Water-Food-Energy Nexus:
Towards a widening of the water agenda

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Preface

The time that water challenges could be addressed in isolation has past. Trends as population growth and economic development are increasing the demand for water, food, and energy. In addition the impact of climate change will have huge consequences on water and food availability. If we fail to move to a more sustainable use of our natural resources the social and economic consequences will be enormous.

It is clear that there is no place in our interlinked world for isolated solutions aimed at just one sector. If the world is going to reduce hunger and eradicate poverty in a sustainable way we have to achieve security for water, food and energy simultaneously. In such an effort water will be the medium by which we should address this nexus.

This widening water agenda requires an approach addressing issues between sectors, countries, regions, and stakeholders where it is important to identify and name the most important barriers and obstacles and to exploit opportunities. Such a new water agenda must involve the private sector under governmental set principles to ensure a green economy where water will play the interlinked topic.

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1 Water is a lot more than water

No water no life is probably one of most famous phrases on water. Although completely true, its simplification does not express the complexity of water, its challenges, interlinkages and potentials. The water agenda is also not static and issues less relevant in the past play a prominent role in nowadays water policies and require urgently an extension of the water agenda.

1.1 Water

The importance of water is probably best demonstrated by the fact that "water" is on average five times more used in Google search compared to "Obama', with the only small exception during the US 2008 elections (Figure 1). Water-wars, more drop per crop, water for all, Millennium Development Goals, water pricing, water is a gift of God/Allah, water scarcity, water illnesses, water conservation; in our daily life we are constantly confronted with topics related to water. Even the minority part of the world population that has access to safe water and sanitation is still almost yearly confronted with drought and flooding. The other less-fortune majority part of the world experiences daily facts as: every 21 seconds a child dies from a water-related illness; women spend 200 million hours a day collecting water; more than 3x more people lack water than live in the United States; and more people have a mobile than a toilet.

Water is and will always be one of the challenges we have to deal with given its vital role it plays to human life and on the contrary the complexity to deal with it. Water shortage and allocation issues are caused by the fact that only 2.5% of water on earth is fresh water, and of this only 0.4 percent is surface water (Figure 2). The scarcity in some places is alternated by extreme flooding events in other places, with over 1500 big flooding events over the last ten years affecting nearly 900 million people.

So how much water do we need? The UN suggests that each person needs 20-50 liters of water a day to ensure their basic needs for drinking, cooking and cleaning. In the USA and Europe between 200 and 350 liters per person per day are supplied to households. At the same time ten times more water is required to produce our daily food. This water for food number is even more striking since return flows from domestic water are often in the order of 70-90% and, if cleaned properly, can be reused. This in contrast to the water used to produce food where at basin scale levels return flows are often less than 30%.
[http://water.org/] [WWAP, 2012] [http://www.emdat.be]

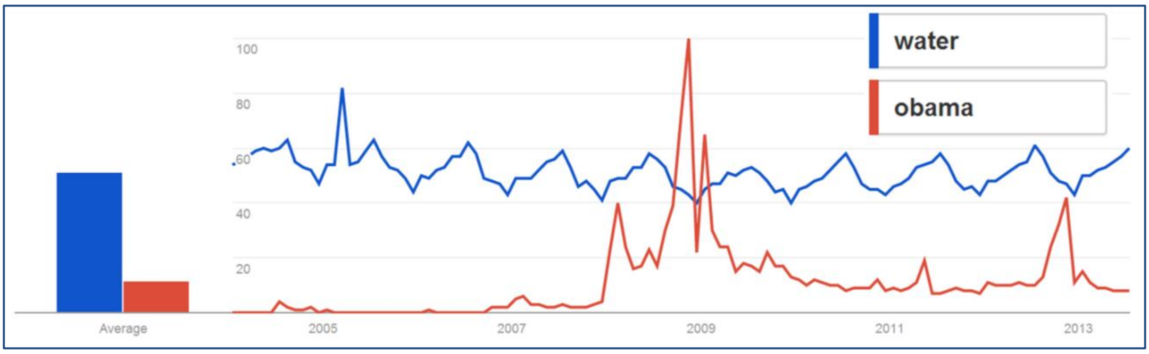

Figure 1. Water is a more popular search word in Google than Obama. [Google Trends, Jul-2013]

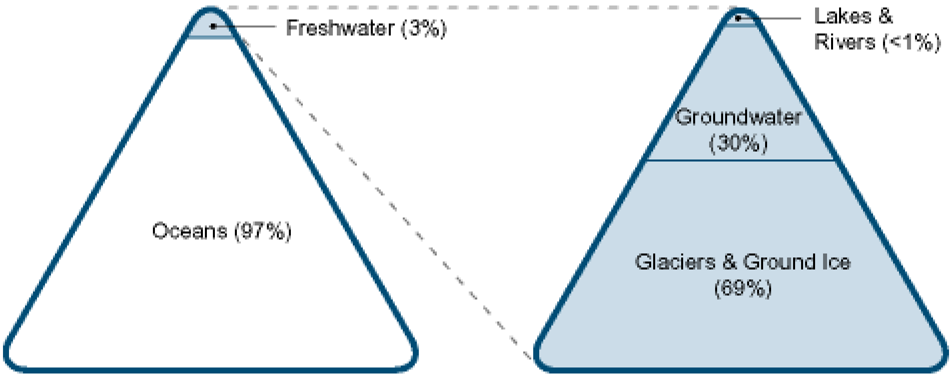

Figure 2. Of all water on earth less than 3% is fresh , of which only a very small fraction is actual manageable. [ICA, 2012][http://www.gemi.org/water/watertrends.htm]

1.2 Water and food

The interdependence between food security and sustainable water resource management is significant. Globally, agriculture consumes 70 percent of available freshwater resources and is often used in irrigated systems that are inefficient and environmentally unsustainable. Global population growth projections of two to three billion people over the next 40 years, combined with changing diets, are expected to increase food demand substantially by 2050. However, as the biggest consumer of allocated water, food production also represents the largest unknown factor of future global water demand. Based on current use patterns, agricultural water consumption will increase by approximately 19 percent to feed a larger and richer global population of 9.1 billion people.

Between 2,000 and 5,000 liters of water is needed to produce enough food to satisfy a person's daily dietary. About 80% of agricultural water consumption, which is evapotranspiration from crops, comes directly from rain, and about only 20% from irrigation. Arid areas like the Middle East, Central Asia, and the western United States tend to rely almost completely on irrigation, while large-scale irrigation development occurs in South and East Asia. Latin America and Sub-Saharan Africa have limited irrigation partly as the climate conditions are in favor for rainfed or the lack of any water at all. Lack of investments is another reason for this limited developed irrigation sector in these regions. Obviously, in cases water is not scarce this water consumption by agriculture should not be considered as problematic. The fact that the natural landscape is still by far the biggest water consumer has gained more attention recently, and focus on managing this water resource is starting to be included in policies.
[USAID, 2013] [WWAP, 2012]

1.3 Water and energy

Water and energy have two interrelated links: water for energy, and energy for water. Every drop of water that has to be pumped, moved, or treated to meet domestic, industrial and food needs requires energy. A typical example of this energy for water is the yearly reoccurring blackouts in India during the irrigation season as farmers pump water for their crops. In some countries up to 40% of total energy consumption is used for pumping, while this number is close to 50% for some states in India (Gijarat, Haryana).

