Helpdesk Report:

The Supply of Water Services to Scale

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Report summary

This report presents a review of the qualitative data on the potential economic benefits and costs of investments in the delivery of water services at scale in developing countries. The range of mechanisms with which water is conserved and managed is considered, for example: water and sanitation for households; wastewater collection; water for irrigation; and catchment management. A brief analysis of the cost-effectiveness of each mechanism is provided, with evidence provided from a range of sources for further reference. A key section of the report explores issues around delivering water services at scale, including the advantages, or not, of scaling up, and presentation of potential business models. The final section presents evidence for the potential economic benefits and costs of research into increasing the sustainability of water system services, including looking at important policy research issues such as climate change, and industry and commerce, and the role of research in water resource management.

Part 1: Review of quantitative data on potential economic benefits and costs of investments in delivery of water services at scale in developing countries

Preamble

The main organising principle in this review is the services provided by the different components of the *water cycle*.

The water cycle can be regarded as a system of services created by the natural flux of water from precipitation to entry into the sea. Some of these water services are of direct human benefit (such as water for households and farmers). Others benefit humankind indirectly through maintaining the natural environment and ecosystems vital to life.

Since the water cycle is a coherent system, its different parts, and the services they provide, have to be considered holistically. If parts of it are neglected (catchments allowed to degrade), abused (pollution) or used unsustainably (over-abstraction), other parts will suffer through shortages, higher costs, or damage to health and life. In a well-managed water system inter-relationships are recognised, and complementarities promoted.

In a water system where a high proportion of renewable flows is already accounted for in different uses, one party's discharge becomes another's intake, a change in consumptive use at one point can be at the expense of availability elsewhere, and the pursuit of water security by one community or nation may be at the expense of another's.

That said, the first part of this report discusses catchment protection, water for ecosystem services and aquatic habitats, water supply and sanitation for households, wastewater collection, treatment, reuse and disposal, and water for irrigation and other productive uses. A final section deals with the costs and benefits of supplying these water services at scale.

Catchment management

Catchment protection is an aspect of the broader topic of Water Resources Management. There is growing evidence that water management at source can save much costlier work downstream, as well as having benefits *in situ.* The following are examples of catchment protection and management funded by downstream parties that benefit from such works. This may be regarded as a case of *victim pays* but could equally be regarded as a *win-win* scenario. Catchment protection necessarily works at scale, when all, or a majority, of land users take part, otherwise the scheme is vitiated.

- In **Costa Rica** and **Ecuador** there are several cases of catchment protection funded by the local hydropower company as a means of safeguarding the integrity of its reservoirs and of water flows into them.
- In **France** the bottled water producer Vittel compensates farmers in the vicinity of its springs for conversion to organic methods, to safeguard the quality of its aquifers.

- In a growing number of cases of **Payments for Ecological Services** (PES) local land users are rewarded for their stewardship of land, forests, wetlands and other vital habitats. Many of these schemes are funded by international donors and NGOs. [1]

- In a well-publicised case in **New York State**, a programme for watershed protection, including the encouragement of farmers in the upper catchment area to convert to more environmentally-friendly cultivation practices, is expected to save $4.5 to $6.5 billions of dollars (in present values) compared with the cost of a new downstream water filtration plant for New York City's population (OECD, 2011, p. 83). Data from other US cities (Portland Oregon, Portland Maine and Seattle) also confirm the extremely high financial savings from watershed protection, compared with the cost of building new water treatment and filtration systems (Emerton & Bos, 2004).

Conclusions

Promoting catchment protection and management services amongst upper-catchment land and forest users can be a highly cost-effective means of safeguarding water supplies, as well as generating other local economic and environmental benefits. These services are potentially capable of being supplied by a variety of stakeholders.

Protection of ecosystems & aquatic habitats

An important part of water "infrastructure" consists of natural systems such as forests, catchments and wetlands that store water, regulate its flow and help to preserve its quality. If these natural systems are destroyed or compromised, their functions have to be replaced by man-made facilities, often at high cost. Ensuring that sufficient water, of suitable quality, is available to furnish ecosystems and aquatic habitats will help to ensure that they continue to provide their vital services.

