses are, therefore, increasingly aware of the risk water poses to their operations and their financial bottom line. In a CDP (2013) Water Disclosure report, 70% of businesses identified water as a 'substantive risk', with the majority of those expecting the impacts to be felt within the next five years. For some respondents, the anticipated financial impact was as high as US$1 billion (ibid).

Box 1 Definition of water stress and water scarcity

One of the most commonly used measures of water scarcity is the 'Falkenmark indicator' or 'water stress index'. This method defines water scarcity in terms of the total water resources that are available to the population of a region; measuring scarcity as the amount of renewable freshwater that is available for each person each year. If the amount of renewable water in a country is below 1,700m^3 per person per year, that country is said to be experiencing water stress; below 1,000m^3 it is said to be experiencing water scarcity; below 500m^3, absolute water scarcity. However, this definition ignores the fact that, while water may be physically available, insufficient investment in water-security institutions and infrastructure may mean those who need water cannot access it – sometimes called economic scarcity.

Box 2 South Africa's looming water deficit (McKinsey, 2009a, p63-65 & 83)

South Africa has a diversified and thriving economy, but its continuing political and social harmony depends on a continuation of high economic growth to meet the expectations of its citizens and to redress historical inequities. On current trajectories, and unchanged policies, its urban, agricultural and industrial growth projections to 2030 are incompatible with the country's water endowment.

In the base case scenario, demand for water will be 17% greater than available supply by 2030. The impact of climate change might increase the size of this shortfall. Competition for limited water supplies will intensify in each of the basins feeding the largest cities – Johannesburg, Pretoria, Durban and Cape Town. Household demand is expected to increase from the growth of incomes and improved service coverage, while industry, power generation, mining and agriculture – the sectors that will drive the growth of incomes – are all water intensive.

Closing the projected supply-demand gap for water in 2030, and thereby enabling South Africa's growth potential to be achieved, can be achieved with a portfolio of different measures – supply-side transfer schemes, new dams, and modifications to existing structures, but also the re-engineering of existing irrigation schemes to make them more water efficient and better use of water in mining and industrial operations.

Too much water

The number of people at risk from floods is expected to rise from 1.2 billion today to around 1.6 billion in 2050 (approximately 20% of global population); the economic value of assets at risk is expected to rise to roughly US$45 trillion in 2050, an increase of 340% from 2010 (OECD, 2012). This is largely because of the growth of economic assets in locations prone to flooding and the expectations, under the majority of climate scenarios, that sea levels will rise and coastal storm surges will become more frequent.

Box 3 Economic impact of flooding in Pakistan (Saeed, 2013; GoP, 2012)

Three years of repeated floods in 2010, 2011 and 2012 have inflicted serious damage on Pakistan's economy, halving its potential economic growth. The economy grew on average at a rate of 2.9% per year during this period. That is less than half the 6.5% that Pakistan could potentially have managed if it had not faced the economic and human losses associated with flooding.

Pakistan lost a total of 3,072 lives and $16 billion to the floods in 2010, 2011 and 2012. An initial estimate made by the National Disaster Management Authority of the floods' impact shows agriculture sector losses at US$2 billion due to damages to 1.05 million acres of standing crops.

Consecutive years of flooding has also pushed up the country's inflation and unemployment rate as it has disrupted supply chains, damaged major crops like sugarcane, rice and cotton, and hampered industrial production.

Poor quality water

Different users of water are reliant not just on there being enough water but also that it is of sufficient quality.

Poor quality water can have a direct impact on the economy by, for example, reducing agricultural yields or by increasing water-treatment costs. Research on the impact of using polluted water for irrigation in China, which considered the impacts on yields and produce quality but not on human health, estimated a cost of 7 billion Yuan (approximately £700million) a year (World Bank, 2007).

Poor water quality can also have a significant indirect cost on the economy through the impact it has on health.

It was estimated in 2008 that the Philippines lost US$1.4 billion, or 1.5% of GDP per year, because of poor water quality and poor sanitation and hygiene. The health impacts, predominantly from premature deaths, represented the largest source of quantified economic costs. Estimated to be about US$1 billion, this item explained about 72% of total economic costs. The second most important economic impact was on water resources, which accounted for about 23% of the total costs. This included having to treat polluted water prior to piping it into houses.

On the other hand, it was estimated that improvements in the treatment or disposal of waste had the potential to reduce costs by US$363 million.

The findings of this study indicate that poor water quality and sanitation have significant economic costs. However, it also shows that the economic gains from improving water quality and access to sanitation could be substantial (USAID/WSP, 2008).

Drivers of water insecurity

Nations can either have a 'favourable' or 'unfavourable' hydrology, which makes it much more difficult and expensive for some nations to move towards water security than others.

Figure 2 Rainfall variability and GDP (bubble size = GDP per capita) (Brown & Lall, 2006)

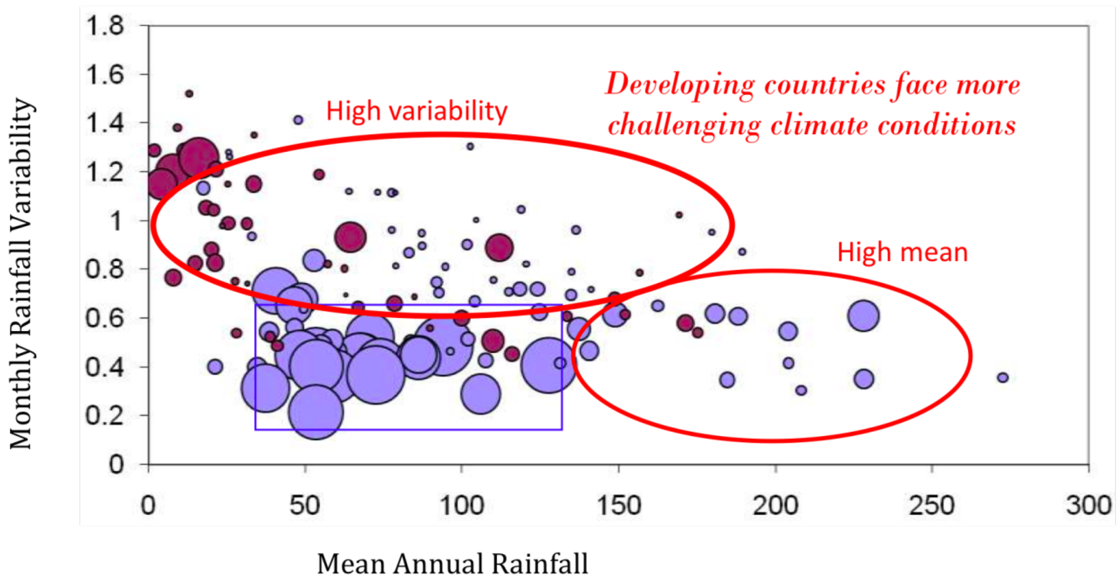


Figure 2 shows that larger economies tend to be concentrated in areas with low monthly and intra-annual variability of rainfall, while smaller economies either have highly variable rainfall or have very low or high mean annual rainfall. However, there are exceptions to this rule and large economies have developed in areas with an unfavourable hydrology, e.g. Saudi Arabia and Singapore (WRI, 2013).

In addition to the natural hydrology of an area, there are three broad drivers of water insecurity: increasing water demand (e.g. from expansion of energy production and industry), population growth, and climate change. The impact of changes in water demand on the different components of water insecurity (scarcity, hazards and pollution) are presented in Table 2, followed by consideration of the impact of population growth and climate change.

	Water scarcity	Water- related hazards	Water pollution
Agricultural intensification	70% of blue water withdrawals are for irrigation (UN-Water, 2013c) and, given the need to produce almost 50% more food by 2030 and 100% more by 2050 (OECD, 2010b), demand may increase further (UN 2009). However, given the increasing demand for water from manufacturing, electricity and domestic use, the OECD (2012) states that there is little scope for increasing water for irrigation. Unsustainable use of groundwater for irrigation poses a serious risk. The Indus River plains aquifer underlying the India-Pakistan border, the North China plain aquifer, and aquifers in the Middle East are particularly at risk (UNEP, 2012).	Flood intensity and impact can be exacerbated by changes in land use and unplanned development in alluvial plains (FAO, 2013).	Diffuse pollution from agriculture caused by leaching of agro-chemicals from soils has a high impact on water quality and the biota it supports. In lower-income countries (LICs) 54% of organic water pollution is from the agricultural sector. It is estimated that there are 12,000km^3 of polluted freshwater in the world, equivalent to six years of irrigation use (FAO, 2011).
Expansion of industry and energy production	Water demand is projected to increase by 55% globally from 2000-2050. The increase in demand will come mainly from manufacturing (+400%), electricity (+140%) and domestic use (+130%) (OECD, 2012).	Some industrial and energy facilities (e.g. hydropower schemes) can alter the hydrological cycle. However, well-designed multipurpose hydropower schemes can provide water storage and, therefore, mitigate flood risk.	Effluent discharges from industry can have very significant environmental impacts, particularly at the regional and local scale. Small-scale industries, such as agro-processors, textile dyeing and tanneries, can release toxic pollutants into local waters (UNESCO, 2012).
Urbanisation	The urban population is projected to increase by 2.9 billion to a total of 6.3 billion in 2050, increasing problems of adequate water supply, sanitation and drainage, especially in urban slums already faced with a backlog of unserved populations (ibid).	Close to 2 billion people live in highly flood-prone areas. 136 coastal cities incurred on average US$6 billion worth of costs due to flooding in 2005.The urban poor are particularly at risk (World Bank, 2012a).	Over 80% of wastewater worldwide (and 90% in developing countries) is not collected or treated, and urban settlements are the main source of pollution (UN-Water, 2014a)..Untreated wastewater is causing major health and pollution threats to downstream and underground water and people (Bahri, 2009).
Changing diets	3 billion middle-class consumers could join the world economy by 2030. China's per capita meat consumption could increase by 40% to 75kg (McKinsey, 2011). Producing 1kg of beef can be 4 times as water intensive as producing 1kg of rice (UNESCO, 2012). Changing diets will exert a significant demand on water resources.	Increases in livestock production may lead to deforestation and land use change, which may lead to increased flood risk at a local scale (FAO, 2007).	In intensive livestock systems, there may also be pollution from feed and fodder production in the form of nutrient loadings and pesticides (Thornton & Herrero, 2010). Pollution from slaughterhouses may also occur.
Land use change and deforestation	Land use change can exacerbate soil erosion and reduce soil water-holding capacity, and decrease the recharge of groundwater and existing surface-water storage capacity, through siltation and sedimentation of rivers and reservoirs that subsequently result in water scarcity over time.	The importance of wetlands in regulating flood and drought risk is well understood (UNESCO, 2012). There is also a link between deforestation and increasing flood risk, which has been observed at the micro level and for particular catchments (FAO, 2007).	Deforestation results in the degradation and desertification of watersheds and catchment areas, and reduces the amount of usable safe water available downstream (ibid).

Table 2 The relative impact of drivers on different components of water security (scarcity, hazards and pollution)

Box 4 Population growth and water security

Population growth will drive greater water demand in the agriculture, industry and energy sectors. This will have profound impacts upon countries that are vulnerable to water stress (particularly in Africa, central and southern Asia, the Middle East, Central America, and South America). Furthermore, the fact that the majority of population growth will occur in urban areas may lead to an increase in exposure to water-related hazards if these are poorly sited and designed. The world population is projected to grow until at least the second half of this century. Thus, in a rapidly warming scenario, the most adverse impacts on water availability associated with an increase of 4°C may coincide with maximum water demand as the world population peaks.

Box 5 Climate change and water security

Stern (2007) concludes that climate change will be felt most profoundly through water and that the poorest and most vulnerable will suffer most. The impacts will be felt through changes in the amount, distribution and intensity of precipitation, which will lead to human and economic losses. Changes to the water cycle are likely to range from accelerated glacier melt, altered precipitation, run-off, and groundwater recharge patterns, to extreme droughts and floods, water quality changes and saltwater intrusion in coastal aquifers. Modelling, observation and theory suggest that greenhouse gas forcing will lead to an intensification of the water cycle. This implies that, on the planetary scale, dry areas will become drier and wet areas wetter.

The World Bank (2012e) stated that a (4+°C) warmer world would experience:

- extreme precipitation events (expressed as total annual precipitation during the five wettest days in a year) increasing by 20% in RCP8.5 (4+°C), indicating an additional risk of flooding;
- particularly significant soil moisture decreases over much of the Americas, as well as the Mediterranean, southern Africa, and Australia;
- 43-50% of the global population living in water-scarce countries by the end of the 21st century.

There remains significant uncertainty around the spatial distribution of water stress and flood risk, and different global climate models disagree on the magnitude and direction of change at the regional level. However, studies that compare different levels of warming conclude that changes found at lower levels of warming (e.g. 2+°C) are expected to be amplified in a 4+°C world, while the direction and spatial patterns of change would be similar (Bates et al, 2008).

There is a consensus within the research that it is the combination of climate change, population change, and changes in patterns of demand for water resources that will determine future water risks, rather than climate change alone. This will be further shaped by levels of adaptive capacity. In many of the poorest countries, particularly in sub-Saharan Africa, the currently unmanaged levels of climate variability are several times greater than predicted climate change. Reducing this ‘adaptation deficit’ by enhancing physical and social capital is a prerequisite for adaptation to climate change and is needed to protect the poorest and most vulnerable populations. There are numerous ‘low-regret’ actions – typically policies that would be priorities for development even without climate change – especially in water supply and flood protection (World Bank, 2010a).

For poor countries already facing hydrological variability, climate change will make water security more difficult and costly to achieve (World Bank, 2014). Climate change may also reintroduce water-related risks for countries that have in recent years benefited from a benign hydrology and relative water security.

Climate change and population growth make it clear that there is a pressing need not only to reduce water insecurity now, but to make sure water resources are 'fit for purpose' over the medium and long term.

In addition to these drivers, policy and market failures exacerbate water insecurity throughout the world. These include water pricing, poor water governance and insufficient investment in water institutions and infrastructure. Two failures are worth highlighting: low water prices and poor water governance.

The price of water does not reflect its true cost: Prices for water are typically administratively determined through mechanisms that are often political and rarely take economic value into account. Water prices are typically kept artificially low and do not respond automatically to short-term and long-term changes in supply (IWMI, 2010b). In the majority of developing countries, the price of water is not a reflection of the true cost of procuring, treating and distributing that water (OECD, 2003). Low water prices often lead to wasteful use and pollution, and mean that governments do not raise sufficient money to invest in improving water infrastructure (OECD, 2010a). For example, it is estimated that a US$145 billion investment between 2010-15 in water supply and wastewater infrastructure has been required to meet MDG targets (WHO, 2012). However, current levels of investment are far below such targets (only US$3.8 billion was invested during 2010 in Africa (ICA, 2012)).

However, many governments maintain low prices in an attempt to ensure access and affordability, and to court political popularity.

There are, therefore, competing trends towards full cost pricing of water versus more customary subsidies or essentially free water. The OECD (2012) states that water pricing that better reflects the costs of providing and treating water can be used to signal scarcity and to create incentives for efficient water use in all sectors (e.g. agriculture, industry, domestic). The impact of tariffs on poor or deserving groups of consumers can be mitigated by using progressive tariffs (whose unit rate rise with larger volumes of consumption), or by cross-subsidy from more to less affluent users. Some countries also cover the water bills of poor households from social security payments.

Weak water governance: Water governance is understood as the systems that determine who gets what water, when and how, and who has the right to water and related services. The allocation of water is often determined by factors beyond the control of those institutions which manage water resources. For instance, policies and investments around energy or agriculture are often made without regard to the availability of water resources. In most places, decisions affecting water are carried out within a fragmented institutional setting in which responsibilities are unclear and maybe conflicting (UNDP, 2013). Integrated water-resource management has been adopted in many countries to overcome this fragmentation and to improve governance. Poor governance and/or weak political will to commit the necessary financial and human resources to water-supply development and water-resource management stifles progress. Even where sufficient financial resources are allocated, serious and widespread capacity constraints undermine effective implementation and the equitable targeting of services (WaterAid, 2012). Weak water governance means that water resources are not allocated efficiently or equitably, which can lead to sectors such as agriculture or energy underperforming, ecosystems being degraded, and communities spending more time and resources to access water. The inefficient allocation of water resources therefore poses a significant risk to sustained economic growth.

Water security

Given the multiple hydrological, economic and institutional drivers that lead to water scarcity, water-related hazards and pollution in a range of countries, questions over what can be done to reduce these impacts and what the associated economic advantages of such a strategy might be are pertinent.

Water security is a concept that represents an 'ideal scenario' of well-managed water resources, supporting inclusive economic growth and social wellbeing.