Desalination as solution to fight water shortage is another show case of energy for water. Energy required for desalination is high and in the order of 3-5 kWh per cubic meter of water. Costs associated to this depends on electricity prices which vary substantially from country to country and even within one country differentiations can be found and are often use specific. Typical prices for countries like China, India and Pakistan are in the range of 0.10 US$ per kWh, while in European and North American countries prices are about 0.20 US$. Energy costs are about halve of the total costs for desalination so costs for 1 cubic meter of desalinized water range from 0.50 to 2.00 US$ per cubic meter, making it too expensive to be used for irrigation. With expected increase in energy prices desalination will be even more expensive.

Biofuels are the most disputed example of water use to generate energy. Estimates indicate that in order to produce 1 kWh somewhere between 40 and 400 liters of water are required to grow these biofuels. Obviously, this is not very relevant if water is not scarce in the area where the biofuels are grown. Hydropower is already used for centuries as energy sources. Although this is a typical example of water for energy the water is not actually consumed. Other forms of energy production require also water, such as for cooling, oil and gas production, and more recently fracking of shale gas, but total consumption is relatively low compared to biofuels. [USAID, 2013] [Immerzeel, 2011] [Webber, 2008] [Singh, 2009] [Gerbens-Leenes, 2009]

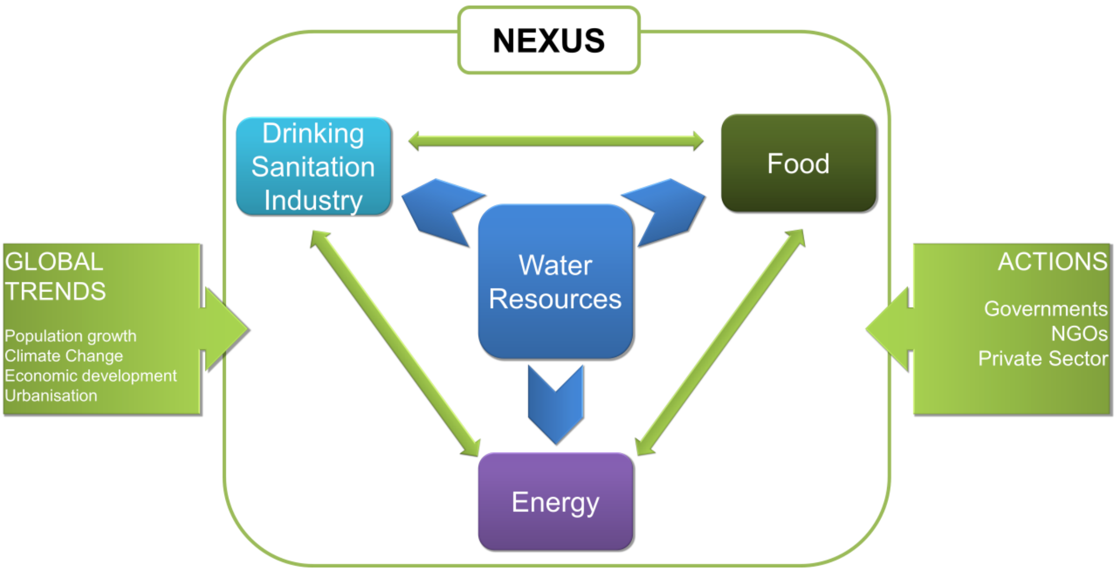

Figure 3. The widening of the water agenda: Water-Food-Energy Nexus

1.4 Water-food-energy nexus

It is clear that the world's water, food and energy systems are tightly linked and are therefore often referred to as the water-food-energy nexus (Figure 3). Over the past few decades the world has undergone some major global transitions around the nexus of food, water, and energy. These transitions include urban population transition, with the majority of the global population now residing in cities; nutrition transition, with demand for new food including increased consumption of animal products and other high-value foods; climate change transition, with increased temperature and uncertainty in rainfall; agricultural transition, with huge increases in food demands; and energy transition, with a move from cheap fossil fuels to renewable energy resources. These changes happened so fast that well-tried solutions and historically based planning to water-management problems are no longer viable and require a widening of the water agenda.

A nexus approach is therefore needed to support a transition to sustainability. Typical pathways to achieve this are: increased productivity of resources, waste as a resource in multi-use systems, economic incentives, policy coherence, productive ecosystems, integrated poverty alleviation, capacity building and awareness rising. These issues are often summarized as a development towards a Green Economy. Such a Green Economy “is an economy that results in improved human well-being and social equity, while significantly reducing environmental risks and ecological scarcities”.
[UNCSD, 2010][Hoff, 2012]

BOX: Energy for Water

In July 2012 more than 670 million people were left without power in 20 out of 28 states in India signifying the single largest black-out in history. The first step in the chain of events that led to the power outage was a weak monsoon in 2012 with rainfall 18 percent below normal. This hit farmers first who started using electric water pumps to irrigate their fields, increasing electricity demand. This increase in demand coincided with a reduced supply from hydropower, which provides around 19% of India's electricity needs.

The 2012 blackout should be seen as a warning for what the future might hold, as energy demand in India is increasing due to an increasing population and rising consumption by a growing middle class. While it may appear as an option to fill this gap through usage of combustion and nuclear power plants, these are also dependent on water for cooling. Although water played a major role in the event in order to reach solutions not only water with regard to energy security, but also with regard to securing food production and water supply should be considered. This illustrates the importance of viewing the whole water-food-energy nexus.

BOX: Water-food-energy in the Middle East

The Middle East region is considered the most water-scarce region of the world. Disputes over water lead to tension within communities, and unreliable water services are prompting people to migrate in search of better opportunities. Water investments absorb large amounts of public funds, which could often be used more effectively elsewhere. As the region’s population continues to grow, per capita water availability is set to fall by 50 percent by 2050, and, if climate change affects weather and precipitation patterns as predicted, the region may see more frequent and severe droughts.

When trying to match future water supply and demand, three broad strategies can be considered: (i) increasing the productivity of existing water use, (ii) increasing supply, and (iii) reducing demand by shifting the economy towards less water-intensive activities. For the region the use of desalination might an interesting option to overcome projected future water shortages.

The cost of desalination by means of fossil fuel has been projected to increase from 1.30 US$/m3 currently to 2.50 US$/m3 in 2050. Half of the costs, when making use of reverse osmosis by fossil fuel, is for energy usage. There is, however, uncertainty about the energy price as well as future energy requirements, which depend on crude oil prices and technological breakthroughs. As alternative, desalination by concentrating solar power is seen as a sustainable option by researchers. The cost of desalination of sea water by means of this concentrating solar power has been projected to decrease over time from currently 1.80 US$/m3 to 0.90 US$/m3 in 2050.

Further research on the linkages between concentrating solar power and desalination is on-going and includes beside technical challenges also economic valuation criteria combined with potential environmental issues regarding waste from desalination. If successful, such an approach might reduce partly some of the water shortages experienced in the region. [Droogers et al., 2012] [Trieb, 2008]

2 The Future of Our Water

It is undisputed that if mankind fails to manage and preserve our water resources in a more sustainable way, the social and economic consequences will be enormous. Pressures from climate change, a growing population, economic development and environmental needs will increase over the coming decades. Although those future projections are often associated with large uncertainties, the overall trend is very clear: growing pressures on water resources and shifting trends in regions and timing of these pressures.

2.1 Socio-economic drivers

The world has seen major changes in population distribution between 1950 and today. Europe was home to 22% of the world's 2.5 billion people. Germany, Britain, Italy and France all counted among the 12 most populous countries. But strong economic growth in Asia coupled with high fertility rates in Africa have contributed to a big regional shift in the global population. The UN's latest World Population Prospects expects the world to grow from 7.2 billion people today to 9.6 billion in 2050. Compared to previous estimates this is 300 million more and reflects increased fertility rates in sub-Saharan countries such as Nigeria and Ethiopia, and other populous countries. More than half of the extra 2.4 billion people in 2050 will be African. India will swell to 1.6 billion people; it is on track to overtake China in 2028. China's population will peak in 2030; India's is predicted to do so around 2063 (**Figure 4**).