Preserving ecosystems, like the creation of man-made infrastructure, comes with a cost. This is often an *opportunity cost,* measured by the sacrifice of their use for something else, such as timber, agriculture or property development. Restoring degraded ecosystems to their previous state also involves both capital and recurrent costs. In both cases, keeping ecosystems functioning entails investment, but this can bring tangible economic benefits (Box 1).

Box 1. Economic benefits of ecosystems as water "infrastructure"

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 enters 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 $2 million per year.

[1] Described at length in the FAO's 2007 *State of Food and Agriculture: paying farmers for environmental services.*

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 $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, 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 $34 million for the local economy, equivalent to $500/ha.

The creation of the **Mantadia National Park in Eastern Madagascar** and its buffer zone has reduced deforestation, and mitigated the resulting flooding, to the benefit of downstream rice farmers. The net present value of this protection in terms of avoided losses of production is estimated to be $126,000.

Emerton & Bos, 2004 Value: counting ecosystems as water infrastructure. IUCN, Gland

The **Mount Kenya Forest** (Box 2) provides watershed protection vital to downstream water users in Kenya. Preserving these services means enlisting the support of all local stakeholders. It is important to consider how local costs and benefits of conservation arise, and to ensure that potential "losers" are adequately compensated. In this case, although total benefits and costs (mainly opportunity costs) are roughly balanced, their distribution is very different. Specifically, *local* benefits are heavily outweighed by the *local* opportunity costs. Hence the onus is on *international and national* beneficiaries from forest preservation to devise financial systems to compensate and motivate all parties involved. In this study, estimated total economic benefits outweigh conservation costs (including opportunity costs) before mitigation credits are considered, hence the latter effectively have a zero cost.

Box 2 Kenya. Mount Kenya Forests – the Economics of Community Conservation

The annual economic benefit of maintaining land under forest cover in the Mount Kenya Forest Reserve (including the avoided cost of forest degradation and loss) is estimated to be US$ 77 million, comprising watershed protection (71%), local domestic use by forest-adjacent households (17%), local cultivation under *shamba* arrangements (6%), licensed use of timber and non-timber forest products (3%), recreation and tourism (1%) and tea zone and other government revenues (2%). In these various ways the forest provides direct livelihood support averaging $300 p.a. to the 40,000 households living adjacently. Omitted from this analysis are un-quantified benefits from carbon sequestration, micro-climatic regulation, future option value, biodiversity, etc.

The direct opportunity cost of preserving the forest cover is, however, of a similar magnitude. The land could have a value of $72 million p.a. for settled agriculture, sufficient for c. 8,000 households. Although the majority of adjacent households would have clear benefits from keeping the forest under present arrangements, a sizeable minority – those inclined to clear the forest for agriculture – would lose. There are also losses to be considered from damage to crops from wild animals in the forest, estimated to amount to c.

$1 million p.a. Altogether, the local costs, mainly opportunity costs, from preserving the forest – amounting to $73mn p.a. - greatly exceed the purely *local* economic benefits of $18 mn.

Lucy Emerton, Mount Kenya: the economics of community conservation. Paper no 6 in "Community conservation research in Africa: principles and comparative practice." Institute for Development Policy and Management, University of Manchester, 1998

Climate change mitigation as an incidental benefit of watershed conservation

In 2001 the **Convention on Biological Diversity** estimated that the value of tropical forest ecosystems for "climate benefit" was typically in the range $360-$2200 per hectare.[2] Work done for the **Ethiopian Climate Resilient Green Economy** programme indicated that afforestation, reforestation and forest management would be likely to deliver c. 40 million tonnes of CO_2e by 2030 at a unit cost of c. $5/tonne (well below the reference value of $15/t.)[3]

Around 700,000 ha in the **Bale Mountain Eco-Region in Ethiopia** (including the Bale Mountains National Park) have been identified as suitable for a REDD project using three types of Sustainable Forest Management schemes. These are: forest areas managed by Community-Based Organisations with exclusive user rights, Joint Forest Management Schemes involving CBOs and the OFWE/EWCA[4], and forest areas under the full management of the latter bodies. The REDD[5] project in the Bale region is expected to generate c. 18 million tCO2 credit over a 20 year period from avoided deforestation and forest enhancement.[6]

Conclusions

Many areas protected for their biodiversity also play a key role in safeguarding water supplies. As in the previous case of catchment protection, projects to protect biodiverse natural assets can have a variety of benefits, and are often cost-effective means of water management, compared to downstream hardware and infrastructure. These projects can also be cost-effective means of trapping and reducing carbon emissions. However, in all cases empirical studies show the importance of considering the distribution of costs of such projects compared with their benefits.