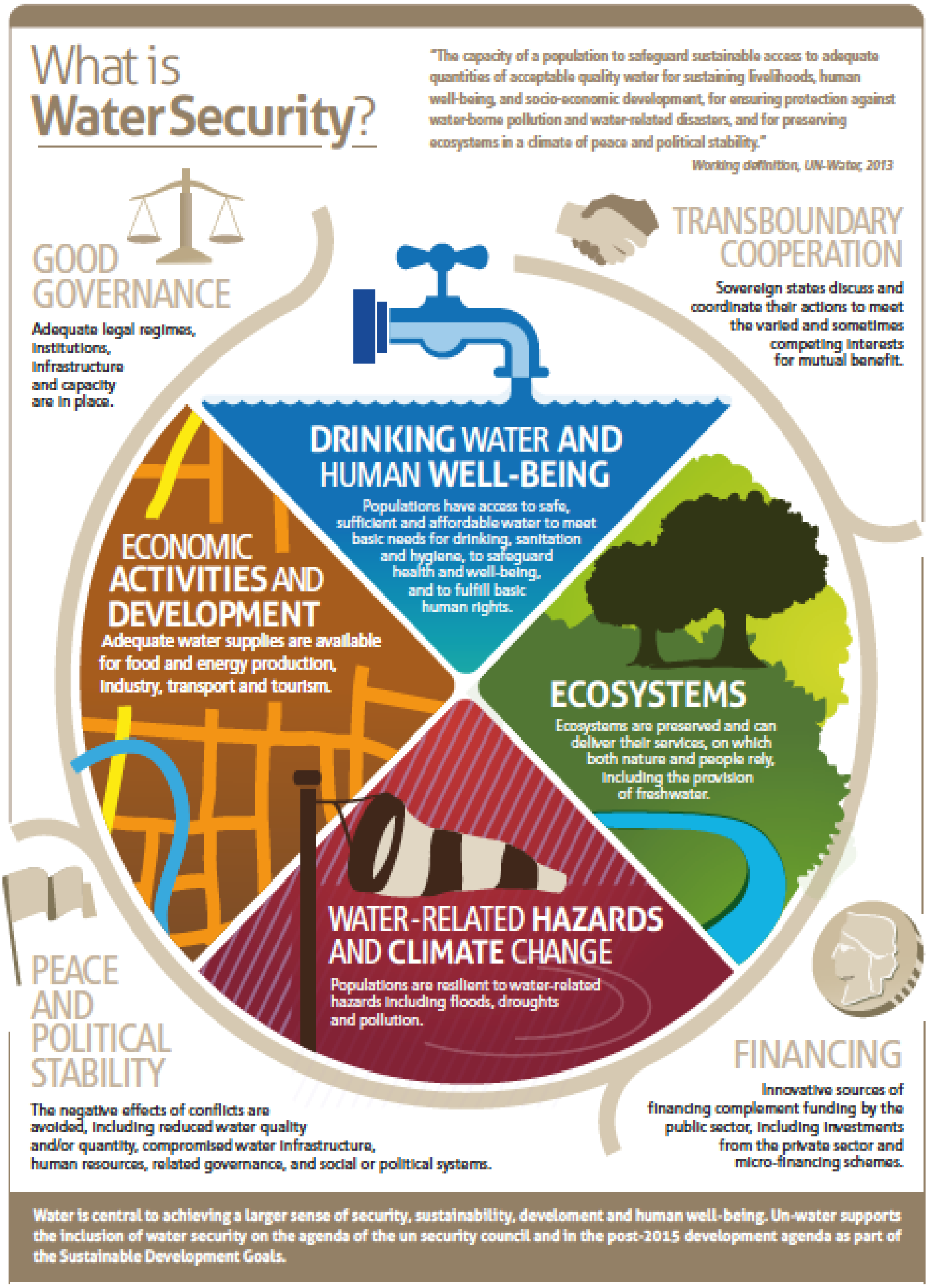
> Water Security is defined by UN Water (2013a) as: "The capacity of a population to safeguard sustainable access to adequate quantities of acceptable quality water for sustaining livelihoods, human well-being and socio-economic development, for ensuring protection against water-borne pollution and water-related disasters, and for preserving eco-systems in a climate of peace and political stability".

The four pillars of water security, illustrated in Figure 3, are:

- sustainable economic development;
- human health and wellbeing;
- protection against water-related hazards;
- healthy ecosystems.

The evidence around the four pillars of water security and their contribution to economic development is considered in Part 2 of the Topic Guide.

Figure 3 Illustration of water security (UN-Water, 2013e)



About 1 billion people in the industrialised world live in a water-secure world. This has been brought about by large and sustained investment in water infrastructure, often coupled with good governance systems and in some cases a 'favourable' hydrology, which has made achieving water security easier. Not all water-related risks have disappeared, but the number of deaths from water-related diseases, floods and droughts is relatively low and has remained stable in the OECD since the 1990s (UNESCO, 2012). Insurance can mitigate residual risk to a degree, although this is not always sufficient and there is evidence that the economic costs of water-related disasters in the industrialised world have risen sharply since 1990 (largely due to the increase in the value of exposed assets) (Bouwer, 2011). Furthermore, climate change may also reintroduce water-security challenges for countries that have benefited from a benign hydrology and relative water security (World Bank, 2014).

Outside of the industrialised world, water insecurity is widespread, and the human and economic costs are high. This is captured in the following headline statistics:

- About 1.2 billion people reside in regions where water is physically scarce (WHO, 2009)
- Another 1.6 billion people face economic water shortage, a condition where countries lack the necessary infrastructure and financial capacity to take water from rivers and aquifers and deliver it to households (UN-Water, 2014b)
- The number of people at risk from floods is projected to rise from 1.2 billion today to around 1.6 billion in 2050 (OECD, 2012)
- Despite improvements in some regions, water pollution is on the rise globally (UN-Water, 2014a)
- 783 million people are still without access to improved sources of drinking water (WHO, 2014)
- 2.5 billion people, including almost one billion children, live without even basic sanitation (ibid)
- Half of the world's wetlands have been lost since 1900 (UN-Water, 2014a)
- Over 40% of the world's population live in transboundary river basins (ibid). Weak coordination of international waters can result in political tensions and reduce the benefits, e.g. energy production that can arise from cooperative management of shared waters.

Water insecurity hits the poor hardest

These aggregate figures conceal the fact that within both developed and developing countries, particular users and sectors bear far greater risks than others. For example:

- In the majority of developing countries, women and girls are more vulnerable to water insecurity than men. A significantly larger number of women than men are engaged in rainfed agriculture, which means they are more vulnerable to changes in precipitation patterns. They are also the primary water providers to their households and, when water is scarce, they forgo education and employment in order to fetch water. In addition, women are 14 times more likely to die in a natural disaster, which includes droughts and floods, than men (UN Women, 2014). Afterwards, they also face a greater risk of sexual assault and trafficking. The brunt of water insecurity falls on women and girls;
- The poorest are much more vulnerable to water risks than their wealthier neighbours. The urban poor are more likely to live on marginal land, which is at risk from water-related hazards and has non-existent or poor water and sanitation infrastructure. The rural poor are largely dependent on rainfed subsistence agriculture and more vulnerable to inter and intra-annual variability in precipitation (FAO, 2013).

Water is typically a public good,[1] and if managed sustainably and equitably, potentially benefits all users, underpinning economic growth as well as basic human needs and environmental integrity. However, given existing inequalities in the distribution of water-related risk, it is important to ask the question of 'water security for whom'.

The water cycle, trade offs and synergies

It is more meaningful to think of water as a *cyclical medium* than as a *sector,* since it moves through various physical states and locations, all the while delivering 'services' to users and to the natural environment. The same water can be used many times between its precipitation and its eventual evapo-transpiration or discharge into the sea. However, depending on how it is used, it can deliver a greater or lesser economic benefit. A unit of water that is withdrawn and consumed in the headwaters of a basin has a lower economic benefit than a unit of water that is reused several times, e.g. a unit of water that passes through a hydropower plant, provides navigational and ecosystem service benefits, is used for cooling in a power plant, and finally used for agricultural irrigation.

In this context, there is an important distinction between *consumptive* and *non-consumptive* water use. The former reduces the availability of water to others through losses in transpiration of plants or evaporation from water bodies or land surfaces. Pollution of water also effectively reduces its availability for beneficial use elsewhere. In contrast, non-consumptive use releases water for potential use by others, by drainage into water bodies, ground aquifers, etc., unless it is polluted, in which case its reuse may not be possible without costly treatment.

Water consumption at one time and point in the system can reduce the availability of water at a different time or for another use. A decision to release water through hydropower turbines to generate power in winter is likely to be at the expense of the availability of stored water for irrigation in summer. Abstraction of water upstream by farmers for crops and livestock may very well be at the expense of other farmers and city users downstream. These dilemmas are far from being theoretical, as the case of Aral Sea demonstrates, where, at its most serious, over-abstraction for irrigation and energy led to a 26m drop in water levels and a 92% reduction in water volume (Micklin, 2010). River basins have to be managed in such a way as to optimise the contribution of their water to human welfare and economic livelihood.

It is also the case that water security itself might have a cost. Water security can be at the expense of other 'securities' (e.g. energy and food) and vice versa. For instance, importing water-intensive items rather than producing these domestically may be a sensible response to water stress, but could lead to lower national food security. Conversely, efforts to improve national energy and/or food security may reduce water security. A case in point is Saudi Arabia's programme of subsidising the production of wheat using groundwater, which failed due to overdrawing from the aquifers and the high cost of the fiscal subsidy entailed (UN-Water, 2013d). The efforts of one country to increase its own water security may also be at the expense of the water security of its neighbours – hence the importance of considering the transboundary dimension.

It is, therefore, clear that decisions about water management have to be *holistic,* taking account of the inter-relationships of water use in different parts of its cycle.

[1] Providing benefits to the whole of society, to which none can be excluded. Public goods are necessarily provided by public authorities, since private providers could not make a profit from them.

Some of the ‘services’ or benefits conferred by water will accrue to identifiable users, and can be captured in economic benefits valued in various ways. However, there are also **‘system’ values** of water, comprising the sum total of all benefits of water in a river basin or other hydrological region. System benefits take account of interactions and trade offs between different water uses, *opportunity costs* , *synergies*, and *externalities*,[2] both positive and negative (Whittington et al, 2013).

The water nexus

The cross-cutting nature of water and its interdependency with other vital domains is acknowledged in the increasing use of the term ‘nexus’ in discussions of the links between water and energy, water and food, water and climate change, water and trade, water and ecosystems, etc. Due to the complex way water in which is connected to many other sectors and users, this term needs to be used carefully as there is not a single ‘nexus’.

A recognition that many of the problems facing water come from outside the boundary of what is commonly considered to be the ‘water sector’ has led to calls to think ‘outside the water box’ when formulating solutions.

Two examples of the water nexus are provided below:

The US drought in 2012 had an impact on 80% of US farms and ranches, resulting in crop losses in excess of US$20 billion and a wide range of ripple effects. Corn crops were greatly reduced due to a lack of rainfall, affecting food and livestock feed supplies and prices, as well as corn ethanol production. Power plants had to scale back operations or even shut down because the water temperatures of many rivers, lakes and estuaries had increased to the point where they could not be used for cooling. Household, municipal and farm wells in the Midwest had to be extended deeper into aquifers to make up for the lack of rainfall, draining groundwater supplies and demanding more electricity to run the pumps. The full costs are estimated to be as high as US$50 billion (National Drought Forum, 2012).

Quantified models of specific river basins can also illustrate the water nexus. They demonstrate trade offs in the use of the water for different purposes, and also the potential synergies from adopting integrated water-resource management. In the Zambezi River Basin, the model suggests that full development of all irrigation potential on its own would reduce firm capacity in hydropower by 21% and average energy by 9%. Alternatively, the restoration of natural flooding in the Zambezi Delta through revised reservoir operating procedures could generate benefits through fisheries, agriculture, environmental and flood protection, but could reduce hydropower production at two key dams by between 3% and 34%. Compared with uncoordinated unilateral operation, an integrated approach to water management can optimise the aggregate economic and social benefit, even where sector performance is sub-optimal (World Bank, 2010c).

Integrated Water Resources Management

The nature of water makes it necessary to manage it in an integrated manner that takes into account the interlinked risks and opportunities it presents to different sectors and users.

[2] An opportunity cost arises when the use of water for one purpose deprives someone else of its use; a synergy is created when an outcome results in a total impact greater than the individual value of its components; externalities are unintended impacts on other parties, not factored into the decision of the active agent.

Water-resources management (WRM) aims to manage the hydrological cycle in order to satisfy all the actual and potential users of water. It includes such activities as catchment protection (including afforestation and land use regulation), groundwater development and control, water storage and river control, flood management, providing minimum flows for ecological purposes, wetland protection, and control of pollution, among others.

Water Resource Management: "...a set of activities (or functions) aimed primarily at (i) ensuring that society has timely and reliable access to water resources of enough quality in the right location, (ii) protecting society from water-related risks (floods and droughts) and (iii) ensuring the protection of aquatic ecosystems and the environmental sustainability of water use" (OECD, 2011, p12-13).

GWP's regularly updated *Toolbox* offers a suite of tools for promoting water security, comprising policy guidance, creation of the enabling environment, institutions, management instruments, and case studies.

Integrated Water Resources Management (IWRM): "a process which promotes the coordinated development and management of water, land and related resources in order to maximise the resultant economic and social welfare in an equitable manner without compromising the sustainability of vital eco-systems" (GWP, 2014).

Case studies of the application of IWRM can be found in the *Toolbox*; Lenton & Muller, 2009.

Approaches to the economic valuation of water

The economic evidence presented in this Topic Guide is collated from a range of sources and the values have been calculated using a range of methods (of which a number are reviewed here).

In most cases, users pay either nothing or a sub-economic rate for their use of water; therefore, using the level of water tariffs as a proxy for benefits would greatly understate the real benefits enjoyed. Other valuation methods are necessary.

The Dublin Statement on Water and Sustainable Development (UN, 1992) stated that: "Water has an economic value in all its competing uses and should be recognized as an economic good" (Principle 4). A distinction needs to be made between the *value, cost* and *price* of water, which are often very different from each other. The economic *value* of water is particularly apparent in situations of water scarcity. Water has different economic values in its different uses. It has an economic *cost* of supply, which also varies in different situations and for different purposes. Water provided to a particular user, in a specific place, at a certain time, has an economic benefit, but also entails an economic cost. The relationship between the specific benefit and the specific cost is the basis of the *economic* justification for supplying that user. Finally, the *price* of water is a financial or fiscal transaction between the provider and the user, which is often closely controlled by public authorities, and often bears little relation either to its value in specific uses, or its cost of supply.

Allocating water purely on the basis of such economic principles is complicated, and difficult to apply in practice (Turner et al, 2004). However, the basic concept of comparing the costs and benefits of supplying water in specific locations and to specific categories of users is fundamental to water policy, especially in situations of growing stress, and this requires some estimation – however rough – of the value of the water in its various states and uses.

The methods of valuing water depend on the sector concerned, the type of use, and the information available:[3]

- *Household* consumption is commonly valued using Willingness To Pay (WTP) evidence from direct surveys, using structured questionnaires or various kinds of ‘choice experiments’. This ‘stated value’ approach can be supplemented and cross-checked by ‘revealed preference’ evidence, such as inferring users’ preferences from their changes in consumption following a tariff change or by estimating what they are actually spending at present.

- *Irrigation* water use can be valued in either of two different ways. The marginal productivity of water (the extra value of output that can be obtained from additional applications of water) can be estimated from changes in yields during crop-water trials. Alternatively, the more common approach (the ‘net-back’ method) is to derive the value of water as the residual from farm budget data, after all other costs have been allowed for. This latter method makes the crude *assumption* that all the residual, or unexplained, farm surplus is due to water, rather than to other factors.

- *Industrial* water valuation poses a greater problem. For many industrial (and commercial) enterprises, water is a small part of their total costs. It would therefore be misleading to use the ‘residual method’ as in irrigation, and attribute the whole residual surplus to water. Much industrial bulk water is self-supplied from wells and rivers. Many firms recycle water by treating and reusing waste flows. One valuation device is to regard the cost of recycling as the upper limit on industrial WTP, as above this level firms would rationally recycle rather than buy in.

- The aforementioned uses all involve the *abstraction* of water. Water also has *in-stream* values for waste *assimilation* and dilution, flushing sediment, the functioning of ecological systems, navigation, and various kinds of recreation (fishing, water sports, sightseeing, rambling, etc.). There are various valuation options. Often, these natural functions of water (assimilation, dilution, flushing) can be compared with the extra cost of alternatives (*dredging*, treatment). The value of water for navigation can be imputed from its cost advantage over the next cheapest transport mode (e.g. railways). The value of water for recreation and ecological purposes (the maintenance of low flow regimes and wetlands) is generally estimated by WTP or travel cost[4] surveys. It is increasingly common to use the *benefit transfer approach* to derive empirical values for these environmental effects – as the term suggests, evidence is transferred from situations where it is available to locations and projects which seem to be broadly comparable.[5]

- *Hydropower* water usage is normally valued according to the cost advantage of hydropower over thermal and *other* alternative ways of generating electricity. In this, as in other cases, it is important to compare like with like, and to be clear about the basis of the estimate.[6]

---

[3] This is reviewed more fully in Winpenny et al, 2010.

[4] The travel cost valuation method infers the valuation that visitors place on a free amenity from the amount of time and expense they incur in getting to the site.

[5] A number of results are reviewed in Turner et al*,* 2004.

[6] If a *short-term* approach is taken, capacity is assumed to be fixed for both alternatives to be compared. In the *long term*, new investment can be made in either. Marginal and average costs will also differ for both alternatives.

These methods of valuing water allow policy makers and practitioners to compare the net economic benefit of providing water for different uses. Some of these methods also capture the significant non-market value of water which includes social and environmental benefits. Valuing water can support the efficient and equitable allocation of water, demonstrate where good internal rates of return on investment in water infrastructure can be achieved, and inform the design of economic instruments (e.g. water tariffs and pollution taxes).

SECTION 2

The four pillars of water security

The first pillar of water security: sustainable economic development

In many countries and periods throughout history, the harnessing and development of water resources has been a fundamental *driver* of economic growth. This was, for instance, the major factor in the development of the American Western States for much of the 20th century, and galvanised the recovery of the Tennessee Valley region from the Great Depression of the 1930s. It has been estimated that investments in water infrastructure by the US Army Corps of Engineers between 1930-1999 yielded returns of US$6 for every US$1 spent (UNESCO, 2009b).

In relation to the contribution that well-managed water resources can have in supporting and driving economic growth, the Topic Guide considers the interlinked agriculture, energy and industry sectors.

Water and agriculture

There is a consensus that, over the next few decades, the growth in global demand for food will require some expansion of irrigated areas and major changes in their productivity (growing more food with less water (Moser, 2012)). The backdrop to this view is the increasing competition for water between agriculture and the rapid growth of cities, industry, mining and other sectors that place a higher economic value on water than the majority of farmers. Climate change is likely to intensify this competition.

Agriculture is a vital part of developing countries' economies. In Africa, it employs 65% of Africa's labour force and accounts for 32% of GDP (World Bank, 2013).

Rainfed and irrigated agricultural systems differ substantially, as do the economic risks and opportunities which they face. Rainfed farming accounts for more than 95% of farmed land in sub-Saharan Africa; 90% in Latin America; 75% in the Near East and North Africa; 65% in East Asia; 60% in South Asia (IMWI, 2010a). India, China and the United States have the largest area of irrigated agriculture. Although globally irrigated land only accounts for approximately 20% of agricultural land, it currently provides 40% of the world's food.

Some of the key risks and opportunities are summarised in Table 3.