Sometimes this transition is expressed as the world's PIN code changing from currently 1114 (1 billion people in the Americas, 1 billion in Europe, 1 billion in Africa and 4 billion in Asia) to 1125 in 2050 to 1145 in 2100 (**Figure 5**).

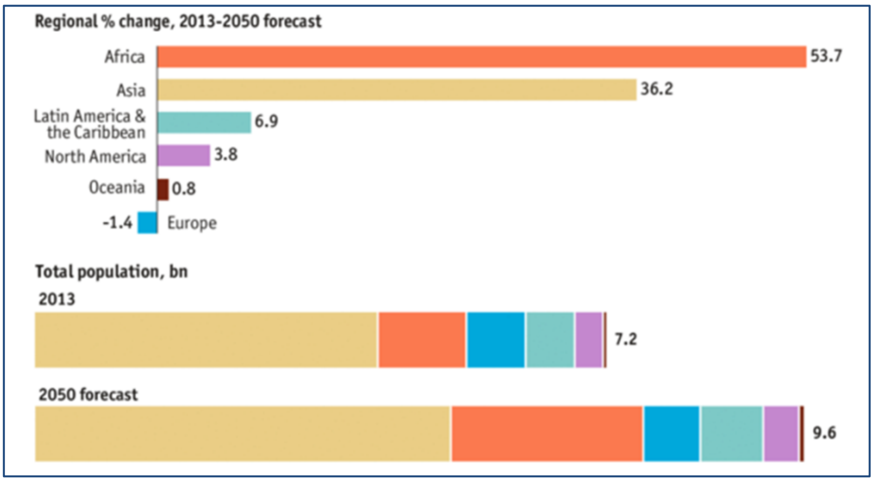

Figure 4. The World's population will increase with an unequal regional distribution. [Source: UN, 2013; Graph: http://www.economist.com/blogs/graphicdetail/2013/06/daily-chart-10]

It is clear that such a growing population requires more food and recent projections indicate that crop demand will nearly double in the coming 50 years. Besides this population growth dietary change is the other main factor driving how much more food we will need. With rising incomes and continuing urbanization, food habits change toward more nutritious and more varied diets, so a shift in consumption patterns away from cereals toward livestock and fish products and high-value crops. Per capita food supply in OECD countries will level off well above 2,800 kcal, which is usually taken as a threshold for national food security. People in low- and middle-income countries will substantially increase their calorie intake, but a significant gap between poor and rich countries will likely remain in the coming decades.

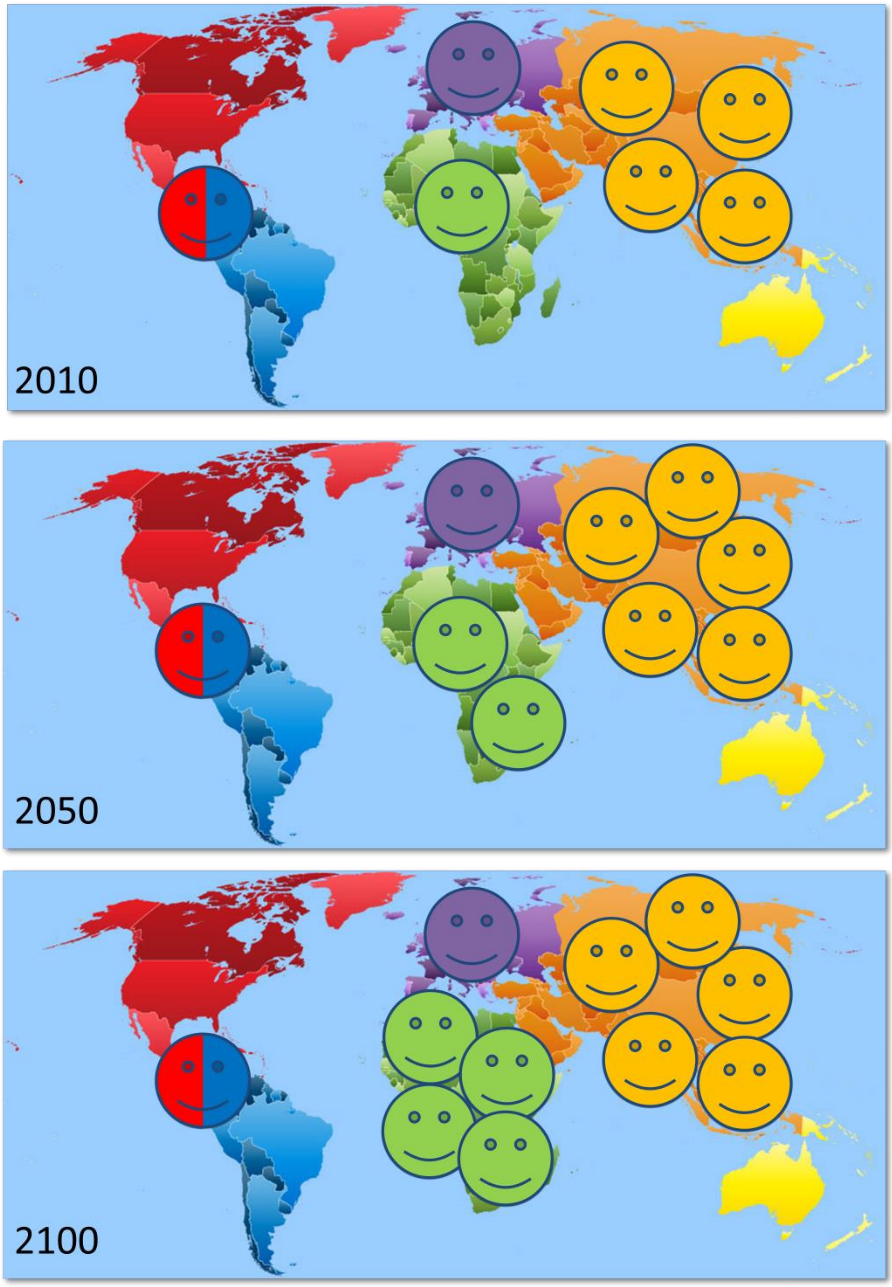

Figure 5. The world's population PIN code is currently 1114 (1 billion people in the Americas, 1 billion in Europe, 1 billion in Africa and 4 billion in Asia) and will change from 1125 in 2050 to 1145 in 2100 (based on Hans Rosling).