Water supply and sanitation for households

There is a range of benefits to households from having a reliable source of clean, safe water in or near to where they live. They are less at risk from contracting water-borne disease. They spend less time collecting water. The provision of water in sufficient quantities aids personal and household hygiene and adds to personal amenity and comfort. Sanitation offers similar benefits, and in addition the provision of suitable on-site toilets in schools promotes girls' educational prospects.

[2] CBD *The value of forest ecosystems.* 2001, p. 120
[3] CRGE, pp 30 & 35
[4] Oromiya Forest and Wildlife Enterprise, and Ethiopian Wildlife Conservation Authority.
[5] Reducing Emissions from Deforestation and Forest Degradation
[6] Tsegaye Tadese, "The Bale Mountains REDD project: some early lessons." FAO 2010, p. 108

Water quality standards are defined by WHO guidelines. To achieve them, water treatment is necessary to remove suspended solids, bacteria, algae, viruses, fungi, minerals and chemical pollutants[7], either off-site or at point-of-use. Sanitation is defined by the JMP[8] as "the methods for the safe and sustainable management of human excreta, including the collection, storage, treatment and disposal of faeces and urine". There are a number of different ways of providing community-level access to water and sanitation, which reflect significant variations in the level of service. Access can be provided via a handpump or a reticulated network system. In the case of the latter, it may be done using a household connections (within the house or the yard) or through a public connection. Investments required can range from digging a well and maintaining it, to building water transport and distribution networks.

The JMP distinguishes between "improved" and "unimproved" sanitation solutions. An improved drinking-water source is protected from outside contamination, especially faecal matter. An improved sanitation source separates human excreta from human contact. It includes, for example, flush/pour-flush facilities to piped sewer system, septic tank or pit latrine, ventilated improved pit latrine, pit latrine with slab and composting toilets. All options which are "unimproved" will either not deliver the anticipated benefits, are costly, or are unsustainable (e.g. bottled water or water delivered by tanker).

Coverage

During the 1980s and 1990s, there was considerable investment in the provision of water supply and sanitation in developing countries. By 2000, however, a significant proportion of the world's population remained (and still remains) without access to improved water and sanitation. Recent reports[9] estimate that:

> 2.6 billion people (over one third of the world population), 72% of them living in Asia, do not use improved sanitation. However, there are considerable regional disparities, with only half of those in developing regions using improved sanitation.
>
> 87% of the world population and 84% of the people in developing regions use improved sources of drinking water. However, 884 million people, almost all of them in developing regions, do not use improved sources of drinking water. Sub-Saharan Africa accounts for over a third of this total.

There are very significant urban-rural disparities in the provision of both drinking water and sanitation. The rural population without access to an improved drinking water source is over five times greater than in urban areas, with disparities particularly striking in Sub-Saharan Africa. Similar disparities exist in regard to sanitation. Urban growth also presents a problem, as the increase in drinking water and sanitation facilities is scarcely keeping up with population growth and migration in urban areas[10].

The world is off track for the MDG target and, even with huge efforts, the proportion of people without access to basic sanitation will not be halved by 2015, leaving 2.7 billion people without access to basic sanitation by that date.

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[7] "Benefits of investing in water and sanitation: an OECD perspective" OCED 2011
[8] Joint Monitoring Programme of the WHO and UNICEF
[9] See e.g. "Progress on Sanitation and Drinking Water 2010" World Health Organisation Geneva, UNICEF
[10] Progress on Sanitation and Drinking Water 2010 Update. WHO and UNICEF

However, at the current rate of progress, the world is expected to exceed the MDG target of halving the proportion of the population without sustainable access to safe drinking water. Even so, 672 million people will still lack access to improved drinking-water sources in 2015. An exception is Sub-Saharan Africa, which will miss the target at current rates of progress.