	Rainfed agriculture	Small-scale irrigated agriculture	Large-scale irrigated agriculture
Risks	• Water productivity, 'the volume of crop produced per drop', tends to be low in rainfed farming systems, while losses from evaporation are high. • Land is often degraded, crops frequently die because of drought or floods and few methods are in place for managing water more effectively. • In parts of sub-Saharan Africa and South Asia, productivity is particularly low, which results in food insecurity and poverty for rural communities. • Climate change poses a significant threat to rainfed agricultural systems. • Women are particularly at risk due to their greater dependence on rainfed agriculture in many developing countries.	• Small-scale irrigation, which is controlled by users, has a mixed history, with many examples of poor management leading to sub-optimal increases in yields. • Poor farmers (often women and young people) cannot always afford the upfront investment costs for irrigation technologies and other inputs. • Competition between upstream and downstream users, and the depletion of groundwater, may be aggravated by the unregulated nature of small-scale private irrigation (Giordano et al, 20120). • About 1.2 to 1.5 billion rural households in Africa and Asia depend on groundwater withdrawal to support their livelihoods. Overexploitation of groundwater poses a significant risk (BGS, 2011).	• Despite the contribution of irrigated agriculture to increasing food production and to overall socio-economic development, irrigation has come under increasing criticism for concerns such as socio-economic inequity, social disruptions and environmental degradation (Hussain & Bhattarai, 2004). • Where water is over-applied it can, over time, lead to soil degradation, i.e. salinisation reducing crop yields. • There are many examples of the poor financial performance of large irrigation projects, due to inflated construction costs, corrupt practices and rent seeking. • Unsustainable exploitation of groundwater resources is a significant risk (particularly in MENA, India and China).
Opportunities/Benefits	• Improving the productivity of rainfed agriculture has significant potential to reduce poverty. Water management can be improved through: supplementary irrigation, on-farm water conservation practices, and improvements in soil, nutrient and crop management. There is potential to double yields in rainfed agriculture based on existing knowledge. • On-farm water balance analysis indicates that, in savannah farming systems in sub-Saharan Africa, less than 30% of rainfall is used as productive transpiration by crops. Thus, crop failures commonly blamed on 'drought'' might be prevented in many cases through better farm-level water management (Rockström et al, 2010). • There is scope to improve productivity where yields are still low, as is the case in areas of sub-Saharan Africa. Here, a combination of good agricultural practices, links to inputs, credit, and markets, combined with weather insurance schemes, can improve agricultural productivity with little impact on water resources (FAO, 2012).	• Decentralised irrigation – small individual systems designed to serve a single or community farm – can often be better tailored to local conditions, purchased and operated by private farmers, and avoid the environmental and social downsides of big dam and canal systems. • Smallholder farmers in sub-Saharan Africa and South Asia are increasingly using small-scale irrigation to cultivate their land and there are examples of it leading to improved yields and reduced risks from climate variability (Giordano et al, 2012). • Irrigated systems are better protected against rainfall variability. However, these systems will increasingly require greater storage capacity to respond to more frequent droughts and floods and changes in rainfall distribution. • In Madhya Pradesh, incomes of farmers who constructed on-farm ponds to irrigate pulses and wheat have risen by over 70%; as a result, they have also been able to improve and expand their livestock herds. In Tanzania, half of the dry-season cash incomes of smallholders come from growing irrigated vegetables.	• Well-performing large-scale irrigation schemes in favourable environments can be very profitable. The expansion of irrigated agriculture in the 1950s and 1960s in Asia saw a doubling of cereal production and a 30% increase in calories available per person. • Investment in water supply and irrigation can produce high economic rates of return, as measured by benefit-cost ratios, and compare well with those in other sectors of infrastructure. • Groundwater use tends to be widely profitable. It has brought major socio-economic benefits to rural communities and in many countries has helped to alleviate agrarian poverty through increasing food security. In South Asia the groundwater boom has also largely been pro-poor, with marginal farmers of holdings smaller than 2 hectares increasing their groundwater-irrigated area by three times more proportionally than farmers with more than 10 hectares of land (GWP, 2012).

Table 3 Summary of the risks and opportunities posed by water to different agricultural systems

Given the low area of irrigated land, especially in Africa, there are opportunities to increase irrigation; evidence suggests that the productivity of key crops, such as wheat, maize and rice under irrigation can produce significantly higher yields. However, there are environmental and social costs associated with small- and large-scale irrigated agriculture, for instance, changed physical and chemical properties of soils or changed water regimes in wetland habitats. The external cost of the damage to people and ecosystems, and clean-up processes from the agricultural sector is significant. In America, for instance, the estimated cost is US$9-20 billion per year (UN-Water 2014d).

Scenarios imply that, despite the possible economic advantages of increasing the area of irrigated land, this will not be possible on a large scale due to increasing demand for water from other sectors. The FAO estimates an 11% increase in irrigation water consumption from 2008 to 2050 (UN-Water, 2013d).

The increased output of food crops implied by future growth in populations and living standards will need to come from increased output and water productivity of rainfed farmers, typically smallholders and often poor.

Relative value of water for agriculture

There is an apparent discrepancy between the high value of food (and conversely the huge personal, social and political costs where its supply is inadequate) and the low average economic value attached to water for agriculture in economic studies.

A recent study compares water values in agriculture, industry and domestic use, drawing on 181 studies from all regions of the world (Aylward et al, 2010). The average values of water reported in the literature (in US$ per m^3) were 0.28 for all agricultural use (1.01 for high-value crops), 0.59 for domestic use, and 0.86 for industrial use, indicating that a unit of water used in industry has, on average, a greater economic benefit than a unit of water used for irrigation. While these economic values give some indication of the potential benefits from specific water allocations, such decisions also need to take into account non-consumptive use, re-use, and the spatial and temporal aspects relevant in each case.

For instance, although the value of water for *agricultural irrigation* of many low-value crops (typically food grains and animal fodder) is very low, water values can be high for high-value crops (e.g. fruit, vegetables, flowers) where the water is reliable. Similarly the value of water can be high for supplementary irrigation taken as insurance against drought. These results are supported by the actual prices paid for water where water markets exist (e.g. in Australia) (Winpenny, 2013, *personal communication*).

Benefit-cost analysis

Investment in water supply and irrigation can produce high economic rates of return, as measured by benefit-cost ratios. This is at odds with the conventional view of water as an 'uneconomic' sector with poor financial returns. In fact, the (weighted) average economic rates of return for both water supply and irrigation projects compare well with those in other sectors of infrastructure.

Railway rehabilitation	**Irrigation**	Road rehabilitation	Road upgrades	Road maintenance	Power generation	**Water supply**
5.1	**22.2**	24.2	17.0	138.8	18.9	**23.3**

Table 4 Economic rates of return for infrastructure projects in sub-Saharan Africa (%) (Foster & Briceno-Garmendia, 2010)

Analysis of Africa's irrigation needs demonstrates a similarly attractive internal rate of return, ranging from 12% in central Africa for large-scale irrigation to 33% for small-scale irrigation in the Sahel (UN-Water, 2013d). However, there are many examples of poor financial performance of irrigation projects, due to inflated construction costs, bad design, corrupt practices and rent seeking that undermine this attractive rate of return (Turral et al, 2011).

Given the near-impossibility of finding extra water for the sector on the scale implied by 'business as usual', there is a clear need to make better use of existing supplies. There is believed to be major scope for this through better management of water in *rainfed* farming, as well as in technological developments in irrigation practice. Water productivity can be raised by cultivating crops with a higher value per unit of water consumed, or by switching to irrigation technologies that result in less consumptive use. However, the improvement of irrigation efficiency has to be done with a view to the needs of the whole basin, since important parts of agriculture depend on water from run-off and drainage.

In this context, it is important to recall that women are estimated to produce up to 80% of food in developing countries, and will be instrumental in delivering the changes called for above. As some of the most vulnerable groups, particularly the rural poor and women, depend on rainfed agriculture, there is an opportunity to promote pro-poor economic growth through increasing agricultural productivity.

Water and energy

By 2030 global energy consumption will increase by 35% (from 2010 levels) and this will increase water consumption by 85% (UN-Water, 2013d). Energy consumption will increase most in non-OECD countries, rising 84% compared with 14% in OECD countries (ibid).

The increased demand for energy will have an impact on the demand for water as the two are interlinked. All sources of energy require water for various production processes, including the extraction of raw materials, cooling in thermal processes, cultivation of crops for biofuels, and powering turbines. The OECD *Environmental Outlook* estimates that demand for water from the energy sector will increase 140% by 2050. At the same time, increasing amounts of energy will be required to treat and pump water.

China, India and the Middle East, which already experience water stresses and are forecast to experience a five-fold increase in electricity production, will increasingly need to explore new technologies for processing primary energies and generating electricity that require much less water (ibid).

Three energy sources that are closely linked to water demand are considered: hydropower, biofuels, and thermal power generation.

Hydropower

Hydropower presents the largest renewable source of electricity generation (15% of global production in 2007), and it is estimated that two-thirds of the world's economically feasible potential is still to be exploited (World Energy Council, 2010). Hydropower uses water as its fuel by running it through turbines and discharging it to a water body further downstream. In most cases the water remains unpolluted and the hydropower production process is largely non-consumptive, apart from evaporation from reservoirs (which would not arise in run-of-river schemes that do not need water storage). Even non-consumptive use may be at the expense of other potential users if the water is returned into a different watershed, into a different part of the river, or at a time inconvenient for other users.

Dams have contributed to economic growth in the 20th century, but the services they provide have come at a cost. While the economic benefits are experienced across a large geographical area, costs are borne by local communities. Hydropower has the potential to boost electrification, provide irrigation, and protect against water-related hazards, all of which can contribute to economic growth. However, it can also lead to resettlement, declining fish stocks, degradation of ecosystems and, therefore, loss of livelihoods. The economic costs of poorly designed, sited and managed hydropower schemes can be substantial.

International focus on dams and hydropower increasingly focuses upon programmes to improve cooperation over access to water to allow stakeholders to maximise the social and economic benefits that can be achieved through shared management of water resources. Such programmes go beyond negotiations over water allocations and focus instead upon the significant economic benefits that can arise for riparian states through cooperation in the management of transboundary water resources, e.g. through hydropower, irrigation, water for industry or domestic use, and reduced flood risk.

The Diama and Manantali Dams on the Senegal River basin are widely reported as successful examples of multipurpose dams. The Governments of Mali, Mauritania and Senegal contributed finance in proportion to the benefits they expected to receive from irrigation, energy and navigation. These benefits were quantified and weighted for each country. The jointly owned dams were built in the 1980s at a cost of approximately US$1 billion. A 2008 evaluation of the dam (undertaken by EIB, KfW and AFD) concluded that the main benefit of the dam is the generation of hydropower, where the production of 740GWh per year exceeded expectations of 540GWh. The evaluation calculates an economic rate of return for the hydropower component of 8% (KfW et al, 2009). Nevertheless, there have been social and environmental costs associated with the project, due to the displacement of 10,000 people and the degradation of fisheries.

However, there is evidence that many hydropower schemes do not reach the expected potential predicted at pre-commissioning stages. Social and environmental trade offs may overtake economic benefits. Hydropower dams, however, seem to be the dam type that, more than other dams, exceeds the targets of achieving economic returns and development outcomes (Granit & Lindström, 2009).

Biofuels
The production of biofuels is a consumptive use of water that may compete directly with food-crop production for water and land resources. Water is required both for growing biofuels and refining them; however, the water intensity depends on the feedstock, where and how the crops are grown, and whether they are first- or second-generation crops.

It is estimated that water demand from biofuels is currently relatively low (approximately 1.4% of the total food crop or 1.7% of all irrigated crops). Despite this relatively low demand, the contribution of biofuels to energy supply is expected to grow rapidly (IEA, 2013) and with it their demand for water.

According to the World Bank, expanding biofuel production to meet various national targets in the next decade would mean that poor people in some developing countries would find it harder to afford an adequate diet. The expansion would push up prices for many food staples by 2020. Global prices for corn and other major grains could rise by as much as 3%, and the price of sugar by 8%. The expansion would also lead to a modest percentage decline in global GDP (World Bank, 2010b).

Thermal power generation
The abstraction of water for cooling purposes by thermal power stations is high and rising across many regions of the world. In the USA in 2005, withdrawals for thermoelectric power accounted for 49% of total water use, and 41% of total freshwater withdrawals, making this by far the largest sector of water abstraction (Kenny et al, 2009).

Although raw water drawn for thermal power and industrial cooling purposes is non-consumptive, because nearly all of it is returned to public water bodies for use by other sectors, the quality of water returned poses risks for operators with the release of large volumes of heated water having a negative impact on fish and other wildlife (United States Government Accountability Office, 2014).

The abstraction, transport, storage and release of cooling water can be highly disruptive for other local water users. In the water-scarce western regions of China, new industries and power stations secure cooling water from local lakes and rivers, draw down groundwater aquifers, and build reservoirs to capture rainwater, all of which disrupt water supplies to other users. As a result, the water table in Inner Mongolia has sunk and grasslands such as Xilingol have turned unproductive (Larson, 2012). In such cases, the sheer volumes of water abstracted for cooling has an unwelcome impact on water levels in regions of growing water scarcity.

Shale gas production, which is expected to increase in Asia, Australia and North America, has slightly higher water intensity than conventional gas, because its extraction method, hydraulic fracturing, injects millions of litres of water into each well (UN-Water, 2013d).

The risk posed by water to energy production can be seen in the following examples:

Location (year)	Description
India (2012)	A delayed monsoon raised electricity demand (for pumping groundwater for irrigation) and reduced hydrogeneration, contributing to blackouts lasting two days and affecting over 600 million people
Midwest USA (2006)	A heat wave forced nuclear plants to reduce their output because of the high water temperature of the Mississippi River
China (2008)	Dozens of planned coal-to-liquid (CTL) projects were abandoned, due in part to concerns they would place heavy burdens on scarce water resources
Australia, Bulgaria, Canada, France, USA	Public concern about the potential environmental impacts of unconventional gas production (including on water) has prompted additional regulation and, in some jurisdictions, temporary moratoria or bans on hydraulic fracturing

Table 5 Examples of water impacts on energy production (IEA, 2012)

Water and industry

On a global scale, industry uses relatively little water in comparison to the agriculture sector, but it does require an accessible, reliable supply of consistent and acceptable quality. Data indicate that approximately 20% of the world's freshwater withdrawals are used by industry, but this figure varies widely from region to region (UN-Water, 2013d). In OECD scenarios for 2000-2050, the growth of industrial demand for water on a business-as-usual basis is 400%, the largest of any demand sector (mostly arising from the BRIC countries) (OECD, 2012).

Within the category 'industry' there are differences between, on the one hand, electronics and drinks which both place a high value on good quality water and, on the other hand, steel, chemicals and leather where volume is more important and where re-use and recycling is also feasible.[7] The water quality of effluent discharges is also important to industry as pollution can affect large volumes of fresh water. While statistics show that industry, in the macro view, is not the worst polluter in terms of concentrations and loads, its effects can be very significant, particularly on regional and local scales (World Bank, 2010d).

[7] The common practice of measuring the value or productivity of industrial water by comparing total value added with the cost of water used is invalid, since it assumes that water is the scarce factor of production, and ignores alternative options open to companies, which limit their willingness to pay for it (see Annex 2).

Taking industry as a whole, valuation studies show that, generally, the value of water used in industry is high when compared with other uses. For example, the average values of water reported in the literature (in US$ per m^3) were 0.28 for all agricultural use, 0.59 for domestic use, and 0.86 for industrial use (Aylward et al, 2010). Other measures of water 'productivity' in industry have also been proposed. One such relates the *dollar value of product obtained per cubic metre of water used*. At the aggregate national sector level these range from over US$100 to less than US$10 (UNESCO, 2009b). As technology improves, industrial water productivity increases.

Low productivity may indicate that water is undervalued or is simply abundant. High productivity is linked to high re-use as withdrawals are reduced. However, these indicators are crude and depend greatly on country context and the industrial mix, and also ignore the opportunity cost[8] of water in each case.

With all these reservations, the evidence is that water is vital for industrial growth, industrial demand for water is increasing rapidly especially in emerging economies, and industry makes more productive use of water compared to most other use sectors. Water security for industry is vital for broader economic growth (Box 6).

Box 6 The Metolong Dam in Lesotho

This dam was designed to support the garment industry and promote economic growth, recognising that water constraints could have a significant impact on economic growth in the future. The local garment industry employs 50,000 people and contributes 38% of GDP, including much of the country's exports. This industry accounts for half of all water consumed in Maseru, the capital city, and the current lack of water and wastewater infrastructure is a major constraint on continued economic growth. The dam aims to provide sufficient bulk water for Maseru and the surrounding lowlands to meet domestic and industrial needs for the next 40 years.

Key messages for water and sustainable economic development

- Water is an essential input to agriculture, energy and industry; water insecurity will hamper economic growth and limit rates of poverty reduction.
- Where water is scarce and competition for its use is becoming serious, its allocation can be guided by comparisons of the economic value of a unit of water in its different uses.
- Studies at the global level suggest that, on average, water for industry has the highest value, while water for low-value crops has the lowest; however, there are many local exceptions to this ranking. Maintaining equitable and sustainable access to water for all users will be locally significant.
- In a number of major regions, there is insufficient water to meet all the increasing demands for water from agriculture, energy and industry without major changes to business as usual.
- To meet growing demands for food and changing dietary preferences, unprecedented improvements to water efficiency in the agriculture sector are required.
- Given the limits to increasing the area of irrigated agriculture, most of the increment in output will need to come from greater productivity (including that of rainfed agriculture).
- 90% of global power generation is water intensive. There is an increasing risk of

[8] What it is worth in its next best alternative use. For water-abundant regions this can be negligible.

conflict between power generation, other water users, and environmental considerations.

- Although the link between water and energy is most clearly drawn through *hydropower,* in many regions the crunch point is happening through the impact of *thermal and nuclear* power generation, the production of *biofuels,* and the use of *non-conventional fuels* such as shale gas.
- As demands for energy increase with regard to exploration, energy supplies will potentially generate significant impacts upon water resources, requiring mitigation.
- Floods, droughts and heat waves have caused serious interruptions to power production in many countries and financial losses, with costs running into billions of dollars.
- Industrial demand for water is increasing rapidly, especially in emerging economies, and water is vital to supporting the growth of the industrial sector.

The second pillar of water security: human health and wellbeing

Improving water-resource management, increasing access to safe drinking water and basic sanitation, and promoting hygiene have the potential to improve the quality of life of billions of individuals.

The MDGs established in 2000 included targets to halve, by 2015, the proportion of the population without sustainable access to safe drinking water and basic sanitation. Whilst the MDGs have performed well on delivering access to improved water, the progress on sanitation has been much weaker.

Delivering improved water and sanitation services delivers significant economic and human development benefits, including welfare, convenience, health and dignity and their delivery is critical to wider achievement of development objectives, including economic development and improving the lives of women and girls (Swedish Water House, 2006).