Producing meat, milk, sugar, oils, and vegetables typically requires more water than producing cereals—and a different style of water management. Increasing livestock production requires even more grain for feed, leading to a 25% increase in grain requirements. Thus, diets are a significant factor in determining water demands. While feed-based meat production may be water costly, grazing systems behave quite differently. Overall, this combination of more people,

increased food consumption and changing diets will put enormous pressure on future water demands.
[UN, 2013] [http://www.economist.com/blogs/graphicdetail/2013/06/daily-chart-10] [Molden, 2007]

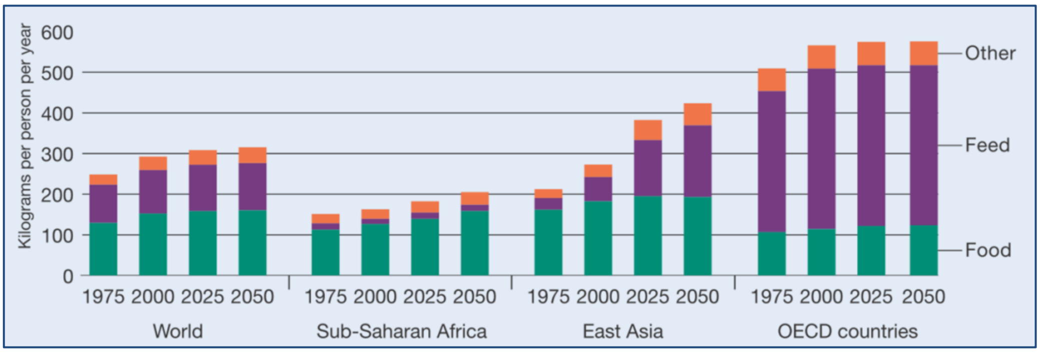

Figure 6. Future demands for grains per capita are driven by expected feed demands for animals. [Source: Molden et al., 2007]

2.2 Climate change driver

There is no doubt that one of the most pressing environmental challenges we face is climate change. The World Bank states that "Climate change is a fundamental threat to sustainable economic development and the fight against poverty" and "…that without bold action now, the warming planet threatens to put prosperity out of reach for millions and roll back decades of development". The fact that climate change is happening already and can be attributed to human use of fossil fuel is hardly disputed in the science community. Evidence based on observations of climate records over the last hundred years and progressing understanding of how climate works has led to the conclusion by the United Nations Intergovernmental Panel on Climate Change (IPCC) that "it is very likely that most of the observed increase in global average temperatures is due to increase in anthropogenic greenhouse gasses concentrations". Exemplary to this is that our atmosphere crossed an important - and potentially dangerous - milestone: the global concentration of carbon dioxide in the atmosphere – the primary driver of recent climate change – has reached 400 parts per million for the first time in recorded history.

Climate change projections from over 20 institutions world-wide as combined in the 2013 IPCC Assessment Report are based on four future scenarios. These four scenarios, referred to as RCPs (Representative Concentration Pathways), are RCP8.5, RCP6, RCP4.5, and RCP2.6 and correspond to concentrations of CO_2 equivalents of 1370, 850, 650, and 490 ppm by the end of this century. This range of pathways reflects the uncertainty in how the world will develop over the coming decades, which is mainly governed by global issues regarding the economy, energy policies and population development.

Under the so-called "Copenhagen Agreement" in 2009, the scientific view was recognized that in order to prevent dangerous anthropogenic interference with the climate system the increase in global temperature should be below 2 degrees Celsius. These two degrees are heavily discussed as on the one hand it is believed that this target is unrealistic while on the other hand it is believed that we have to do so otherwise the social and economic consequences will be enormous. A recent scientific report of the World Bank claims that if we fail doing so a cascade of cataclysmic changes that include extreme heat-waves, declining global food stocks and a sea-level rise affecting hundreds of millions of people will be triggered.

The linkages between water, food and energy are prominent in climate change discussions. Water availability and also water requirements will be altered by climate change. Shifts in precipitation are projected, and already observed, where the general trends are that dry regions will experience even drier conditions and wet regions will receive more rains. Moreover, seasonality changes show the same trends: dry season will be drier and wet seasons wetter. Water demand will increase given that crops require more water under higher temperatures. This phenomenon is also valid for natural vegetation with consequences that reductions in runoff up to 20% can be expected. These impacts on water will affect our food production including shifts in growing seasons, crops and regional shifts.
[IPCC, 2007] [http://www.worldbank.org/en/topic/climatechange/overview] [http://climate.nasa.gov/400ppmquotes/] [World Bank, 2012] [Knutti and Sedláček, 2013] [http://www.theclimatechangeclearinghouse.org/HydrologicEffects/EvapAndTrans/default.aspx]

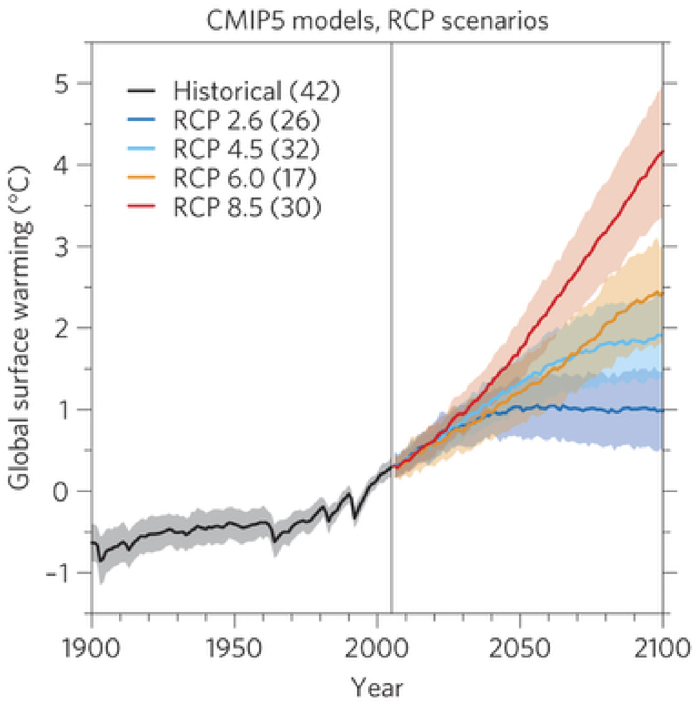

Figure 7. The world is heating althiough uncertainty to what extent remains. [Knutti and Sedláček, 2013]

BOX: Intergovernmental Panel on Climate Change

The Intergovernmental Panel on Climate Change (IPCC) is the leading international body for the assessment of climate change. It was established by the United Nations Environment Program and the World Meteorological Organization in 1988 to provide the world with a clear scientific view on the current state of knowledge in climate change and its potential environmental and socio-economic impacts.

The IPCC is an intergovernmental scientific body which reviews and assesses the most recent scientific, technical and socio-economic information produced worldwide relevant to the understanding of climate change. It does not conduct any research nor does it monitor climate related data or parameters. Its main task is to accept, adopt and approve reports.

Because of its scientific and intergovernmental nature, the IPCC embodies a unique opportunity to provide rigorous and balanced scientific information to decision makers. By endorsing the IPCC reports, governments acknowledge the authority of their scientific content. The work of the organization is therefore policy-relevant and yet policy-neutral, never policy-prescriptive.

BOX: Water Footprint

The water footprint is an indicator of freshwater use that looks not only at direct water use of a consumer or producer, but also at the indirect water use. The water footprint can be regarded as a comprehensive indicator of freshwater resources appropriation, next to the traditional and restricted measure of water withdrawal. The water footprint of a product is the volume of freshwater used to produce the product, measured over the full supply chain. Sometimes the term “virtual water” is used as well to emphasise that in almost every product water is required to produce this product, whether it is a hamburger, coffee, car, clothing, or a computer.

The total amount of water required to produce our daily food is in the order of 3500 liter per person per day in the developed world. Calculations have revealed for example that producing one hamburger takes 3850 liters of water, one cup of coffee 130 liters and 1 kg of rice 2500 liters. Obviously, if water is not a limiting factor in the place where the product is grown, it is not very relevant in terms of water security. However, if products are grown in water scarce regions and transported to other regions, one can speak about “virtual water trade”.

Virtual water trade refers to the idea that when goods and services are exchanged, so is the water required to produce this. When a country imports one tonne of wheat instead of producing it domestically, it is saving about 1,300 cubic meters of real indigenous water. If this country is water-scarce, the water that is 'saved' can be used towards other ends. If the exporting country is water-scarce, however, it has exported 1,300 cubic meters of virtual water since the real water used to grow the wheat will no longer be available for other purposes. This has obvious strategic implications for countries that are water-constrained such as those found in the Southern African countries. [Hoekstra 2011] [Turton, 2000].

The costs if appropriate actions to overcome the looming water crisis are not taken are tremendous. These costs will not be limited to the water sector only, but the nexus with food and energy will aversively impact the global economy. Since this is becoming more evident the positive sight is that we realize that if we fail to act the social and economic consequences will be enormous.

3.1 Too much and too little

Farmers in Cambodia are every year confronted with floods as well as droughts. Between July and October their lands are completely flooded, while from January to June they have to irrigate their crops. This seasonality aspect of “too much and too little” occurs also in a spatial context. Some regions are never water short, while other regions are in a constant struggle to fulfil their water needs.

One of the most vital needs to people is access to safe drinking water and basic sanitation. Under the Millennium Development Goals it was agreed to achieve to halve the proportion of people without sustainable access to safe drinking water and basic sanitation, by 2015. Currently, this has been achieved already since the percentage of people without access reduced from 24% to 11% in 2011. Despite this unprecedented progress, 768 million peoples still drew water from an unimproved source nowadays.

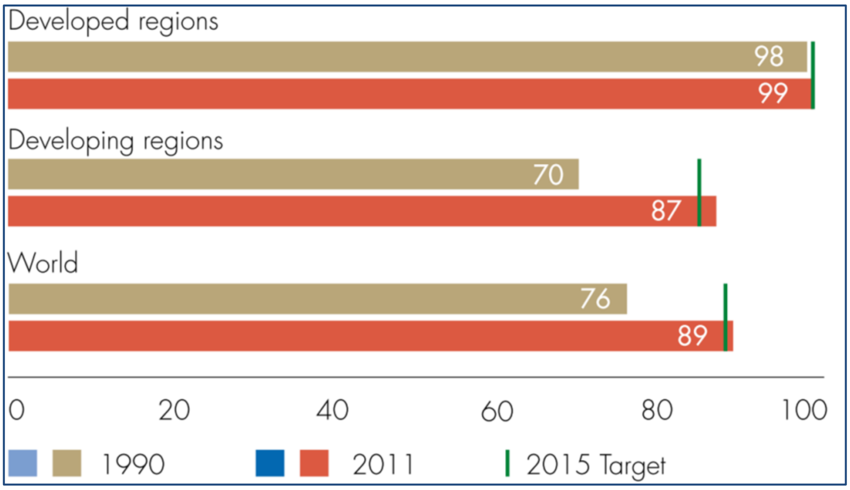

Figure 8. More than 2.1 billion people have gained access to improved drinking water sources since 1990, exceeding the MDG target. [Source: UN, 2013]

On the other hand are many people confronted by too much water resulting in uncontrolled flooding. Asia and most noticeable countries like China, India, and Bangladesh are known for their returning floods events. Especially in China almost every year millions of people are affected by floods. The 2010 Pakistan flood event had a huge impact and over 20% of the country was underwater affecting over 20 million people and destroying crops and infrastructure. The New York floods in 2012, caused by super-storm Sandy, had a devastating impact on people in the city. More than 350,000 citizens had to be evacuated and the estimated costs were between US$ 10 and 20 billion.

The unpredictability of these water shortages and flooding makes it very difficult to deal with. The Cambodian farmer’s living pattern is completely adjusted to the system of annual flooding, while the devastating floods in Pakistan and New York came as a complete surprise.
[Fox and Ledgerwood, 1999] [http://www.preventionweb.net/english/hazards/statistics/?hid=62] [NOAA, 2012]

Table 1. China has the highest number of people affected by floods. [EM-DAT, 2013]

Disaster	Date	Affected (no. of people)
China P Rep	1998	238,973,000
China P Rep	1991	210,232,227
China P Rep	1996	154,634,000
China P Rep	2003	150,146,000
India	1993	128,000,000
China P Rep	1995	114,470,249
China P Rep	2007	105,004,000
China P Rep	1999	101,024,000
China P Rep	1989	100,010,000
China P Rep	2002	80,035,257

3.2 Economic costs

The price people have to pay for their drinking water is in many cases negatively correlated to their income. People living in informal settlements often pay 5-10 times more per liter of water than wealthy people living in the same city. Even if people are connected to the public network there are often limitations to the services provided by utility companies, such as rationing of certain areas, low water pressure, periodic shortages, or leaks in the network, that alternative water access should be used. The alternative sources of water are typically provided by the private sector and includes water tankers, water carts, kiosks, bottled water, community taps and standpipes. These alternatives tend to be much higher priced than utility services and cost a substantial part of income of the poor.

On the contrary, it is claimed that investments in the water sector are often very profitable with high returns in investments. The UNDP has found that on average, every US dollar invested in water and sanitation provides an economic return of eight US dollars. A more detailed study by the World Health Organization (WHO) found that investment in safe drinking water and sanitation contributes to economic growth and that for each $1 invested, the estimates returns are in the range of $3 - $34, depending on the region and technology. Other assessments claim that if everyone had access to adequate sanitation and water services, the world's health sectors would save around $12 billion every year.
[UNDP, 2006] [UN-DESA, 2007] [UNDP, 2006][WSP, 2000] [WSSCC, 2011] [Prüss-Üstün A, Bos R, Gore F, Bartram J. 2008.]

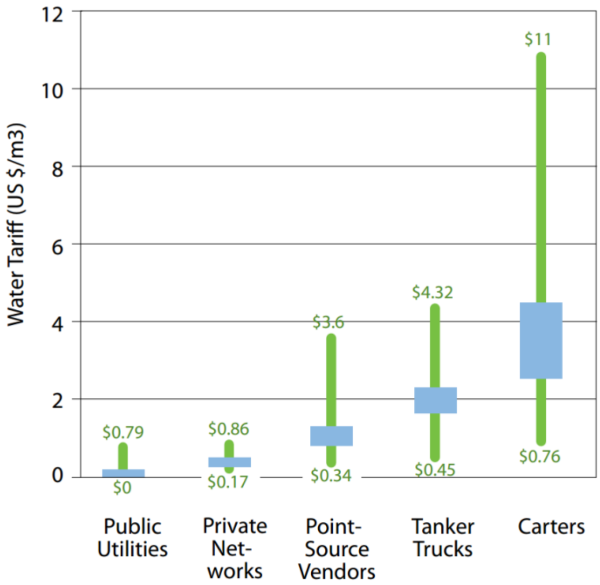

Figure 9. Alternative sources of drinking water, often the only option for millions of people in the developing world, is much higher than the price of water provided by utilities. [Source: Kariuki and Schwartz, 2005]

BOX: Reservoir operations: irrigation or energy driven

Reservoirs are typically built to retain water for periods when this is needed, to prevent flooding by reducing peak flows runoff or to generate hydropower. Most reservoirs are tailored towards one of these functions, where the other two are often seen as an associated benefit. By changing managerial rules, these functions can shift. A typical example of such a shift are the reservoirs in the Aral Sea Basin in Central Asia.

The original idea in Soviet times was to operate the hydro-infrastructure in irrigation mode. The water resources of the two main rivers (Syr Darya and Amu Darya) were managed with the aim to maximize crop production. Part of the hydropower produced during irrigation water-releases in spring and summer was conveniently utilized in the downstream for driving lift irrigation and vertical drainage pumps along the 30,000 kilometers of irrigation channels. In return, the upstream areas received energy supplies in the form of gas and coal to cover winter energy demands.