There are clear benefits to individual people and their families from receiving clean, safe water in or close to where they live. They are at less risk of contracting water-borne disease, they spend less time fetching water, and they have more time and energy available for personal washing, cooking and cleaning the household. Likewise, improved household sanitation provides benefits for public health, less time spent seeking privacy, more dignity and less embarrassment, greater opportunities for female education, and greater pride and communal and personal prestige. Safe and convenient ‘watsan’ (water and sanitation) is particularly important to women and girls, since they are mainly involved in the collection of water and its use in cooking and cleaning. They are also badly disadvantaged by the lack of suitable toilet facilities at home, in schools, and other public buildings.

These benefits are very real for the *welfare* of those concerned. Although they can be expressed in economic terms (through the *willingness-to-pay* concept), such benefits are not easily captured by conventional national income data.

Economic benefits of improved access to water and sanitation services

The direct link between the provision of clean, safe drinking water to urban populations and the level of public health in cities has been traced in a number of historical studies of countries that have reached developed status. In the USA the impact of filtration and chlorination of drinking water had a dramatic impact. It was found that clean water was responsible for nearly half the total mortality reduction in major cities, three quarters of infant mortality reduction, and nearly two thirds of child mortality reduction. Rough calculations suggest that the social rate of return to these technologies was greater than 23 to 1, with a cost per person/year saved by clean water of about US$500 in 2003-value dollars (Cutler & Miller, 2005).

Throughout the world, households and communities with access to reliable and safe water supply and sanitation are more likely to be healthier and out of poverty, compared with their less fortunate compatriots. In northwestern and eastern Nigeria a 10% decrease in the number of people using an unprotected water source is correlated with a decrease in child mortality of up to 2.4% (Ward et al, 2009).

Models developed by the WHO show that investments in a range of water-supply and -sanitation interventions can have high benefit-cost ratios. The benefits are typically savings in time spent in household duties, including fetching water, and, to a lesser extent, savings in the various costs incurred through illness. These benefits accrue disproportionately to women and girls.

Box 7 Economic benefit cost justification of water supply and sanitation projects (Hutton & Haller, 2004)

Hutton and Haller (ibid) estimate benefit-cost results for five types of watsan interventions in five WHO sub-regions. The data relate to infectious diarrhoea, regarded as the 'marker' disease for watsan and accounting for the largest part of the global death and disease burden from WASH factors.

The following interventions are modelled:

1. MDG for water supply, with priority to those that already have improved sanitation
2. MDG for both water and sanitation
3. Access for all to improved water and sanitation
4. Universal disinfection of water at point of use on top of intervention 3
5. Universal access to regulated piped water and sewage connections into homes

The resulting benefit-Cost ratios are:

		Intervention type				
WHO region	Total pop (million)	1	2	3	4	5
Sub-Saharan Africa	481	11.5	12.54	11.71	15.02	4.84

Some obvious caveats to this study should be noted. While the costs are tangible and short term, most of the benefits are intangible and delayed, and for sub-Saharan Africa the majority of benefits (over two thirds) are of the convenience variety, typically time savings. The valuation of time savings is contentious in societies with high unemployment or seasonality of work, or with only partial involvement in the cash economy. On the cost side, it should also be recalled that interventions 1-4 in Box 7 represent basic levels of service, and that higher service standards – as used in the current discussions of the post-2015 Sustainable Development Goals – would change the above economic returns.

The 2004 WHO work by Hutton & Haller has been updated and its scope extended, but with similar positive conclusions (Hutton, 2007; Hutton, 2012).

In terms of achieving the sanitation MDG in off-track countries,. 90% of the benefits also accrue as time savings; therefore, similar caveats apply (Bartram, 2008). However, part of the benefit of improved sanitation, as for water supply, accrues to public health authorities, who need to spend less on the control and treatment of water-related diseases, and can instead spend their budgets on other deserving aspects of public health. In Indonesia, World Bank research estimates that in 2006 the country lost US$6.3 billion (2.3% of GDP) from poor sanitation and hygiene, causing health costs and economic losses (WSP, 2008). In Bangladesh, the estimated annual economic loss caused by inadequate sanitation was US$4.2 billion, equivalent to 6.3% of gross national product in 2007 (UN-Water, 2013b).

The high benefit-cost ratios of the interventions are striking,[9] and they indicate the high net welfare benefits of water and sanitation projects: some of them will translate into early gains in productive activity; others should benefit growth over a longer period. There should also be economies in public spending on health.

An estimate of the overall economic benefits from meeting the MDGs for water and sanitation is shown in Table 6.

Type of benefits	Breakdown	Monetised benefits (US$)
Time savings from improved water supply and sanitation	• 20 billion working days per year	• US$63 billion per year
Productivity savings	• 320 million productive days gained in the 15-59 age group • 272 million school attendance days per year • 1.5 billion healthy days for children under 5	• US$9.9 billion per year in total for the three categories of benefit
Healthcare savings		• US$7 billion per year for health agencies • US$340 million for individuals
Value of premature deaths averted, based on discounted future earnings		• US$3.6 billion per year
Total benefits		**US$84 billion per year**

Table 6 Overall global benefits from meeting the MDGs for water supply and sanitation (OECD, 2010a, p31)

Water resources and access to drinking water and sanitation

Water security clearly has a significant role to play in providing access to improved water and sanitation services, and in helping countries realise the associated economic and welfare benefits. Water scarcity puts these gains at risk.

There is a direct link between water security in the context of households and the wider issue of water-resources management at the basin or national level. It is not uncommon for watsan services to be planned and initiated without a full assurance of the adequacy of the water resources that will feed these services. The result is that sources may turn out to be contaminated; wells and rivers dry up in dry periods; pumping for new watsan connections causes shortages of water for other users. The release of untreated wastewater or dumping of septic-tank waste from newly installed toilets and latrines may likewise contaminate sources for other users. Climate variability and change will increase the challenges in maintaining sustainable drinking water and sanitation services, with flood risks posing a particular risk.

Reports from official agencies paint a consistent picture of a high level of 'non-functionality' of existing taps and wells installed under watsan programmes. In one such survey, of almost 7,000 water sources of various types in Oromia Region of Ethiopia, 41% were discovered to

9 For a fuller discussion see OECD, 2010a.

be non-functional for various reasons, including unreliable water supply (Ethiopia Ministry of Water Resources, 2006). Surveys by NGOs provide further corroboration, with 46% of hand-dug wells with hand pumps and 36% of springs in Oromia labelled as non-functional (Tearfund, 2005).

A study by ODI (2014) indicates that positive benefit-cost ratios (BCRs) will be achieved in building adaptation to climate risks in water and sanitation programmes. For example, in Malawi, raising and lining rural latrines to prevent flood-induced collapses increases BCRs from 2.1 to 2.9; in Tanzania, the drought-resistant construction of boreholes for rural water supply increases BCRs from 1.4 to 1.7.

Evidence of the contribution of water scarcity to this high rate of non-functionality has not been collected and it is likely to differ substantially across areas. Expert opinion is that poor water-resource management could account for up to 20% of non-functionality; however, further research is required to test this (ibid).

Key messages on household watsan and water security

- The social costs of poor or non-existent watsan services are very high and these translate into the loss of major potential economic benefits, which at the global level are estimated to be US$84 billion a year.
- Women and girls are particularly disadvantaged by the lack of such services as they often bear primary responsibility for collecting household water and for cleaning.
- The extension of watsan services to those previously without them shows very high benefit-cost results, reflecting time savings, averted costs of healthcare and premature deaths, productivity gains, and other benefits.
- Water-related hazards, particularly an increased risk of flooding under climate change, pose significant risks to watsan services; however, appropriate adaptive responses can reduce these risks and provide economic returns.

The third pillar of water security: water-related hazards

Between 1990 and 2000, in several developing countries, natural disasters caused damage representing between 2% and 15% of their annual GDP. Water-related hazards account for 90% of all natural hazards, and their frequency and intensity is increasing (UNESCO, 2012).

In countries especially at risk (e.g. China, India and Bangladesh, but also high-income economies), the threat of flooding has driven major strategic investment programmes. Between 2003 and 2009 the UK Government spent over £900 million to reduce the risk of flooding for over 250,000 households. The estimated long term benefit of each pound spent was valued at eight pounds (Fisher & Johns, 2010). These benefit-cost ratios are considerably higher than those for other major priority public expenditures, including infrastructure projects in transport and energy.

Drought is another major water-related hazard. According to the United Nations Global Assessment Report, since 1900 more than 11 million people globally have died as a consequence of drought and more than 2 billion have been affected by drought, more than any other physical hazard (UN-Water, 2013d). However, these figures are most certainly lower than the real total as few countries systematically report and record drought losses and impacts. Drought in sub-Saharan Africa is the dominant climate risk; it destroys economic livelihoods and farmers' food sources and has a significant negative effect on GDP growth in one third of the countries (ibid).

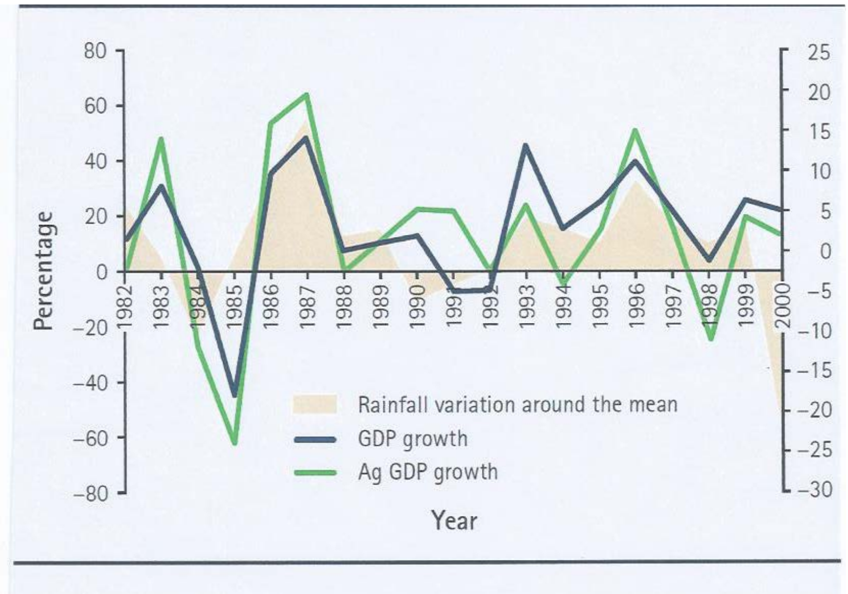
Drought can be *seasonal, year-to-year,* or *secular* (lasting for a number of years). Countries that are arid or semi-arid have developed degrees of resilience to drought, although when it strikes it still leaves lasting human and economic scars. Other countries are experiencing it increasingly due to the climatic fluctuations believed to be associated with climate change.

Water-related hazards such as droughts will intensify under climate change. A major challenge for decision makers, however, relates to how to manage uncertainty regarding the spatial and temporal impacts of climate change. Responding to current impacts of climate variability upon water resources is a good first step. The Environment Agency for England has developed tools to manage investment decisions regarding flood and drought risk management. These tools identify triggers and sequence decision-making processes to allow short-term decisions to be made as part of a longer-term adaptive response to climate change, despite uncertainty about climate impacts (Jeuken & Reeder, 2011).

Economic impacts

A series of studies have demonstrated significant negative macroeconomic impacts arising from countries being ill-prepared to counter droughts and floods (sometimes both in succession) and other extreme events such as storms. One of these (Figure 4 and Box 8) is based on a model created for Ethiopia as part of the World Bank's country water strategy.

Figure 4 Rainfall and agricultural growth for Ethiopia, 1982-2000 (Rainfall (left-hand y axis), agricultural GDP growth and total GDP growth (right hand y axis)) (Grey & Sadoff, 2007)



Box 8 Climatic variability and economic growth in Ethiopia (Sadoff, 2006)

A model developed for the World Bank's Ethiopia Country Water Resources Assistance Strategy in 2006 sought to quantify the impact of hydrological variability on the country's growth and poverty levels. Ethiopia is particularly vulnerable, with highly variable rainfall and endemic drought and floods. It has fragile and degrading landscapes and low levels of infrastructure to mitigate its variable hydrology. Its economy is fragmented, especially in agricultural markets, with high transportation and marketing costs.

The model shows that historical levels of hydrological variability diminish economic growth projections for Ethiopia by over one third and raise poverty rates by 25%. A single drought event in a 12-year period will decrease average GDP growth rates by 5-10%. Taking account of actual historical levels of variability and the partial impacts of floods, GDP growth rates fall 20-40%.

In order to de-link economic performance from rainfall, Sadoff (ibid) recommends actions on several fronts: "Ethiopia must make major investments to create a 'minimum platform' in water infrastructure, institutions and management capacity. Investments must be made in roads, irrigation, hydropower and other complementary parts of a marketing system to encourage farmers to become less dependent on subsistence agriculture and more engaged in commercial farming and non-agricultural activities".

This is an elaborate model that lends greater credibility to the case for water security, and its structure helps to counter the objection commonly heard that such evidence fails to deal with the 'counterfactual problem'. That said, the time and resources entailed in such modelling will limit its use.

Other estimates have been made about the macroeconomic impact of hydrological variability in East Africa, with differing conclusions – some major, others minor. In Kenya, losses from flooding from El Niño in 1997-98 and drought from La Niña in 1998-2000 ranged from 10-16% of GDP during those years. Growth of GDP in Mozambique was reduced by 1% annually due to water shocks. In Zambia, hydrological variability is estimated to lower agricultural growth by 1% each year. Similarly, in Tanzania, the impact of the 2006 drought on agriculture caused losses equivalent to 1% of GDP (McKinsey et al, 2009b). Reducing the damaging impact of this hydrological variability would have major benefits for the macroeconomy (Foster & Briceno-Garmendia, 2010).

The IMF assessed the total macroeconomic impact of Zimbabwe's drought in 1991-2 as a reduction of GDP by 9%, an increase in inflation to 42%, and in food prices by 72%. The production of maize, cotton and sugarcane fell by 83%, 72% and 61% respectively, and more than 23% of the national cattle herd died or was slaughtered (IMF, 2003).

Estimates such as these can be challenged on the grounds that they do not deal with the counterfactual scenario in a satisfactory way, i.e. what would have happened without the climatic event in question? This requires a deeper and wider analysis. From a different angle, they are unlikely to adequately reckon the medium-/long-term costs of floods, droughts and other extreme water-related occurrences, which can persist years after the events happen if assets are destroyed and victims are pushed below the poverty line.

The Africa Infrastructure Country Diagnostic notes the impact of water insecurity upon growth and development in Africa: "the region's weak capacity to buffer the effects of hydrological variability and unpredictability in rainfall and run-off can encourage risk-averse behaviour at all levels of the economy. It discourages investment in land, advanced technologies, or agriculture. An unreliable water supply is also a significant disincentive for investments in industry and services" (Foster & Briceno-Garmendia, 2010, p272).

Key messages: water security and water-related disasters

- Between 1990 and 2000, in several developing countries, natural disasters, the majority of which are water related, caused damage representing between 2% and 15% of their annual GDP.
- Investment in the reduction of flood risk shows high benefit-cost returns where it has been done, as in the UK where the returns are 6:1.
- Serious droughts can impose macroeconomic costs of 10% or more of GDP in the year in question; the costs can persist in subsequent years if they lead to loss of livelihoods, destruction of assets (e.g. livestock) and greater indebtedness.
- For developing countries heavily dependent on the production and export of natural resources, or dependent on sources of power and energy that are vulnerable to the climate, there is a strong correlation between hydrological variability and changes in GDP.
- The impacts of flooding, drought and other extreme water-related events can extend into the medium and long term through their destruction of assets and the increased impoverishment and indebtedness of populations.
- These impacts are felt disproportionately by the poor and vulnerable, particularly women and girls.

The fourth pillar of water security: healthy ecosystems

Water security is essential for maintaining functioning aquatic and terrestrial ecosystems and vice versa. The maintenance of minimum water levels in rivers and aquifers, and the avoidance of excessive water pollution is essential for the viability of ecosystems. Ecosystems are important in their own right and also for the 'services' which they provide, such as water purification, and which can be valued in monetary terms. Where ecosystem services are lost or degraded, they may need to be replaced by costly man-made infrastructure.

The valuation of ecosystem services, including that of aquatic systems, is rapidly expanding, with a growing literature, much of it based on small and localised cases. This literature contains applications of the full range of valuation techniques in environmental economics (Emerton & Bos, 2004). For example, a global economic assessment of 63 million hectares of wetlands estimated their value at US$3.4 billion per year (Brander & Schuyt, 2010).

'Natural infrastructure' creates and protects economic services, and water is an important part of this. Natural systems such as forests, catchments and wetlands store water, regulate its flow and help to preserve its quality. If these natural systems are destroyed or impaired, their functions may have to be replaced by man-made facilities, often at high cost. Water security entails preserving and nourishing these natural aquatic ecosystems.

The value of water purification by natural ecosystems in the Catskill Mountains upstream from New York, obviating the need for costly water-treatment plants, is a widely quoted example. The Millennium Ecosystem Assessment (2005) also quotes studies showing the higher economic productivity of intact wetland compared to intensive farming (net present value of US$5,800/hectare, compared to US$2,200), and of intact mangroves compared to shrimp farming (US$1,000/hectares compared to US$200). These results are location specific, but they convey a serious warning against the frequent casual assumption that converted ('developed') aquatic ecosystems are automatically more 'productive' than the originals.

Box 9 Economic value of ecosystem services (Emerton & Bos, 2004)

The **Nakivubo Swamp in Uganda** runs through the capital city Kampala and has a key role in assuring urban water quality. A large amount of untreated household sewage and the effluent of the city's sewage works enter the swamp prior to passing into Lake Victoria close to the intake of the water works supplying the city with drinking water. The swamp provides a natural filtration and purification of the wastewater: the infrastructure required to provide a similar level of wastewater treatment would cost up to US$2 million per year.

Flood attenuation is one of the main benefits bestowed by the **Lower Shire wetlands in Malawi and Mozambique and the Barotse Floodplain in Zambia.** The wetlands minimise flood peaks and reduce flow velocity due to their storage of flood water. The present value of the avoided costs of relocation, damage repair and replacement of structures has been estimated to be US$3 million.

More than one third of the **District of Pallisa in eastern Uganda** is occupied by wetlands. These contain useful products and support a wide range of activities – subsistence farming, grazing, fishing, collection and harvesting of wild products for food, handicrafts, etc., medicine, building, transport, etc., as well as the storage and supply of water particularly in dry periods. The annual value of these goods and services has been estimated to be US$34 million for the local economy, equivalent to US$500/hectare.