This basin-wide management approach during the Soviet times has become an uncoordinated management situation with conflicting interests for the upstream countries (Kyrgyzstan, Tajikistan and Afghanistan) and the downstream countries (Uzbekistan, Turkmenistan and Kazakhstan). The hydraulic infrastructure is distributed over various independent countries and a mixture of regional, national, and interstate institutions now handles allocation decisions, which used to be centrally administered during Soviet times. As a result, water and energy allocation among the various sectors and users is not efficient. Future water resources development in northern Afghanistan will further add fuel to the water and energy conflict in the region.

In short, the upstream-downstream conflict consists of opposed demand patterns for energy and water resources, in space and in time. Kyrgyzstan and Tajikistan need to release water from a number of large reservoirs during the cold months to generate hydropower for heating. There, hydropower provides the cheapest source of energy with generating costs as low as 0.1 cent/kWh. The winter releases frequently cause flooding in the downstream areas. At the same time and in order to have enough hydropower generating capacity during the cold months, these upstream states spend the warmer summer months saving water in those reservoirs. That is precisely when the downstream countries have the most pressing need for irrigation water where the degradation of agricultural soils and insufficient flows for ecosystems are issues of growing concern. In the region, cotton is an important cash crop, and, at the same time, wheat is considered essential in order to meet national food security goals. Especially for Uzbekistan, considerations of self-sufficiency have become more important in recent times where food grain prices have increased considerably on the world market.

[Lutz, A.F., P. Droogers, W.W. Immerzeel. 2012]

4 The need for actions

The competition for scarce water resources is intense and on the rise. Many rivers do not have enough water to meet all the demands or even enough to reach the sea. The need to take actions is urgent and decisions on allocations and options to improve productivity of water should be taken to ensure that people, economy and environment will not be further negatively affected.

4.1 Water for food

Greater competition raises questions like who will get the water and how will allocations be decided? Conflicts can grow between farms and cities, between those upstream and those downstream, between food and nature. Agriculture is central in meeting these challenges as the production of food and other agricultural products takes 70% of the freshwater withdrawals from rivers and groundwater. Obviously, it is not only irrigated agriculture that consumes (evaporates) water, but also rainfed agriculture consumes water that is not available for other use. Globally, 55% of the gross value of our food is produced under rainfed conditions on nearly 72% of the world's harvested cropland. However, global average rainfed cereal yield is about 2.2 metric tons per hectare, which is about 65 percent of the irrigated yield of 3.5 metric tons per hectare.

The so-called yield-gap between actual yields and the obtainable yields can be closed by better water, soil and land management practices. At the global level the potential of rainfed agriculture is claimed to be large enough to meet present and future food demand through increased productivity. Assuming an optimistic scenario with significant progress in upgrading rainfed systems by reaching 80% of the maximum obtainable yield combined with another 7% increase in crop area would be sufficient to feed the world in 2050. However, if such rainfed yield improvements are not met, the expansion in rainfed cropped area required to meet rising food demand would be around 50% by 2050. Globally, the land for this is available, but agriculture would then encroach on marginally suitable lands and add to environmental degradation, with more natural ecosystems converted to agriculture.

Expanding the irrigated lands would be an alternative strategy to provide a more secure food future. However, such an expansion would require more withdrawals of water for agriculture, assuming this is available. In Sub-Saharan Africa there is very little irrigation, and expansion seems warranted. Doubling the irrigated area in Sub-Saharan Africa would increase irrigation's contribution to food supply from only 5% now to an optimistic 11% by 2050.

Key in the entire water-food actions is not only looking at maximizing production in terms of kg per hectare, but chance focus on so-called water productivity: the amount of food that be produced by one cubic meter of water. The key principles for improving water productivity at field, farm and basin level, which apply regardless of whether the crop is grown under rainfed or irrigated conditions, are: (i) increase the marketable yield of the crop for each unit of water transpired by it; (ii) reduce all outflows (e.g. drainage, seepage and percolation), including evaporative outflows other than the crop stomatal transpiration; and (iii) increase the effective use of rainfall, stored water, and water of marginal quality.
[Molden, 2007] [Rosegrant, 2002][FAO, 2003]

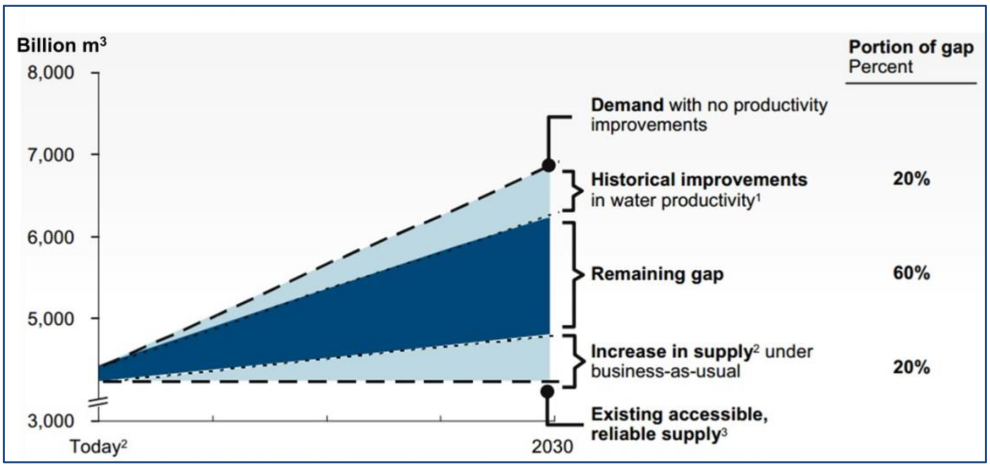

Figure 10. Business-as-usual approaches will not meet demand for water in the future. [Source: Water Resources Group: Charting our water future (2009)]

4.2 Drinking and sanitation

"Access to sanitation is deeply connected to virtually all the Millennium Development Goals, in particular those involving the environment, education, gender equality and the reduction of child mortality and poverty" said UN Secretary General Ban Ki-moon. In 2012 the Millennium Development Goal (MDG) target of halving the proportion of people without sustainable access to safe drinking water has been met, even well in advance of the MDG 2015 deadline. Between 1990 and 2010, over two billion people gained access to improved drinking water sources, such as piped supplies and protected wells. However, at least 11% of the world's population – 783 million people – are still without access to safe drinking water.

The MDG target for sanitation is still far from realized and is unlikely to do so by 2015. Only 63% of the world now have improved sanitation access, a figure projected to increase only to 67% by 2015, well below the 75% aim in the MDGs. Currently 2.5 billion people still lack improved sanitation causing 3.5 million deaths every year. Better health and hygiene education combined with large scale investments in improved toilets are highly needed but at the same time expensive and complex to implement and maintain at large scales.
[WHO-UNICEF, 2012] [http://practicalaction.org/]

4.3 Water and security

Water as a threat to security starts at a very local level. As water becomes scarcer at community water points, women and children who gather the water may find themselves at the forefront of conflicts as they compete against each other for access to scarce water resources. Such conflicts can easily emerge into larger conflicts between various tribes and countries. On the other end of the spectrum can large scale water planning issues be the start of serious tensions and even armed conflicts between countries.

Competition and disputes over water and watersheds exist in many places around the world. The causes and nature of these disputes vary widely; from small-scale clashes over pasture and water, to urban protests over changes in water pricing schemes, to sub-regional disputes between provinces over water for agriculture or hydropower, to upstream/downstream countries competing for a share of an increasingly limited water supply.

An important aspect of building consensus on water related issues can be self-interest of developed countries. A typical example is that the US fears that water problems will contribute to instability in countries important to U.S. security interests. Water security is therefore an increasingly important component of the U.S. Government's diplomatic and development efforts to promote peace and security within and between key countries and around trans-boundary river basins. Growing demands on limited fresh water, degradation of fresh water quality, and greater variability in rainfall patterns are potential drivers of tension fears the US.
[ICA, 2012]

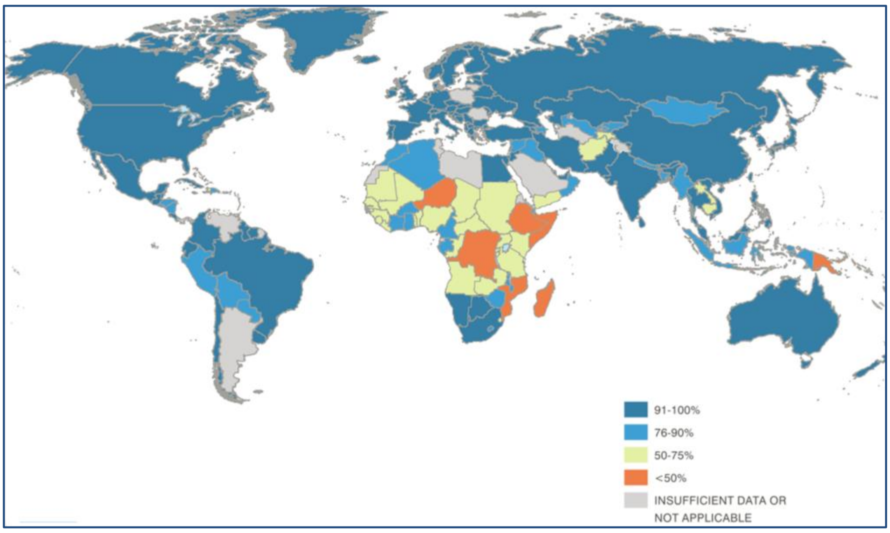

Figure 11. Sub-Saharan Africa has the lowest drinking water coverage of any region. [Source: WHO-UNICEF, 2012]

4.4 Climate change

It is clear that the need to adapt to climate change is felt by many. International efforts to limit greenhouse gas emissions will not be sufficient and fast enough to prevent the harmful effects of changes in precipitation, increase in temperatures and increased frequency and severity of extreme weather events. On the other hand can climate change also create opportunities, particularly in the agricultural sector. Increased temperatures can lengthen growing seasons, and higher carbon dioxide concentrations can enhance plant growth. However, these positive opportunities will not be sufficient to compensate for the negative effects of climate change as a whole.

The risks of climate change cannot be effectively dealt with, and the opportunities cannot be effectively exploited, without a clear plan for aligning policies with climate change. Developing such planning involves a combination of high-quality quantitative analysis and consultation of key stakeholders. It has been well accepted that the most effective plans for adapting to climate change will involve both human capital and physical capital enhancements. Moreover, it is well-accepted that the capacity to adapt to changes in climate is in part dependent on financial resources, so the donor community will continue to be a key stakeholder in developing climate change policies and implementation measures

Unfortunately, there is no silver-bullet approach that can be used as the ultimate adaptation strategy. Two different types of actions are essential to tackle the climate change challenge. First of all, climate change should be integrated in existing development planning, which is sometimes referred to as "streamlining" or using a "climate lens" in existing development planning. Secondly, separate adaptation planning and implementation is required to overcome the negative impacts of climate change.

It has been advocated that this adaptation planning and implementation has various dimensions. An important dimension is that some adaptation will take place autonomous and other adaptation requires actual planning. A typical example of autonomous adaptation is farmers changing their planting date of crops as response to temperature shifts. An example of actual planning is that irrigation water should be delivered earlier and proper irrigation water requirement monitoring systems should be in place. A second dimension of adaptation is the timing of response, being the short run or the long run. The long run adaptation includes issues like building capacity, changing institutions, and large infrastructural development, amongst others. Typical examples relevant to short run adaptation are related to water allocation and reservoir operations. Finally the third dimension to consider in adaptation is the institutional scale: farm, community, national, and regional. Each of these scales has their specific needs and opportunities.
[Ibatullin et al. 2009].

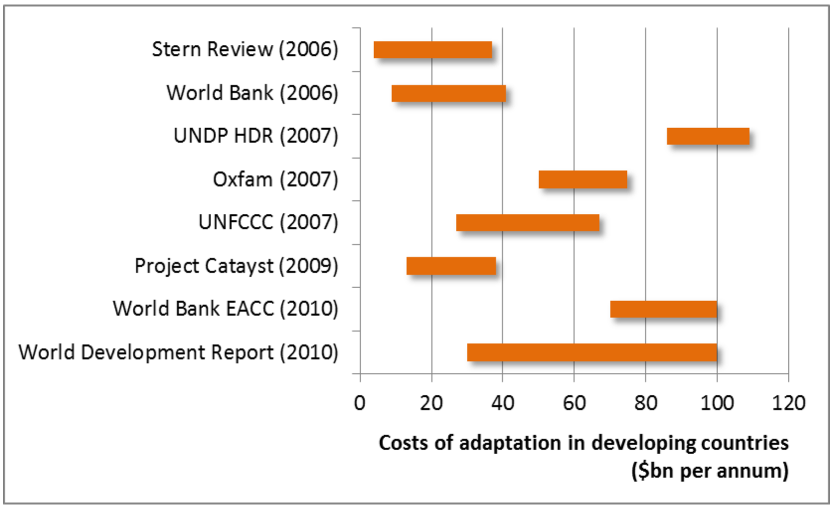

Figure 12. Estimates of the incremental costs of adaptation in developing countries. [Source: Climate Funds Update, 2013]

5 Government's role

Water management and policies was for a long time the domain of the public sector. Governmental ministries used to formulate water policies unilaterally, without serious consultation with stakeholders. The private sector and non-governmental institutions had virtually no discernible role to play. In the last few decades the central institutions have steadily lost power, resources, authority and reputation and this decentralization process has often meant that states or provinces have become increasingly powerful. Moreover, the private sector and NGOs are increasingly becoming an important player in numerous water-related activities. The governmental role in water policies should be therefore reformulated as its role is still very much needed for setting polices that guarantee sustainable and fair use of our water resources.

5.1 Water policies

Water resource policy is typically determined at national or even supra national levels. The actual water resource management tends to be carried out in smaller political, spatial, and geographical domains. Much of modern policy formulation is based on defined uses of water where the range of uses include provision of drinking water, irrigation, industrial needs and the needs of the environment to maintain sustainable natural eco-systems.

Global polices are the highest level and these global policies recognize the centrality of water to socio-economic development. Three dominant processes play an important role to establish global water policies: the MDGs, the UNFCCC and the UNCSD (also referred to commonly as Rio+20). It should be noted, however, that other international forums such as the G8/G20, the World Economic Forum and the World Water Forum can also play an influential role in the recognition of water's central role in socio-economic development. Although these global policies can have a significant influence on national policy, their agendas and negotiations are in fact driven by the member states. It is therefore up to the different member states themselves to take leadership and ensure that water is put on the agenda of these processes.

National and sub-national water policies are as diverse as the number of countries on earth. Policies and actual water management are not always strictly diverted. Also the wide-range of responsibilities, such as urban supply, water quality, flood control, water treatment, sanitation, are country specific organized. One of the main complicating issues is that administrative borders are in most cases different from hydrological borders.