Key messages on water security and ecosystems

- A key aspect of water security entails the conservation and nourishment of aquatic ecosystems, which are important both for their own sakes and because of the 'services' they provide, many of which have an economic value and are costly to replace once lost.
- The value of functioning ecosystems can be very high. A global economic assessment of 63 million hectares of wetlands estimated their value at US$3.4 billion per year.
- Ecosystems are often considered to be 'free' resources and are commonly neglected or converted from natural into other forms of capital. Though their preservation has a cost (including the *opportunity cost* of their resources in other uses) they are a crucial part of the water cycle and thus key to water security.
- Upstream catchments have a vital role in preserving water flows for downstream users.

Synthesis of economic evidence on water security

This Topic Guide has presented the issue of water security as it relates to economic production for the agriculture, energy and industry sectors, human health and wellbeing, water-related hazards, and ecosystems. However, it is worth reiterating that these are interconnected issues and cannot be dealt with in isolation. Optimising one component of water security (e.g. hydropower) may compromise another (e.g. ecosystems) and they therefore need to be managed holistically – one of the aims of the integrated approach.

The following table brings together the evidence for the economic impact of water security for all the sectors. This is for illustrative purposes only because different methodologies are used to make these estimates. It is also the case that there is considerable overlap between the different sectors; for example, with costs associated with drought, including costs to agriculture, industry and hydropower, and with costs associated with poor hydropower performance being based on lost productivity in industry/manufacturing. However, it does illustrate the impact water insecurity can have on different sectors at the country, regional and global level and the scale of these economic losses.

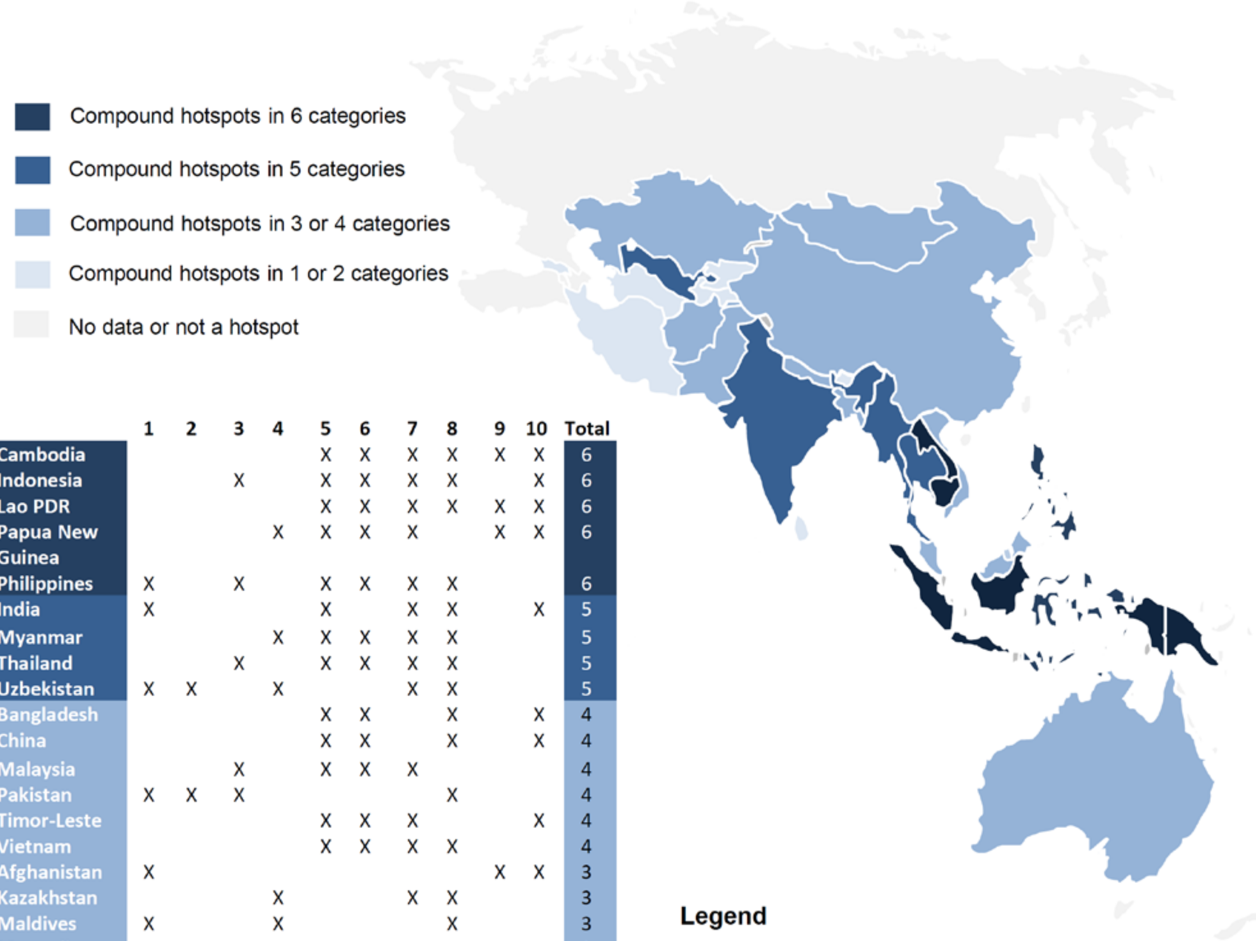
This demonstrates the significant economic risks that water security poses to countries, but also the potential to unleash economic growth if water risks can be mitigated and water used to drive sectoral growth. Table 7 summarises key evidence on the economic costs and benefits of water security.

	Productive Activities			Health	Hazards		Ecosystems
	Agriculture	Energy	Industry		Floods	Drought	
Global	-	-	-	• The overall global benefits from meeting the MDGs for water supply and sanitation are estimated to be US$84 billion a year (WHO, 2004)	• Over the period 1950-2010 the average annual flood damage associated with property losses across the globe was US$11.6 billion (2010 equivalent) (Whittington et al, 2013) • In 2011 the insured losses from floods were US$16.2 billion (Swiss Re, 2012)	• Over the period 1950-2010 the average annual damage from droughts was US$2.5 billion (in 2010 equivalent) (Whittington et al, 2013) • In 2011 the insured losses from drought was US$2.4 billion (Swiss Re, 2012)	• A global economic assessment of 63 million hectares of wetlands estimated their value at US$3.4 billion per year (Brander & Schuyt, 2010)
Regional	• The expansion of irrigated agriculture in the 1950s and 1960s in Asia supported the 'green revolution', which doubled cereal production (IFPRI, 2002)	• The Diama and Manantali Dams in Senegal, Mali and Mauritania were estimated to have an internal rate of return of between 8-24% (KfW et al, 2009)	-	• A lack of safe WASH causes sub-Saharan African countries annual losses equivalent to 5% of GDP (WaterAid, 2013)	• Under a 2°C scenario, flooding could cause around US$50 billion worth of damage to coastal areas of Africa (Christian Aid, 2009)	• A drought in 2003 cost the European Union economy $11.4 billion (Farmer et al, 2008)	• In the Caribbean, the shoreline protection services provided by coral reefs are valued between US$700 million and US$2.2 billion annually (WRI, 2010)
Country/Region	• In Madhya Pradesh, incomes of farmers who constructed on-farm ponds to irrigate pulses and wheat have risen by more than 70% (Giordano et al, 2012) • In Afghanistan, drought and armed conflict have reduced the level of surface water in canals by 70%, causing a 60% drop in irrigated land. It requested US$76 million in aid because 2.5 million people face 'imminent food crisis' due to water shortages (IRIN, 2006). This represents only a fraction of the full economic cost	• In Tanzania, reductions of hydroelectric power resulting from droughts and flooding is expected to cause losses of 0.7-1.7% of GDP by 2030 (World Bank, 2006) • In 2001 in Brazil low river flow depressed hydropower production, leading to a government mandate to cut electricity use by 20%. The estimated impact was US$26 billion (2% of, GDP) (Morrison et al, 2009)	• In Kenya, the loss of industrial production arising from inadequate water storage for hydropower generation between 1991 and 2001 was estimated at US$1.4 billion (around 8% GDP) (Mogaka et al, 2006)	• In Bangladesh, the estimated total economic impacts of inadequate sanitation amounts to a loss of US$4.2 billion each year, equivalent to 6.3% of gross national product in 2007 (UN-Water, 2013b)	• In Ethiopia, the historical levels of hydrological variability diminish economic growth projections by over one third and raise poverty rates by 25%. A single drought event in a 12-year period will decrease GDP growth rates by 5-10% (Grey & Sadoff, 2007) • The flood in Thailand in 2011 triggered an estimated US$12 billion in insured claims – the highest freshwater flood loss on record (Swiss Re, 2012). The World Bank (2012c) estimates that the total economic damages and losses were $46 billion.	• In Mexico water shortages in 2011-2012 caused US$1.18 billion in lost harvests on farmland, killed 60,000 head of cattle and weakened 2 million more livestock, pushing food prices higher (Rosenberg & Torres, 2012) • Water shortages in the United States cost the agricultural sector US$4 billion a year (WEF, 2009)	• More than one third of the District of Pallisa in eastern Uganda is occupied by wetlands. The annual value of these goods and services has been estimated to be US$34 million for the local economy, equivalent to $500/hectare (Emerton & Bos, 2004)

Table 7 Selected costs and benefits associated with water security

One of the characteristics of water insecurity is that, often, multiple stresses and impacts are felt simultaneously. The World Water Development Report (WWDR) (UN-Water, 2013d) presents a map of Asia and Australasia which illustrates the hotspots where multiple water risks overlap. These areas experience significant water-related risks to continued economic growth and social wellbeing.

Figure 5 Water insecurity hotspots across Asia and Australasia (adapted from UN-Water, 2013d, p195)



	1	2	3	4	5	6	7	8	9	10	Total
Cambodia					X	X	X	X	X	X	6
Indonesia			X		X	X	X	X		X	6
Lao PDR					X	X	X	X	X	X	6
Papua New Guinea				X	X	X	X		X	X	6
Philippines	X		X		X	X	X	X			6
India	X				X		X	X		X	5
Myanmar				X	X	X	X	X			5
Thailand			X		X	X	X	X			5
Uzbekistan	X	X		X			X	X			5
Bangladesh					X	X		X		X	4
China					X	X		X		X	4
Malaysia			X		X	X	X				4
Pakistan	X	X	X					X			4
Timor-Leste					X	X	X			X	4
Vietnam					X	X	X	X			4
Afghanistan	X								X	X	3
Kazakhstan				X			X	X			3
Maldives	X			X				X			3
Mongolia				X				X		X	3
Nepal				X				X		X	3
Pacific Islands						X		X		X	3
DPRK				X	X						2
Kyrgyzstan				X			X				2
Tajikistan				X			X				2
Turkmenistan				X			X				2
Australia							X				1
Azerbaijan				X							1
Bhutan				X							1
Georgia				X							1
Iran								X			1
Republic of Korea					X						1
Sri Lanka								X			1

Legend

1 Increasing water scarcity threat
2 High water utilization
3 Deteriorating water quality
4 Poor water quality and low water endowment
5 Flood-prone countries
6 Cyclone-prone countries
7 Drought-prone countries
8 Elevated ecosystem/climate change risk
9 Poor access to drinking water
10 Poor access to sanitation

This evidence reinforces the importance of being sensitive to the multiple water risks in an area, the way they impact different sectors and users, and the way in which they are connected. While this country analysis is useful it does not reflect significant local variation. For example, north China is prone to more stresses than in the south of the country.

Despite compelling evidence that transitioning towards water security can drive economic growth through mitigating multiple risks and supporting productive activities, there is currently inadequate investment in the necessary institutions, information and infrastructure.

SECTION 3

Creating the enabling environment

> *Past neglect, under-investment and under-funding of water cannot continue without disastrous effects* (GWP, 2014)

Investment to create an enabling environment requires financing to develop and deliver the information, institutions and infrastructure required to deliver water security. The World Bank (2012e) reports that for developing countries alone, an estimated US$103 billion per year is needed to finance water, sanitation, and wastewater treatment through 2015. It estimates that to close the infrastructure gap in water supply and sanitation and meet the corresponding MDG targets in Africa within 10 years, annual investment of approximately US$22 billion, equal to 2.5% of GDP, is required. Nearly US$15 billion of this is needed for capital expenditure, and the remaining US$7 billion for operational expenditures. Separate analysis for the Africa Infrastructure Country Diagnostic provides slightly higher numbers. Of the US$93 billion identified need for infrastructure in Sub-Saharan Africa, US$21.9 billion is needed for water supply and sanitation, US$9 billion for multi-purpose water-storage infrastructure, and US$3.4 billion for irrigation (Foster & Briceno-Garmendia, 2010). The total identified need for water infrastructure is therefore approximately US$34 billion every year.

This identified need is far from being met and the neglect of public spending on water in both capital and recurrent budgets has been widely observed, leading to the description of water as the orphan or 'Cinderella' sector (Winpenny, 2003). While funding needs for the water-supply and sanitation sub-sectors average an estimated 2.5% of GDP (and more if water storage and irrigation are included) per country in sub-Saharan Africa, countries often spend much less. A study of 15 countries in the region shows that, on average, they committed 2% of their national budget to water supply and sanitation (van Ginneken et al, 2011). However, another sample of countries shows that only 66% of the domestic water supply and sanitation budget has been executed, and on average, expenditures between 2000 and 2008 were equivalent to about 0.32% of GDP (ibid).

At the same time, some analysis suggests that global investment in water is around 4.9%. However, the bulk of this is in China, the USA and Japan. rather than in developing countries (GWI, 2013). The majority of this is spent on wastewater treatment infrastructure and, to a lesser extent, water supply.

Finance for transboundary water negotiations and projects is very limited, despite the fact that 40% of the world's population lives within transboundary basins and aquifers (Nicol et al, 2002). However, a focus upon transboundary benefits and cooperation can support development. When tensions arise over management of and access to water, riparian states are increasingly encouraged to focus not upon negotiating maximum water abstraction rights but upon collective management of shared water resources to maximise socio-economic benefits such as hydropower, flood prevention or irrigation that come through transboundary water management. For example, the UK-supported Nile Basin Initiative promotes cooperation between nine member states and contributes towards improvements in the lives and wellbeing of the 232 million people living within the Nile catchment. Less than 10% of basin residents have access to electricity; under-investment in water-resources infrastructure for irrigation and flood defences is a major barrier to reducing poverty. By promoting cooperation and the capture of shared benefits, the Nile Basin Initiative has leveraged investment of US$1 billion in hydropower generation, transmission, and trade, and plans to leverage a further US$5 billion through pipeline investments (Nile Basin Initiative, 2012).

Financing the investment shortfall

The cost of this *investment* needs to be *financed* in various ways, e.g. through charging water users, grants from government budgets, external aid, commercial loans and equity. Although international discussion tends to focus on the public domain, much investment is done by individual water users (households, farmers) and industrial and power companies providing their own water services. Capital investment entails not only the one-off initial outlay, but also the sizeable *recurring* expenses of operation, maintenance, repairs and replacements. In aggregate, these operations and maintenance costs are high in relation to annual investment costs (World Bank, 2012b).

Attracting funding for water is widely considered to be problematic – much more so than for transport, telecommunications, energy or power. This is due to a number of factors: the poor creditworthiness of borrowing institutions, the low levels of tariffs and cost recovery, political interference with operations, a lack of suitable collateral, and the capital-intensive, long-term nature of major infrastructure. Water tends to be heavily regulated. Thus, arbitrary decisions by official regulators create *regulatory risk* for the lender and investor. Finally, water is prone to *foreign exchange risk* since its revenues arise principally in local currency, whereas its liabilities to foreign lenders and equity investors need servicing in foreign exchange.

Ultimately, water is paid for by *tariffs* from water users, subsidies (from *taxes*) from national taxpayers, and/or grants (*transfers*) from external sources or philanthropists. These three sources make up the basic revenues which can be used to attract (*leverage*) the repayable sources of finance (EUWI, 2012a).

Private investors can provide substantial capital for water supply and sanitation; overall, however, they prefer to work in middle-income countries where the risk is lower, leaving the poorest countries dependent on volatile public budgets and donor commitments. As such, an estimated 75% of water investment in developing countries comes from public sources. Official development assistance (ODA) for water and sanitation has been rising sharply, from average annual commitments in 2002-2003 of US$3.3 billion to US$8.3 billion in 2009-2010, and is an important source of funding, especially in the poorest countries (World Bank, 2012b).

While this appears to hold true for large-scale investment, there is potentially greater scope for local private sector engagement at the micro level. For example, there is evidence that in Kenya, India and Vietnam, markets for micro- and mesofinance for watsan are growing with the development of lending products such as 'toilet loans' or 'water-tank loans' (EUWI, 2012b). This approach to understanding water financing has been promoted by the OECD[10] and the EU Water Initiative Finance Working Group,[11] among others.

Investing in information, infrastructure and institutions, which are considered the building blocks of water security, is discussed below.

Information

One of the greatest barriers to better management of water resources is the absence of or poor quality of hydrological data in many developing countries (UNESCO, 2009b).

[10] See OECD. (2010) *Innovative financing mechanisms for the water sector*. Paris.
[11] See Winpenny, J. (2011) *Financing for water and sanitation: a primer for practitioners and students in developing countries*. EUWI FWG.

Analysis of complex systems requires a great deal of data and knowledge, and the associated costs and capacity required to acquire this is high. While some parameters, such as rainfall and evaporation, can be measured using remote sensing or other innovative techniques, they still depend on field measurements for calibration. Measurement of other critical parameters, notably flow in rivers and groundwater stocks, still primarily use 'semi-artisanal methods'. Yet, without robust knowledge of the complex local relationships between rainfall, run-off, and stream flow, it is difficult to model the behaviour of hydrological systems and then to negotiate and manage their use in the context of future challenges (Grey et al, 2013).

CGIAR (2014) state that "our ability to accurately predict how much water we have at any location, scale and time, how it is used, and by whom, remains impaired". Data quantity and quality have deteriorated in the last 2 decades due to under-investment. It remains the case that water flows are only measured on 50+% of the land mass. Global water resource availability and flows are still estimated rather than known.

Poor information results in short-sighted decisions and ill-designed investments, the consequences of which are eventually borne, first and foremost, by the poor. In addition, where data exist they are not freely shared, and economic losses to crops, infrastructure, human lives and political stability – due to a lack of accurate data – are only continuing to increase with greater variability triggered by climate change (ibid).

There is, therefore, significant scope for national governments and donors to invest in improving data collection and reliability as the basis for making decisions on how to move towards water security in particular country contexts and river basins. With climate change, historical data may need to be complemented by risk assessment.

Infrastructure and institutions

Investments in water infrastructure and institutions are needed to achieve water security. Countries with a 'difficult hydrology' require more infrastructure and stronger institutions. Water infrastructure is needed to access, store, regulate, move and conserve the resource. Natural assets, such as watersheds and wetlands, have always performed these functions to a degree, but man-made assets are required to complement them. Hard infrastructure ranges from simple small-scale check dams, weirs and bunds to investment in bulk water-management infrastructure, such as multi-purpose dams for river regulation and storage and inter-basin transfer schemes (Grey & Sadoff, 2007).

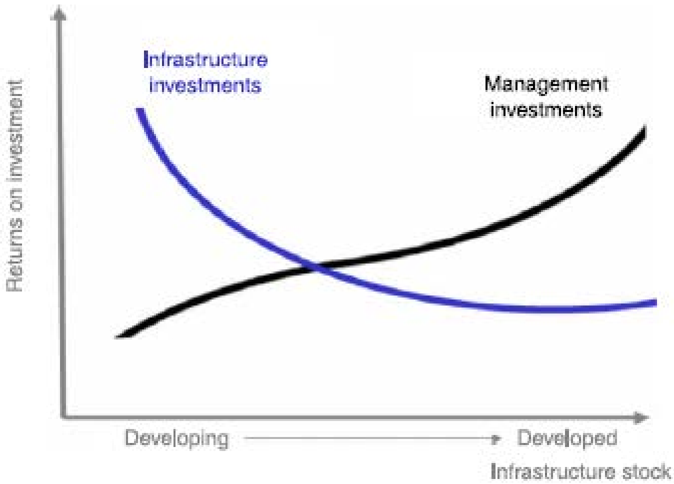
Economies that are particularly vulnerable to water risks, such as those with highly variable rainfall that rely heavily on rainfed agriculture, or those the most productive assets or areas of which lie in flood plains, will require more extensive investments in order to achieve basic water security. Without investment, not only will these economies regularly suffer greater setbacks from water shocks, but this vulnerability will be likely to prove a strong disincentive for domestic or foreign entrepreneurial investments that could shift the structure of the economy toward a more diversified, water-resilient structure (ibid).

The development of water institutions and infrastructure must go hand in hand. Infrastructure will not deliver high, sustained returns if it is not well designed and managed; managers will not be able to optimise the use of the resource without adequate (natural or man-made) infrastructure.

Depending on how developed a country is and the state of existing water infrastructure, it might make sense to invest more heavily in either infrastructure or institutions. Grey and

Sadoff conceptualise the balance of investment in Figure 6. This shows that developing countries, which are less likely to have adequate water infrastructure in place, should focus on scaling up investment in infrastructure. Only when a basic platform of infrastructure is in place is it sensible to shift towards more investment in managing the resource.

Figure 6 Balancing and sequencing investments in water infrastructure and management (ibid)



Strengthening institutions is complex and subject to the existing political economy and socio-economic system.

The diverse structure of water management in dealing with various resource and use/service-related issues is reflected in the complexity and fragmentation of the institutions that exist to govern and manage it. It is rare to find a 'Ministry of Water' (as in Bolivia, India or Tanzania) dealing with all aspects of the sector. It is more common to have separate ministries responsible for water resources, irrigation, environment, power, transport, health, urban water supply, rural water, and so on. Each of these subject areas is connected to water, yet each typically has separate ministerial responsibility and administrative structures, with financing usually determined independently of other interested parties (UN-Water, 2013d).

While some countries have made progress toward effective water governance, the success of institutional reform has been mixed. Each country and region has its specific characteristics and requirements with respect to its water-resources situation and institutional framework; each institution that has an impact on water resources has different reform requirements. This implies that there are no generic solutions, and that problem-solving and institutional arrangements must be tailored for each country and region to meet specific needs and conditions.

Institutional reform needs to be firmly anchored among stakeholders and their leadership. If institutions do not have legitimacy in the eyes of the public, they will not receive support. In this context, stakeholders are more likely to retain the *status quo* or even develop their own informal rules, thereby undermining the integrity of the system. As such, the participation of many different stakeholders and authorities in the management of water resources is crucial.

Key messages

- Investment in water supply and sanitation in many developing countries is significantly below what is required to meet the MDGs and to move them towards water security. In Africa an investment equal to 2.58% of GDP is required. Between 2000-2008 expenditures were equivalent to about 0.3%.
- The high risk associated with investing in the poorest countries deters substantial private investment. These countries are heavily reliant on public investment and on ODA.
- The quality of hydrological data is deteriorating in many countries, and no comprehensive data on global water resource availability exists. Investment in collecting data is needed urgently.
- Investment in infrastructure and institutions are both crucial. The balance of investment between the two is country specific and depends on the hydrology and existing infrastructure among other factors.
- Particularly within the poorest developing countries, donor support to improve information, infrastructure and institutions is critical.

SECTION 4

Key tools, concepts and data sources

Tools and concepts

Understanding a society's water status, needs and problems requires the assembly of relevant data, and careful study and analysis of many factors. This study – which is an essential prerequisite to policy reforms and investment – can be helped by the use of a number of metrics, tools and indicators. However, the uncritical use of these tools and metrics, without taking into account their context and understanding their derivation and limitations, can produce poor policy decisions. The adage 'if it can't be measured it can't be managed' contains some truth, but it is not the whole story.

Simple quantitative indicators (e.g. water 'scarcity' or 'stress' as defined in Box 1) or compound indicators (such as the Water Poverty Index) can be significant at the broadest national level, but only as the first set of possible warning lights. Many other indicators and metrics are necessary, including qualitative assessments, in the course of analysing the status of water in a country or a region within it. Reliance on a single metric or index is dangerous. The UN-Water Country Briefs (section 4.2) illustrate how data from different sources (including financial and economic) can be pieced together to provide a view on a country's water status and development priorities; however, even these can miss out relevant information.

Against this cautionary background, this section reviews some of the key approaches and tools that can be used to assess water security within a country or river-basin context and can inform the development of policies and programmes. It briefly considers:

- The McKinsey Water Cost Curve;
- Cost-benefit analysis;
- Virtual water;
- Water footprinting and corporate water-risk mapping.

The McKinsey Water Cost Curve

The ***Water Cost Curve*** aims to provide a systematic assessment of the options facing a country or region in addressing anticipated water shortages. The production of the cost curve is part of the construction of a national future water scenario, mapping the future availability of water against the projected growth of demand from different use sectors on the assumption of 'business as usual'. In countries facing water stress this will typically show a gap between the availability of water from current sources (plus those under construction) and the unconstrained growth in demand on a business-as-usual basis. This gap sets the target to be met by water planners.

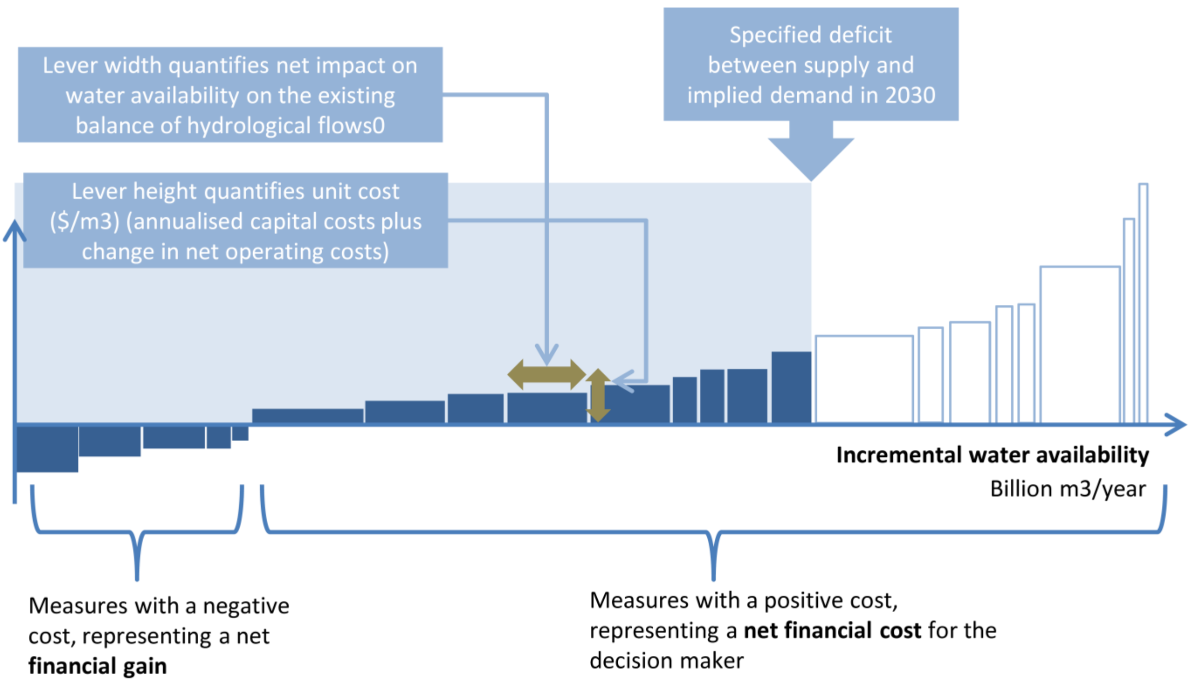
All feasible options for closing the expected gap are then assembled and assessed. These will comprise both actions to enhance supply and those to reduce demand, compared with business as usual. Each measure is assessed according to its quantitative contribution (units of water added or saved) and its cost[12] per unit of water added or saved. The 'cost curve'

[12] Annualised capital cost plus net operating cost.

presents these measures arrayed in ascending order of unit cost, weighted according to the quantitative impact of each. Measures which have other beneficial side-effects ('win-win') display negative costs. The cost curve is illustrated in Figure 7.

The main value of the cost curve is that it presents economic policy makers with all options (demand side as well as supply side) to confront expected water shortages, and provides guidance on how much each measure could contribute to the solution, and the relative cost of each. This is, of course, only the first step in assessing the elements in a viable strategy – social and political factors need to be taken into account, as well as the feasibility and attractiveness of each measure to the agents implementing it (see below).

Figure 7 The water availability cost curve and specified supply-demand deficit (net marginal cost in 2030 (US$/m^3) (adapted from McKinsey et al, 2009a, p72)



A simplistic application of this tool has been criticised for taking no account of socio-political factors, the possible synergies between different measures, or – crucially – the incentives facing different types of water user to implement their respective measures.

More refined applications of the cost curve take some of these factors into account. For instance, the End User Payback Curve takes the viewpoint of the agents that would implement the measures – households, farmers, industrial concerns, municipalities, etc. What is rational from the viewpoint of society on a strict 'cost per unit of water added or saved' criterion may not be appealing to those who have to carry out the measures, since they may be unprofitable, risky or difficult. The Payback Curve addresses these issues by ranking measures in ascending order of years of payback. Measures can also be colour coded according to various types of implementation difficulty, such as poor local supply chains, problems in scaling up, managerial complexity, transactions costs, etc. (ibid).

This methodology helped to inform South Africa's Water for Growth and Development Framework (DWAF, 2008) which now guides national policy (Faurès et al, 2012).

Cost-benefit analysis
The cost-benefit framework can provide a comparison of total economic gains and losses resulting from a proposed water policy. Cost-benefit analysis can provide decision makers with a comparison of the impacts of two or more water policy options using methods that are grounded in time-tested economic principles. Economic efficiency, measured as the difference between added benefits and added costs, can inform water managers and the public of the economic impacts of water programmes to address peace, development, health, the environment, climate, and poverty. Faced by limited resources, cost-benefit analysis can inform policy choices by summarising trade offs involved in designing, applying, or reviewing a wide range of water programmes. The data required to conduct a cost-benefit analysis are often poor; however, the steps needed to carry out that analysis require posing the right questions (Ward, 2012).

Cost-benefit analysis can provide a powerful justification for investing in water resources, as seen in Box 10.

Box 10 Cost-benefit analysis of water and sanitation programmes in India (WHO, 2005)

Over the last two decades India has implemented major investment programmes in improving access to water and sanitation. Karnataka was the site of a US$200 million investment that was completed in 2001 and benefited 5.5 million people. The benefits were substantial and were disproportionately experienced by women because of their traditional role in providing household water, maintaining cleanliness and sanitation. The Net Present Value (NPV) of the project was estimated to be US$85million with an internal economic rate of return of 20%.

Virtual water
Virtual water refers to water which is contained in, or used in the production of, goods (e.g. steel, beverages, food) and services (e.g. tourism, sporting events). Countries trading in physical goods and services are implicitly trading water. In his original formulation, Allan (1999) used the example of Egypt's imports of cereals, which contained an amount of virtual water of a similar order of magnitude to that in the River Nile. The concept has the important policy insight that countries that are short of water should consider using trade to economise on its use, importing water-intensive items and avoiding the export of such goods.

However, empirical studies have shown little or no correlation between the pattern of trade between countries and the water intensity of the items entering into trade (Ramirez-Vallejo & Rogers, 2004). There are various reasons for this: water is rarely, if ever, given a serious economic price as an input; other factors of production (labour, land, skills, technology, capital) can override water endowment in determining comparative advantage and trading patterns. The crucial factor is the *opportunity cost* of water, which is highly specific in location and time (even in a water-scarce economy, water may be plentiful in certain locations and at certain times). A critique of virtual water is offered by Wichelns (2010).

With these important qualifications, it is still rational for national policy makers to factor in their water supply/demand balance at the relevant scale when deciding whether or not to promote sectors of production with a sizeable impact on water use, and to signal this as far as possible through economic pricing for use of the water concerned.

Water footprints and corporate 'water-risk' mapping
A growing number of studies purport to estimate the ***water footprint*** of the consumption and trading pattern of whole nations. A key insight is that consumption has potential implications for the use of water in other countries, through trade (Chapagain & Orr, 2008). A country aspiring to reduce its own water footprint may risk worsening the water situation in its

suppliers (analogous to reducing its own 'carbon footprint' at the expense of that of countries supplying those products (Helm, 2012)).

Although a country's national water 'footprint' is useful in raising its citizens' awareness of the impact of their own consumption on the water situation of others, it cannot become a guide for policy makers without much more refinement and awareness of other, possibly countervailing, factors. A country's production and trading strategy depends on its endowment in a number of key areas (location, climate, labour supply and employment needs, presence of energy and other resources, etc.), of which water is only one.

The key consideration is the *opportunity cost* [13] of water in each use situation, which varies greatly within countries and between seasons, and which, in many cases, is effectively low or zero. The knowledge that 'the average water footprint of wheat produced in country A is *x* cubic metres per annum' is not necessarily useful without knowing much more about the conditions in which water is used for growing wheat in the different regions of the country concerned, and what the alternative uses of water really are.

The water 'footprint' concept has greater traction at the level of individual businesses, where it is one amongst several tools used for assessing commercial 'water risk'. There is a growing recognition among major business that growing water stress and insecurity are becoming one of their main sources of operational and reputational risk.

Operational risk can arise from a cessation of supply (during a drought, or because scarce supplies are diverted to farmers or cities) or due to the pollution of surface or groundwater sources. It may also arise when cooling water becomes too warm to be useful. *Reputational risk* is less tangible, but potentially even more serious. This arises when a company's use of water in a water-stressed area where many people lack access to reliable supplies becomes the object of criticism either locally or among its shareholders and customers.

This has led to the development of a number of tools to assess the exposure of businesses to water risks. Some companies use the *water footprint* concept in making decisions on location, technological choices and procurement patterns. One such study (SAB Miller/WWF, 2009) by the multinational brewing and drinks company SABMiller explores the scope and relevance of the concept in some depth, with reference to its operations in South Africa and the Czech Republic (see Box 11). An interesting methodological feature of some footprinting studies is their inclusion of *green* and *grey* water alongside the more common *blue.*

Box 11 Comparison of water footprint in the brewing industry

The water footprint of SABMiller's brewing operations in South Africa is three times higher than its operations in the Czech Republic. This is attributed to greater reliance on irrigated farm suppliers, higher local evapo-transpiration levels, and a larger proportion of its imported raw materials coming from countries with high crop-water consumption.

The 2009 study concluded that the water footprint of a business must look not only at the total water use per unit of product across the value chain (both 'upstream' in suppliers and 'downstream' in consumers), but also consider where the water is used, the proportion this use represents to total resources in the area, and whether this presents risks to the environment, communities and businesses.

[13] The economic value of water in its best alternative use (e.g. for water used in agriculture this might be its value for urban use, which could be higher. Alternatively, where water is plentiful, it might have low or zero alternative economic value).

This study shows the importance of what happens at all points of the supply chain. All the good work done by a firm to conserve water and reduce pollution within its factory boundaries could be undone and more than offset by actions amongst its suppliers and consumers, over which it has little or no control. In the aforementioned study, the differences in the results between the two countries is affected by differences in evaporative demand for crops, reliance on irrigated crops, the source of imports of barley, reliance on paper packaging, and the proportion of the product that is bottled, among other factors.

Water-risk mapping tools
There is growing interest amongst companies and financial institutions in assessing their own exposure, and that of their clients and their financing partners, to water risks of various kinds.

The World Business Council for Sustainable Development has developed a ***Global Water Tool***, which can provide key hydrological data for the location of potential investments. The Tool is easily used and practical, although its information is fairly general and would need to be supplemented by more detailed investigations if the initial enquiries seemed promising.

In cooperation with WWF, the German portfolio financing institution DEG has developed a ***Water Risk Filter*** which assesses the various dimensions of water risk of its investments across a wide array of countries and financing partners. The aspects taken into account include 33 potentially relevant water indicators for the location of the operation, the type of operation, water use, governance, etc. It is likely that future versions of the Filter will include more on aspects of the supply chain, which are a weakness of the current model (DEG/WWF, 2011).

Data sources and indicators

The following are amongst the main sources of data and indicators useful for practitioners.

FAO Aquastat. An international water information system providing comprehensive and updated data at both the global and for individual country level in Africa, Asia, Latin America and the Caribbean. Covers water resources, water uses, irrigation water use, and wastewater, as well as general country data and climate information. Easy to access and use.