Public-sector and nongovernmental organizations (NGOs) have long dominated the debate on water policy, but within the last five years, a growing number of progressive private-sector companies have also started to lend their perspectives on how best to effectively manage water. These companies have begun by paying much more attention to the water environment in which they function. As they develop a new generation of water-related technologies, they also increasingly influence a new generation of public policies that stimulate the development and use of these technologies.

These evolving private sector 'institutions' for water management and policies presents a potential water management opportunity and a serious water risk. Governments contemplating private sector engagement in water management should be wary of accepting conventional for-profit company forms, especially in contexts of increasing pressure on water resources where allocation trade-offs are likely to be common. The potential of prioritisation of stakeholders makes them inappropriate corporate vehicles for locally-inclusive water investments, the risk

being that they occupy local water rights more than they create local development benefits. Governments should take advantage of the interest of the private sector and should simultaneously set the legal framework to ensure a fair and sustainable use.
[Briscoe, 2009] [Newborne, 2012] [Evian, 2003).

5.2 Governmental actions

During the last century water policies and management was traditionally focussed on infrastructural options. Currently, water policies and management have seen a shift towards soft infrastructure, most notably associated with the management of trade-offs, and increasingly dependent on institutions, policy, legislation and dialogue between competing users. The broad concept of Integrated Water Resources Management (IWRM) has been introduced and is being advocated over the last decades. In the early phases of IWRM the feeling prevailed that by integrating the more classical technical approaches with socio-economic aspects, overall water management could be improved. More recently, IWRM has been expanded by integrating all water resources and not only water in streams and reservoirs as was still the base for IWRM. This extended approach of IWRM is now advocated and is often referred to as “blue and green” water, making the distinction between free water in streams and reservoirs and water available in soils to be used by the vegetation or crop, respectively. This expansion was necessary as many policy makers still limit water issues primarily to drinking, sanitation, industrial and irrigation use.

Sustainable water policies under conditions of inherent uncertainty require a paradigm shift. Key factors include the need for an increasing range of input data and the capacity to adapt to growing pressure on the resource. This will require deliberate efforts to build robustness and resilience into the management structures of water projects as a matter of routine. Such fundamental changes are likely to occur in the non-structural elements of water management measures. It is believed that it is vital to develop new ways to provide specialized information to decision-makers in government, as well as to those affected by the decisions they take. This requires a formal structuring of relationships between technical specialists, government decision-makers and society as a whole.

The range of potential actions governments can take is large and very local dependent. Institutional reform and institutional strengthening are issues advocated by many as the solution to many water related problems. Institutional changes within water management occur due to endogenous factors (water scarcity, performance deterioration and financial non-viability) as well as exogenous factors (macro-economic crisis, political reform, natural calamities and technological progress). Related to this are actions governments can take or promote such as water pricing, water markets, and assurance schemes. At the same time, small scale and large scale infrastructure measures will always be required to ensure water at the right location, time and quality and quantity.
[WWDR,2012] [Tortajada, 2010][Falkenmark, 2007]

BOX: Water markets

The Murray-Darling river basin in the Australian South-East is the main water supply for one of the most significant agricultural regions in Australia. After a long time of increasing water stress a major intervention through the government was put in place in 2000: a cap on the aggregate diversion of water. The cap has effectively stopped the upward trend of water extraction and was a major step in protecting the integrity of the water system for the future and the ecosystems that depend on it.

Already before the cap was introduced a system for water trading was in place, which allows the trading of water rights on a temporary (e.g. for one year) or permanent basis. Being able to trade water rights makes it possible that water rights are going from producers of low value goods and services to producers of high value goods and services, as the latter will be able to pay a higher price. Additionally, it will give incentive to conserve water and use it efficiently. Through the cap the state can influence the total allowance of water rights, making it possible to reduce water use in time of droughts and increasing it in time of water abundance. In times of droughts the reduction in water entitlements will drive up the price, which makes sure that water is being used by those who need it the most.

In 2012 the Basin Plan for the Murray-Darling river basin was signed into law. Among other things it reduces the amount of water entitlements corresponding to 3200 GL/year. Through this measure more water will be available to support the environmental functioning of the river ecosystem and is the first step to make the Murray-Darling river basin management sustainable. [Quiggin 2001; mdba.gov.au]

BOX: Inter-basin water transfer

Inter-basin transfer conveyance schemes are aimed to transfer water from one river basin where it is available, to another basin where water is less available. There are dozens of large inter-basin transfers around the world, most of them concentrated in Australia, Canada, China, India and the United States. The primary purpose usually is either to alleviate water scarcity or to generate hydropower or a combination.

Recent projections show that all reservoirs along the Colorado River—which provide water for 27 million people—could dry up by 2057 because of climate change and overuse. More recently, drought and low Lake Mead water levels have resulted in a multi-billion dollar plan to build a 285-mile pipeline to pump groundwater to the Las Vegas area from as far away as Snake Valley, which straddles the Nevada-Utah state line. [ICA, 2012]

Water shortages in China have become a major threat to development. The second largest economy has 20% of the world's population but only an estimated 7% of its freshwater water reserves. Within the country fresh water is also unequally available with the south of the country having 77% of China's total water resources. China's South-North Water Diversion Project, initially a vision of Mao, will take water from the south of the country to the arid northern region, including the capital Beijing, which suffers from water shortages. The ambitious project has been under construction since 2002 and it is expected to take almost 50 years for all sections to be complete. It aims to pump almost 45 billion cubic metres of water a year to the north, equivalent to the water flow in the Yellow River in northern China. The water will be pumped from the Yangtze. The eastern route will start operation in 2013. It is also planned that there will be a middle route and a western route. The middle route is expected to begin operating in 2014, while the western route is still at planning stages.

These kind of inter-basin transfer projects are frequently criticised by environmentalist and human-rights activists. Water quality, water shortages in the source, displacement of people and irreversible damage to entire ecosystems are projected.

BOX: Policies and accurate information

The 1922 Colorado River Agreement in the USA was meant to have an equal distribution of water amongst all riparian States. However, although most of the Colorado River originates in the basin’s upper states (i.e., Colorado, Utah, Wyoming), the 1922 agreement resulted in a water allocation almost exclusively to the lower states (i.e., California, Arizona, Nevada, and New Mexico). The reason was that the agreement was based on data from the unseasonably wet five years prior to 1922, estimating the average flow to be 17.5 million acre-feet (maf). The actual average flow over the last 100 years has been nowhere near this number and is only 13 maf.

6 Asking the right questions

The way forward is anything but easy. One reason is that our mind sets have to change; another reason is that it takes time establishing a new playing field, yet another reason is that the challenges linked with water, food and energy security differ from region to region. One starting point is the many success stories that do exist, the many agents of change around the globe. This we mentioned in the beginning of this publication. Another starting point is our ability asking the right questions. If we can do that, we are already well on the way towards a widening of the water agenda.

6.1 Lots of questions, no answers (yet)

Instead of presenting conclusions a list of questions is provided as it is believed that discussions and further studies among all people, institutions and companies concerned is required for this water-food-energy nexus.

The questions are:

- How do we ensure that conferences, seminar and workshops are being held with the participation of water specialists, agronomists and energy experts?
- How do we promote consensus building between sectors and countries with regard to water allocation, acknowledging the fact that interests differ (and should differ)?
- How do we attract the private sector to discussions on governance, research and business development capable of addressing various aspects of water, food and energy security?
- How do we ensure policy integration at the national level so that different ministries with different mandates actually work together on the many water challenges?
- Which analyses, tools and decision support systems may increase our understanding of water, food and energy security – and how do we support these?
- How do we facilitate knowledge sharing between sectors, countries and regions of the world?
- What knowledge is missing and how to overcome this knowledge gap?
- …

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