World Bank Little Green Data Book 13. Based on the online database of *World Development Indicators*, and arising out of the World Bank's work on national 'adjusted net savings', taking account, *inter alia*, of the depletion of natural resources (including water) and damages caused by pollution. Contains tables for each developing and emerging country including (for water) freshwater resources per capita, freshwater withdrawals, and access to water and sanitation.

UN-Water Country Briefs. Short (six-page) and attractively produced digests of key water facts for individual countries. Cover national spending on water, aid for water, industrial water intensity, irrigation use, energy, water quality, wastewater status, drinking water and sanitation, and aspects of water governance. Series recently started, not many Briefs produced so far.

JMP – the WHO/UNICEF Joint Monitoring Programme for Water Supply and Sanitation. Produces periodic reports on *Progress on Sanitation and Drinking Water* in the context of the MDGs.

GLAAS. UN-Water Global Annual Assessment of Sanitation and Drinking Water. The most authoritative analysis of the current situation.

UN World Water Development Reports. Produced every three years by UNESCO's World Water Assessment Programme (starting in 2014 this will be produced every year). Large and encyclopaedic, but with an excellent index. Very good for casual browsing or for checking on specific topics using the index. The latest report launched on 22nd March 2014 deals with the water and energy.

Finally, on the topic of ***water accounting,*** *the* aim of estimating the contribution of 'water' to national income lies behind the construction of the **UN *System of Environmental-Economic Accounts for Water*** (SEEAW) launched in 2007. This framework is consistent with, and a supplement to, the internationally used UN *System of National Accounts* (SNA). Although a number of countries are now focusing on the estimation of such accounts, few have progressed to the production of water accounts that are credible and useful for policy makers. For further information see Winpenny (2012).

The general case for water security as an essential key to economic growth

Whittington, D., Sadoff, C. & Allaire, M. (2013) *The economic value of moving toward a more water secure world. TEC Background Paper no 18*. Global Water Partnership.

This is an important paper sponsored by the GWP by authors, two of whom (Whittington and Sadoff) are world leading water economists – the former an academic, the latter a senior World Bank official. The paper makes a basic distinction between the 'user value' and the 'system value' of water, the first of which is easier to value in economic terms than the latter. The paper is particularly strong at the conceptual level; it also has a lot of empirical content.

Waughray, D. (ed.) (2013) *Water security: the water-food-energy-climate nexus.* Island Press.

This is a lively, topical and approachable account of why water security is important and what it implies for agriculture, energy, trade, national security, cities, people, business, finance and climate – to name the main chapter. It concludes with an account of New Economic Frameworks for Decision Making (basically about the McKinsey methodology) and Innovative Water Partnerships. Each chapter contains text from a main contributor, followed by shorter discussion pieces from others. The book is a useful complement to other books in this area, insofar as it includes perspectives by businesspeople and other practitioners, and contains news of recent initiatives and partnerships.

Integrated Water Resource Management (IWRM)

GWP. (2014) *Toolbox*. Available at: http://www.gwp.org/en/ToolBox/TOOLS/The-Enabling-Environment/Investment-and-Financing-Structures/

The Global Water Partnership's *Toolbox of Integrated Water Resource Management* is an authoritative set of materials on IWRM, comprising 1-2 pages of content on 60+ 'tools', each an aspect of the overriding IWRM approach. The text on each 'tool' contains a description of content, lessons learned from its use, and guidance on case material, key organisations and references and websites. A final section contains Case Material which is continually updated and refreshed.

Lenton, R. & Muller M. (eds.) (2009) *Integrated Water Resources Management in practice: better water management for development*. Earthscan.

This is the best of a number of books on IWRM in practice. It contains a variety of case studies from different authors that show the variety of what people mean by IWRM, and how important it has been in overcoming water problems in different countries and thereby enabling sustainable growth. The case studies include watershed management in India; groundwater management in Denmark; wetlands in Bangladesh; irrigation in Mali; the Murray-Darling Basin in Australia; a river basin in Mexico; the Yangtze; South Africa; the Mekong to name but a few. The case studies explore the local political, institutional and social factors in each case that have influenced the path of reform and its outcomes. Lenton is currently Director of the Water for Food Institute in Nebraska, and Muller is Visiting Professor at the University of Witwatersrand and formerly Director-General of the South African Department of Water Resources and Forestry.

Scenarios

OECD. (2012) *Environmental Outlook to 2050: the consequences of inaction*. Paris.

Chapter 5 on water contains global scenarios of the future growth of water demand for OECD countries, the BRICs and the rest of the world, breaking down demand into irrigation, domestic, livestock, manufacturing, and electricity. It demonstrates the incompatibility of current trends based on business as usual and the future availability of water. Policies for reconciling the two are presented.

Methodology and tools

McKinsey et al. (2009) *Charting our water future: economic frameworks to inform decision-making*. 2030 Water Resources Group.

An influential report produced for a consortium of clients, including IFC and a number of leading multinational companies and banks. The report constructs various scenarios to 2030 for South Africa, India, Brazil, and China, showing how the projected demand for water in different sectors relates to its availability, and how the demand/supply gaps can be managed. This is the origin of the 'McKinsey Water Cost Curve', which ranks the many options for saving water or adding to its availability. Refinements to the basic Cost Curve are explained.

SABMiller/WWF. (2009) *Water footprinting: identifying & addressing water risks in the value chain.* Woking/Godalming.

A concise and approachable account of how water footprinting has been assessed by a leading multinational brewing company, based on its operations in South Africa and the Czech Republic. Illustrates the scope and limitations of this tool, and the fact that a company's water footprint can depend largely on the activities of its suppliers and customers, largely beyond its own power to control.

Data sources

UNESCO World Water Assessment Programme: *World Water Development Reports*. Hitherto produced every three years to coincide with meetings of the World Water Fora (2012, 2009, 2006, 2003, and 2000). These are large glossy documents produced by a large team of writers, including authors from most of the UN-Water 'family' of agencies; hence, they are very authoritative. They are best regarded as continually updated encyclopaedias of water, providing reference material (and data sources) on most aspects of the topic, aided by excellent detailed indexes. Henceforth the WWDR will be produced annually, starting with the report on *Water and energy* released in March 2014.

Economic benefits – general

OECD. (2011) *Benefits of investing in water and sanitation: an OECD perspective*. Paris.

A very useful compilation, written by Tremolet and Scatasta, of the evidence of economic benefits from water-resource management, and the supply of water services to households, wastewater treatment, etc. Discusses the various kinds of benefit, and how they can be valued in economic terms.

Economic benefits of improved water supply and sanitation

Hutton, G. (2007) 'Unsafe water and lack of sanitation', in Lomberg, B. (ed.) (2007) *Solutions for the world's biggest problems: costs and benefits.* Cambridge University Press.

Hutton's chapter (12) offers a concise and updated version of his milestone report (with Haller) for the WHO in 2003, which has been extensively quoted. This version, unlike the original, includes the valuation of avoided premature death and of disability-adjusted life years (DALYs) averted. The author focuses on three interventions: MDG target for water supply alone, MDG target for water supply and sanitation combined, and universal access to WS&S plus disinfection at the point of use. Benefit-cost ratios for the 9 possible outcomes range from 8 to 1 to 15 to 1. The evidence is at the global and regional aggregated level, but includes a large body of results built up from disaggregated studies. The composition of the benefits shows that, for each intervention, time savings (typically of women and girls) make up 80-90% of benefits.

A further update of the same body of work is contained in WHO. (2012) *Global costs and benefits of drinking-water supply and sanitation interventions to reach the MDG target and universal coverage*. *WHO/HSE/WSH/12.01*. Geneva. The authors note that the economic returns found in this study are 'more conservative' than previous ones, due to higher investment costs estimates, more complete inclusion of operations and maintenance (O&M) costs and a more conservative (i.e. lower) assumption for the economic value of time saved (p8). That said, 'advocacy messages can confidently put the economic returns at least at two times the investment for water supply and at least at five times the investment for sanitation' (p9).

Water security and food

IWMI. (2007) *Water for food, water for life: a Comprehensive Assessment of water management in agriculture*. Earthscan.

A huge (644-page) collection of chapters on all aspects of water use in agriculture, compiled by 700 leading specialists and 50 peer reviewers. Very authoritative, but the absence of an index is not helpful, and the report is sparse on costs and financing aspects.

Turral, H., Burke, J. & Faurès, J-M. (2011) *Climate Change, Water and Food Security*. Rome: FAO.

An excellent report from FAO reviewing the likely impact of climate change on agriculture, broken down by region and production regime. The second half of the report discusses prospects for adaptation and mitigation respectively.

Water security and industry

Chapter 20, 'Freshwater for industry' in UNESCO/UN-Water. (2012) *UN World Water Development Report 4 Volume 2*. Paris. Available at: http://www.unesco.org/new/fileadmin/MULTIMEDIA/HQ/SC/pdf/WWDR4%20Volume%202-Knowledge%20Base.pdf

Written by UNIDO officers, this is a good conspectus of the issues, with many graphics and boxes with case material. It comprises key issues about water use, an account of the main external drivers, the principal risks and uncertainties, challenge areas, and an account of what industrial companies can do and are doing to confront these challenges.

Water security and energy

DFID (2009). *Water storage and hydropower: supporting growth, resilience and low-carbon development. A DFID Evidence-into-Action Paper*. London/East Kilbride. Available at: http://reliefweb.int/sites/reliefweb.int/files/resources/40F3E613CFE321F1492576FC0023DE59-water-strge-hydropow-supp-grwth.pdf

Reviews evidence supporting the case for water storage. Includes material additional to that contained in this Topic Guide, plus further useful references.

Chapter 17, 'Water for energy', in International Energy Agency. (2012) *World Energy Outlook 2012.* Paris: IEA/OECD. Available at: http://www.iea.org/publications/freepublications/publication/WEO2012_free.pdf

An excellent concise account of the issues with many telling examples of the 'water-energy nexus'.

UN-Water. (2014c) *The United Nations World Water Development Report 2014: Water and Energy*. Paris: UNESCO. Available at: http://www.unwater.org/publications/publications-detail/en/c/218614/

This is another excellent review of the water-energy 'nexus' from an authoritative source.

Water and ecology

Emerton,L. & Bos, E. (2004) *Value: counting ecosystems as water infrastructure.* UK: IUCN.

Although starting to become dated, this is a very good, concise and approachable account of the environmental economics behind ecosystem conservation, with a number of case studies illustrating the economic and financial values of specific ecosystems.

Forest Trends, The Katoomba Group & UNEP. (2008) *Payments for Ecosystem Services: Getting Started. A Primer*. Nairobi: UNEP. Available at: http://www.unep.org/pdf/PaymentsForEcosystemServices_en.pdf

One of the best introductions to this *en vogue* topic, taking a practical, hands-on viewpoint.

Further information on the valuation of natural (including aquatic) ecosystems can be obtained on the website of the WAVES programme.

Glossary

Blue, green & grey water: Blue water refers to water either available in surface sources, such as rivers, lakes and wetlands, or stored in groundwater aquifers. Green water is rainwater stored in the soil as soil moisture. Grey water has both a narrow and a wider meaning: narrowly, it is wastewater from household cleaning, cooking and washing (but not from toilets); its wider meaning is all wastewater after its direct use by households, industry, and other users, including run-off from urban areas (as in the concept of 'greywater footprint').

Green growth: This has been defined as that "...compatible with, or driven by, actions to reduce greenhouse gases." Other definitions take the concept wider, to include the protection of ecosystems, respect of environmental 'carrying capacity' and the mitigation of all human impacts on the natural world (Huberty et al, 2011; UNEP, 2011). The OECD (2011, p4) defines it as "...fostering economic growth and development, while ensuring that natural assets continue to provide the resources and environmental services on which our wellbeing relies."

Integrated Water Resources Management: A paradigm promoted by the Global Water Partnership, originally defined as "a process which promotes the coordinated development and management of water, land and related resources in order to maximise the resultant economic and social welfare in an equitable manner without compromising the sustainability of vital eco-systems" (GWP, 2014).

Virtual water: The volume of water contained or used in producing goods and services; normally used in the context of international trade.

Water footprint: "The water footprint of an individual, community or business is defined as the total volume of freshwater that is used to produce the goods and services consumed by the individual or community or produced by the business. Water use is measured in terms of water volumes consumed (evaporated) and/or polluted per unit of time" (SABMiller/WWF, 2009).

Water scarcity: "...a gap between available supply and expressed demand of freshwater in a specified domain, under prevailing institutional arrangements (including both resource pricing and retail charging arrangements) and infrastructural conditions" (Faurès et al, 2012, p5). Although, on this definition, scarcity can arise at any absolute level of water availability, it is commonly expressed in absolute terms using Total Annual Renewable Water Resources (TARWR) of a country per head of its population (also known as the Falkenmark Index, after its Swedish originator). A figure of TARWA below $500m^3$ is commonly regarded as indicating 'absolute water scarcity', whereas 501-$1000m^3$ signifies 'relative water scarcity'.

Water stress: "The symptoms of water scarcity or shortage, e.g. widespread, frequent and serious restrictions on use, growing conflict between users and competition for water, declining standards of reliability and service, harvest failures and food insecurity" (ibid, p72).

Water poverty Index: A measure described by its authors as "a holistic tool to measure water stress at the household and community levels, designed to aid national decision makers ....The index combines into a single number a cluster of data directly and indirectly related to water stress. Subcomponents of the index include measures of access to water, water quantity, quality and variability, water uses (domestic, food, productive purposes), capacity for water management, and environmental aspects" (Sullivan et al, 2003).

Water Resource Management: "...a set of activities (or functions) aimed primarily at (i) ensuring that society has timely and reliable access to water resources of enough quality in the right location, (ii) protecting society from water-related risks (floods and droughts) and (iii) ensuring the protection of aquatic ecosystems and the environmental sustainability of water use" (OECD, 2011, p12-13).

Water sector: Commonly used to include a number of aspects of the water cycle – water-resources management (including catchment protection), development of bulk water supplies, agricultural water use, flood control, navigation, hydropower, water supplies for industry, mining, tourism and other 'productive' uses, household water supply, wastewater collection, treatment and disposal, protection of the aquatic environment, etc.

Water security: This is the capacity of a population to safeguard sustainable access to adequate quantities of acceptable quality water for sustaining livelihoods, human wellbeing and socio-economic development to ensure protection against water-borne pollution and water-related disasters, and for preserving ecosystems in a climate of peace and political stability (UN-Water, 2013a).

References

Allan, J. (1999) 'Water stress and Global Mitigation: Water, Food and Trade', *Arid Lands Newsletter #45*.

Aw, D. & Diemer, G. (2005) *Making a Large Irrigation Scheme Work. A Case Study from Mali. Directions in Development*. Washington, D. C.: World Bank.

Aylward, B., Seely, H., Hartwell, R. & Dengel, J. (2010) *The Economic Value of Water for Agricultural, Domestic and Industrial uses: A Global Compilation of Economic studies and Market Prices*. FAO.

Bahri, A. (2009) *Managing the other side of the water cycle: making wastewater an asset. TEC Background Paper no 13*. Global Water Partnership.

Bartram, J. (2008) *Sanitation is an Investment with High Economic Returns. UN-Water Factsheet No. 2*. WHO.

Bates, B., Kundzewicz, Z., Wu, S. & Palutikof, J. (eds.) (2008) *Climate Change and Water.* Intergovernmental Panel on Climate Change.

BGS. (2011) *Groundwater Resilience to Climate Change in Africa*. Available at: http://www.bgs.ac.uk/gwresilience/

Bouwer, L. M. (2011) 'Have disaster losses increased due to anthropogenic climate change?', *American Meteorological Society 92(6)*, p39-46.

Brander, L. & Schuyt, K. (2010) *The economic value of the world's wetlands*. TEEB.

ten Brink, P., Russi, D., Farmer, A., Badura, T., Coates, D., Förster, J., Kumar, R. & Davidson N. (2013) *The Economics of Ecosystems and Biodiversity for Water and Wetlands. Executive Summary*. TEEB.

Brown, C., and Lall, U. (2006) "Water and economic development: The role of variability and a framework for resilience," Natural Resources Forum, 30: 4, 306 – 317, DOI:10.1111/j.1477-8947.2006.00118.

Carbon Disclosure Project (CDP). (2013) *CDP Global Water Report 2013; Moving Beyond Business as Usual*. CDP/Deloitte. Available at: https://www.cdp.net/en-US/Results/Pages/Water-Disclosure-Reports.aspx

CGIAR. (2014) *Water Data and Accounting in Basins*. IMWI. Available at: http://wle.cgiar.org/research-programs/river-basins-strategic-research-program/ac-4-4-water-data-and-accounting-in-basins/

Chapagain, A. & Orr, S. (2008) *UK Water Footprint: The Impact of the UK's Food and Fibre Consumption on Global Water Resources*. WWF.

Christian Aid. (2009) *The Economic Cost of Climate Change in Africa*. Christian Aid/Practical Action. Available at: http://www.christianaid.org.uk/images/economic-cost-of-climate-change-in-africa.pdf

Cutler, D. & Miller, G. (2005) 'The role of public health improvements in health advances: the Twentieth Century United States', *Demography 42/1*.

Helm, D. (2012) *Carbon Crunch: How We're Getting Climate Change Wrong – and How to Fix it*. Yale University Press.

DEG/WWF. (2011) *Assessing water risk: a practical approach for financial institutions.* Berlin. Available at: http://awsassets.panda.org/downloads/deg_wwf_water_risk_final.pdf

DFID (2009). *Water storage and hydropower: supporting growth, resilience and low-carbon development. A DFID Evidence-into-Action Paper*. London/East Kilbride.

Emerton, L. & Bos, E. (2004) *Value. Counting Ecosystems as Water Infrastructure*. Gland, Switzerland/Cambridge, UK: IUCN.

Ethiopia Ministry of Water Resources. (2006) *Final sector review report of water supply, sanitation and hygiene*. Addis Ababa.

EU Water Initiative Finance Working Group (EUWI). (2012a) *Pricing Water Resources to Finance Their Sustainable Management*. Brussels.

EUWI. (2012b) *Small-scale Finance for Water and Sanitation*. Brussels.

FAO. (2007) *Towards a New Understanding of Forests and Water*. Rome.

FAO. (2011) *The State of the World's Land and Water Resources for Food and Agriculture*. Rome.

FAO. (2012) *Food Security and Agricultural Water*. Rome.

FAO. (2013) *Climate Smart Agriculture Sourcebook*. Rome.

Farmer, A., Bassi, S., & Fergusson, M. (2008) *Water Scarcity and Droughts. Economic and Science Policy, European Parliament.* Brussels. Available at: http://www.europarl.gr/ressource/static/files/projets_pdf/water_scarcity.pdf

Faurès, J-M., Hoogeveen, J. & Winpenny, J. (2012) *The Water Cost Curve has also been proposed for use in the agricultural sector*. FAO, p50-55.

Fisher, J. & Johns, D. (2010) *Funding Future Investment in Flood and Coastal Erosion Risk Management in England*. OECD.

Foster, V. & Briceno-Garmendia, C. (eds.) (2010) *Africa's infrastructure: a Time for transformation*. World Bank: Africa Infrastructure Country Diagnostic (AICD).

van Ginneken, M., Netterstrom, U. & Bennett, A. (2011) *More, Better or Different Spending?* Washington, D.C.: World Bank.

Giordano, M., de Fraiture, C., Weight, E. & van der Bliek, J. (2012) *Water for Wealth and Food Security*. Colombo: IMWI.

Global Water Intelligence (GWI). (2013) *Market Profile: The Global Water Market. A Bright New Future for Water?* Oxford.

Government of Pakistan (GoP). (2012) *Pakistan: Flood Impact Assessement*. *Pakistan Economic Survey 2011-12*. Available at: http://www.finance.gov.pk/survey/chapter_12/SplSection.pdf

Granit, J. & Lindström, A. (2009) *The Role of Large Scale Artificial Water Storage in the Water-Food-Energy Nexus*. Stockholm International Water Institute.

Grey, D. & Sadoff, C. (2007) 'Sink or swim? Water security for growth and development', *Water Policy 9*, p545-571.

Grey, D., Garrick, D., Blackmore, D., Kelman, J., Muller, M. & Sadoff, C. (2013) *Water Security in One Blue Planet: Twenty-first Century Policy Challenges for Science*. The Royal Society.

Global Water Partnership (GWP). (2012) *Groundwater Resources and Irrigated Agriculture – Making a Beneficial Relation More Sustainable*. Stockholm. Available at: http://www.gwp.org/Global/The%20Challenge/Resource%20material/Perspectives%20Paper_Groundwater_web.pdf

GWP. (2014) *Toolbox*. Available at: http://www.gwp.org/en/ToolBox/TOOLS/The-Enabling-Environment/Investment-and-Financing-Structures/

Huberty, M., Gao, H., Mandell, J. & Zysman, J. 'Shaping the green growth economy: a review of the public debate and the prospects for green growth', *Green Growth Knowledge Platform*, 1st March 2011. Available at: http://www.greengrowthknowledge.org/resource/shaping-green-growth-economy-review-public-debate-and-prospects-green-growth-0

Hussain, I & Bhattarai, M. (2004) *Comprehensive Assessment of Socio-Economic Impacts of Agricultural Water Uses: Concepts, Approaches and Analytical Tools*. IMWI.

Hutton, G & Haller, L. (2004) *Evaluation of the Costs and Benefits of Water and Sanitation Improvements at the Global Level*. Geneva: World Health Organization.

Hutton, G. (2007) 'Unsafe water and lack of sanitation', in Lomborg, B. (ed.) (2007) *Solutions for the World's Biggest Problems: Costs and Benefits*. Cambridge University Press

Hutton, G. (2012) *Global Costs and Benefits of Drinking-water Supply and Sanitation Interventions to Reach the MDG Target and Universal Coverage. WHO/HSE/12.01*. Geneva.

International Energy Agency (IEA). (2012) *World Energy Outlook 2012.* Paris: IEA/OECD. Available at: http://www.iea.org/publications/freepublications/publication/WEO2012_free.pdf

IEA (2013) *Renewable Energy: Medium-Term Renewable Energy Market Report*. Paris.

IFPRI. (2002) *Green revolution: curse or blessing*. Washington, D. C.

IMF. (2003) *Fund Assistance for Countries Facing Exogenous Shocks*. Washington, D. C.

Infrastructure Consortium for Africa (ICA). (2012) *ICA Water Platform Summary*. Stockholm.

International Water Management Institute (IWMI). (2010a) *Managing Water for Rainfed Agriculture*. Colombo.

IWMI. (2010b) *Water Pricing and Allocation. IWMI Water Issue Brief 6*. Colombo.

'In-depth: Running Dry: the humanitarian impact of the global water crisis', *IRIN Humanitarian News and Analysis*, 8th September 2006. Available at http://www.irinnews.org/InDepthMain.aspx?InDepthId=13&ReportId=60533

Jeuken, A. & Reeder, T. (2011) 'Short term decision-making and long term strategy – how to adapt to uncertain climate change', *Water Governance*.

Kenny, J., Barber, N., Hutson, S., Linsey, K., Lovelace, J., & Maupin, M. (2009) *Estimated Use of Water in the United States in 2005*. US Geological Survey.

KfW, BEI & AFD. (2009) *Joint ex post Evaluation of the Manantali Dam Project*. EIB.

Larson, C. 'China's Looming Conflict Between Energy and Water', *environment360*, 30th April 2012. Available at: http://news.world.edu/?0a79QKbT

Lenton, R. & Muller, M. (eds.) (2009) *Integrated Water Resources Management in Practice: Better Water Management for Development*. GWP.

Lindström, A. & Granit, J. (2012) *Large Scale Water Storage in the Water, Energy and Food Nexus*. Stockholm: SIWI.

McKinsey et al. (2009a) *Charting our Water Future: Economic Frameworks to Inform Decision-making*. Water Resources Group.

McKinsey et al. (2009b) *Shaping Climate-resilient Development: A Framework for Decision Making*. Economics of Climate Adaptation Working Group.

McKinsey. (2011) *A Glass Half Empty: Regions at Risk Due to Groundwater Depletion Why is This Issue important?* UNEP.

Micklin, P. (2010) 'The past, present and future Aral Sea. Lakes & Reservoirs', *Research & Management 15(3)*, p193-213.

Millennium Ecosystem Assessment. (2005) *Living Beyond our Means: Natural Assets and Human Well-being.* Washington, D. C.

Mogaka, H., Gichere, S., Davis, R. & Hirji, R. (2006) *Climate Variability and Water Resources Degradation in Kenya*. Washington, D. C.: World Bank.

Morrison, J., Morikawa, M., Murphy, M., & Schulte, P. (2009) *Water Scarcity and Climate Change: Growing Risks for Business and Investors*. Ceres/Pacific Institute. Availabe at http://www.pacinst.org/reports/business_water_climate/full_report.pdf

Moser, D. 'Fourth Water for Food Conference opens', *University of Nebraska-Lincoln*, 30th May 2012. Available at: http://newsroom.unl.edu/announce/todayatunl/1336/7843

National Drought Forum. (2012) *Drought and U.S. Preparedness in 2013 and Beyond*. Washington, D. C.

Nicol, A., van Steenbergen, F. & te Velde, D. W. (2002) *Financing Transboundary Water Management. Policy Brief*. Swedish Ministry of Foreign Affairs.

Nile Basin Initiative. (2012) *Annual Report for 2011*. NBI.

OECD. (2003) *Pricing Water*. Paris.

OECD. (2010a) *Pricing Water Resources and Water and Sanitation Services*. Paris.

OECD. (2010b) *Sustainable Management of Water Resources in Agriculture*. Paris.

OECD. (2011) *Benefits of investing in water and sanitation: an OECD perspective*. Paris.

OECD. (2012) *OECD Environmental Outlook to 2050: The Consequences of Inaction*. Paris.

ODI. (2014) *Adaptation to Climate Change in Water, Sanitation and Hygiene Programmes*. London: ODI.

Ramirez-Vallejo, J. & Rogers, P. (2004) 'Virtual water flows and trade liberalization', *Water Science and Technology 7*, p25-32.

Rockström, J., Karlberg, L., Wani, S., Barron, J., Hatibu, N., Oweis, T., Bruggeman, A., Farahani, J. & Qiang, Z. (2010) 'Managing water in rainfed agriculture – The need for a paradigm shift', *Agricultural Water Management 97*, p543-550.

Rosenberg, M. & Torres, N. 'Stubborn drought expected to tax Mexico for years', Reuters, 21st March 2012. Available at: http://uk.reuters.com/article/2012/03/21/us-mexico-drought-idUSBRE82K1E520120321

SABMiller/WWF. (2009) *Water Footprinting: Identifying & Addressing Water Risks in the Value Chain*. Woking/Godalming.

Sadoff, C. (2006) *Can Water Undermine Growth? Evidence from Ethiopia. World Bank Agricultural and Rural Development Notes, Issue 18*. Washington, D. C.

Saeed, A. 'Floods have halved Pakistan's economic growth – expert', *Thomson Reuters*, 9th September 2013. Available at: http://www.trust.org/item/20130909134725-rm708/?source=hptop

South African Department of Water and Forestry (DWAF). (2008) *Water for Growth and Development in South Africa – Version 6*. Pretoria. Available at: http://www.dwaf.gov.za/WFGD/documents/WfGDv6Nov21.pdf

Stern, N. (2007) *The Economics of Climate Change: the Stern Review*. Cambridge University Press

Sullivan, C. et al. *(*2003). 'The Water Poverty Index: development and application at the community scale', *Natural Resources Forum 27*, p189-199.

Swedish Water House. (2006) *Investing in the Future: Water's Role in Achieving the Millennium Development Goals*. Stockholm International Water Institute.

Swiss Re. (2012) 'Natural Catastrophes and Man-Made Disasters in 2011: Historic Losses Surface from Record Earthquakes and Floods', *Sigma No 2/2012*. Available at http://media.swissre.com/documents/sigma2_2012_en.pdf

Tearfund. (2005) *Making Every Drop Count: Financing Water, Sanitation and Hygiene in Ethiopia*. Teddington.

Thornton, P. & Herrero, M. (2010) *The inter-linkages between rapid growth in livestock production, climate change, and the impacts on water resources, land use, and deforestation*. Washington, D. C.: World Bank.

Turner, K., Georgiou, S., Clark, R., Brouwer, R. & Burke, J. (2004) *Economic valuation of water resources in agriculture: From the sectoral to a functional perspective of natural resource management, FAO Water Reports 27*. Rome: FAO.

Turral, H., Burke, J. & Faurès, J-M. (2011) *Climate Change, Water and Food Security*. Rome: FAO.

United Nations (UN). (1992) *The Dublin Statement on Water and Sustainable Development*. Geneva/New York/Dublin. Available at: http://www.un-documents.net/h2o-dub.htm

United Nations Development Programme (UNDP). (2013) *Users Guide on Assessing Water Governance*. Oslo/Stockholm/Berlin. Available at: http://www.undp.org/content/dam/undp/library/Democratic%20Governance/OGC/Users%20Guide%20on%20Assessing%20Water%20Governance1.pdf

United Nations Environment Programme (UNEP). (2011) *Towards a Green Economy: Pathways to Sustainable Development and Poverty Eradication*. Nairobi. Available at: http://www.unep.org/pdf/water/WAT-Water_KB_17.08_PRINT_EDITION.2011.pdf

UNEP. (2012) *A Glass Half Empty: Regions at Risk Due to Groundwater Depletion Why is this issue important?* GEAS.

UNESCO. (2009a) *Briefing Paper: Implications of Climate Change on Water*. Paris: World Water Assessment Programme.

UNESCO. (2009b) *World Water Development Report (WWDR3). Water in a changing world*. Paris.

UNESCO. (2012) *Managing Water under Uncertainty and Risk*. Paris.

UNESCO/UN-Water. (2012) *UN World Water Development Report 4 Volume 2*. Paris. Available at: http://www.unesco.org/new/fileadmin/MULTIMEDIA/HQ/SC/pdf/WWDR4%20Volume%202-Knowledge%20Base.pdf

UN-Water. (2013a) *Analytical Brief on Water Security and the Global Water Agenda*. Geneva.

UN-Water. (2013b) *Bangladesh UN-Water country brief*. Geneva.

UN-Water. (2013c) *Water use*. Available at: http://www.unwater.org/statistics/fi/?page=1&ipp=10&no_cache=1&tx_dynalist_pi1[par]=YToxOntzOjE6IkwiO3M6MjoiMTIiO30=

UN-Water. (2013d) *World Water Development Report – Managing Water under Uncertainty and Risk*. Geneva.

UN-Water (2013e) What is Water Security? Infographic. Available at: http://www.unwater.org/publications/publications-detail/en/c/210718/

UN-Water. (2014a) *Statistics*. Available at: http://www.unwater.org/statistics/fi/?page=5&ipp=10&no_cache=1

UN-Water. (2014b) *Water scarcity*. Available at: http://www.un.org/waterforlifedecade/scarcity.shtml

UN-Water. (2014c) *World Water Development Report – Water and Energy*. Geneva.

UN-Water (2014d) Water and food security. Available at: http://www.un.org/waterforlifedecade/food_security.shtml

UN Women. (2014) *Facts and Figures*. Available at: http://www.unwomen.org/en/news/in-focus/the-united-nations-conference-on-sustainable-development-rio-20/facts-and-figures [Accessed 20th January 2014]

United States Government Accountability Office. (2014) *Climate change: Energy Infrastructure Risks and Adaptation Efforts*. Washington, D. C. Available at: http://www.gao.gov/assets/670/660558.pdf

USAID/WSP. (2008) *Economic impacts of sanitation in the Philippines*. Jakarta: World Bank.

Van Ginneken, M., Netterstrom, U., and Bennett, A. 2011. More, Better or Different Spending? Washington DC: World Bank

Ward, F. (2012) *Cost–benefit and Water Resources Policy: A Survey*. New Mexico State University. Available at: http://www.iwaponline.com/wp/01402/wp014020250.htm

Ward, J., Kaczan, D. & Lukasiewicz, A. (2009) *A Water Poverty Analysis of the Niger Basin, West Africa Niger Basin Focal Project: Work Package 1*. CSIRO Sustainable Ecosystems/CGIAR Challenge Program on Water and Food.

Water and Sanitation Program (WSP). (2008) *Economic Impacts of Sanitation in Indonesia: A five-country study conducted in Cambodia, Indonesia, Lao PDR, the Philippines, and Vietnam under the Economics of Sanitation Initiative (ESI) Research*. World Bank. Available at: http://www.wsp.org/sites/wsp.org/files/publications/esi_indonesia.pdf

WaterAid. (2012) *Water Security Framework*. London: WaterAid

WaterAid. (2013) *The Economic Case for WASH*. London.

Waughray, D. (ed.) (2013) *Water security: the water-food-energy-climate nexus*. Island Press.

Whittington, D., Sadoff, C. & Allaire, M. (2013) *The economic value of moving toward a more water secure world. TEC Background Paper no 18*. Global Water Partnership.

World Health Organization (WHO). (2004) *Costs and Benefits of Water and Sanitation Improvements at the Global Level*. Available at: http://www.who.int/water_sanitation_health/wsh0404summary/en/

WHO. (2005) *Making water a part of economic development*. Geneva.

WHO. (2009) Fact File of Water Scarcity. Available at: http://www.who.int/features/factfiles/water/water_facts/en/index2.html

WHO. (2012) *Global Costs & Benefits of Water Supply and Sanitation Interventions to Reach the MDG target*. Geneva: WHO.

WHO. (2014) *Millennium Development Goal Drinking Water Target Met*. Available at: http://www.who.int/mediacentre/news/releases/2012/drinking_water_20120306/en/

Wichelns, D. (2010) 'Virtual Water: A Helpful Perspective, but not a Sufficient Policy', *Water Resource Management 24*, p2203-2219.

Winpenny, J. (2003) *Financing Water for All: Report of the World Panel on Financing Water Infrastructure*. Camdessus Report, Global Water Partnership and World Water Council.

Winpenny, J. (2012) *Green Accounting and Data Improvement for Water Resources*. Side Publication 02: UN World Water Assessment Programme.

Winpenny, J., Heinz, I. & Koo-Oshima, S. (2010) *The wealth of waste: The economics of wastewater use in agriculture*. Rome: FAO.

World Bank (2006) *Water Resources in Tanzania: Sustainable Development of Tanzania's Water Resources*. Washington, D. C.

World Bank. (2007) *Cost of Pollution in China – Economic Estimates of Physical Damages*. Beijing/Washington, D. C.

World Bank. (2010a) *Economics of Adaptation to Climate Change. 2010: Consultation Draft of 'The costs to developing countries of adapting to climate change: new methods and estimates'*. Washington, D. C.

World Bank. (2010b) *The Impacts of Biofuel Targets on Land-Use Change and Food Supply - A Global CGE Assessment*. Washington, D. C.

World Bank. (2010c) *The Zambezi River Basin: a Multi-sector Investment Opportunities Analysis*. Washington, D. C. Available at: http://siteresources.worldbank.org/INTAFRICA/Resources/Zambezi_MSIOA_-_Vol_1_-_Summary_Report.pdf

World Bank. (2010d) *World Development Indicators 2010*. Washington, D. C.

World Bank. (2012a) *Climate Change, Disaster Risk and the Urban Poor*. Washington, D. C.

World Bank. (2012b) *Investing in Water Infrastructure: Capital, Operation and Maintenance*. Washington, D. C.

World Bank. (2012c) *Thai flood 2011: Rapid Assessment for Resilient Recovery and Reconstruction Planning*. Bangkok. Available at: http://www.gfdrr.org/sites/gfdrr.org/files/publication/Thai_Flood_2011_2.pdf

World Bank (2012d) *Turn Down the Heat: Why a 4°C Warmer World Must be Avoided*. Washington, D. C.

World Bank (2012e) *Water Papers - Investing in Water Infrastructure: Capital, Operations and Maintenance*. Washington, D.C.

World Bank (2013) *Fact Sheet: The World Bank and Agriculture in Africa*. Washington, D. C.

World Bank (2014) *Water and Climate Change*. Available at: http://water.worldbank.org/topics/water-resources-management/water-and-climate-change

World Economic Forum (WEF). (2009) *The Bubble is Close to Bursting*. Cologny.

WEF. (2014) *Global Risks 2014 Ninth Edition*. Cologny. Available at: http://www.weforum.org/reports/global-risks-2014-report

World Energy Council. (2010) *Water for Energy*. London. Available at: http://www.worldenergy.org/documents/water_energy_1.pdf

WRI. (2010) *Reefs at Risk in the Caribbean*. Washington, D. C.

WRI. (2013) *World's 37 Most Water-Stressed Countries*. Washington, D. C. Available at: http://www.wri.org/blog/world%E2%80%99s-37-most-water-stressed-countries