Health benefits (private and public)

Two principal causes of premature mortality in developing countries are diarrhea and respiratory disease, particularly in children under 5[11]. Diarrhea is associated with the ingestion of pathogens in unsafe drinking water, in contaminated food or from unclean hands, and has a long term detrimental effect, mainly due to its impact on childhood malnutrition. Diarrheal diseases represent about 90% of the disease burden from poor sanitation and water supply, have an annual health footprint as high as 76 million DALYs[12] and kill approximately two million people per year, of whom children under give make up 90 per cent of the mortalities. Many respiratory diseases are also associated with poor sanitation, as are:

- soil-transmitted helminths (round worm, hookworm, etc.)
- beef and pork tapeworms
- water-based helminths (guinea worm and schistosomiasis)
- excreta-related insect vectors

Other significant water-related diseases include malaria, trachoma, schistosomiasis, cholera and lymphatic filariasis.

A very substantial body of evidence exists on the health outcomes from investing in water and sanitation provision, although estimates are necessarily speculative and cover a wide range. The outcomes can be expressed in a number of ways, for example:

- in terms of comparative cost-effectiveness of interventions, using DALYs as the main measure of health outcomes
- as a *global burden of disease*
- as reductions in incidence and prevalence of disease (e.g. by numbers of cases, reductions in "days ill")
- as reductions in disease-specific and generalised (population-based) mortality rates
- as reductions in the risk of contracting disease
- reductions in the health services cost of treating illnesses caused by poor quality water and lack of hygiene and sanitation

The World Health Report 2002 estimated that achieving the millennium goal of "halving by the year 2015 the proposed of people who are unable to reach or to afford safe drinking water" would yield a gain of approximately 30 million DALYs worldwide. Achieving universal access (=98% coverage) of improved water supply and basic sanitation plus disinfection at point of use would result in an additional 553 million DALYs. The 2003 World Health Report estimated that

[11] http://www.who.int/mediacentre/factsheets/fs310/en/index.html
[12] Disability Adjusted Life Year – a standard international measure of the burden of disease and, conversely, of health outcomes

1.6million deaths per year were attributable to unsafe water supply and sanitation, including lack of hygiene.

Separating out the impact of the different input/output components (drinking water supply, water quality, water storage, sanitation, and hygiene) is not straightforward, as there are inter-linkages between them. Health benefits from improved access to water supply are thought to be substantially lower than for sanitation (which is estimated to account for 92% of benefits) and hygiene but vary substantially depending on the level of service provided. Furthermore, there is ongoing debate about whether it is water quality or water quantity which is of greater importance.

There is a separate and growing literature on the economic benefits of **sanitation** *per se.* While the economic benefits from improved water supply for poor families are becoming widely appreciated, those of sanitation still need emphasising. A high proportion of benefits consist of time savings from avoiding queuing for public toilets or seeking out secluded spots in the open. There are also benefits from increased school attendance, especially for adolescent girls, and gains to national productivity from the greater ease of employing women where proper sanitation facilities are provided. Local standards of sanitation have been shown to have an effect on tourist visits to areas concerned (OECD, 2011)[13].

The split of sanitation benefits between the different categories is shown in Table 1.

Table 1. Benefits from attaining the sanitation MDGs in off-track countries (%)

Public health sector benefits due to avoided illness	1.6%
Patient expenses due to avoided illness	0.2%
Time savings from access to improved sanitation	90%
Premature deaths averted	5%
Other benefits: • productive work days gained through avoided illness (0ver 15s) • days of school attendance gained through avoided illness (5-15) • days of life gained for a young child through avoided illness (0-4)	3.1%

Source: Bartram, 2008[14]

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. It is estimated that

[13] "Benefits of investing in water and sanitation: an OECD perspective" OCED 2011
[14] Bartram J, "Sanitation is an investment with high economic returns", UN Water Factsheet No 2

the 1991 cholera epidemic in **Peru** cost $1 billion to control: spending a fraction of this on better sanitation could have saved the much larger sum (Tropp, 2010[15]).

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, economic losses, and offsetting costs in other sectors (WSP, 2008). Corresponding losses in the **Philippines** as part of the same overall study were 41.4 billion, or 1.5% of GDP (USAID/WSP, 2008).

Within WASH programmes, there is evidence that increasing the quantity of water may be more important for health than improving its quality. The promotion of **hygiene** has also been found to be a key intervention, including provision of hand-washing points, hygiene and health education and the promotion of specific behaviours, particularly hand-washing with soap at critical times (such as food production). Box 3 substantiates these points.

Box 3. Impacts of community water supply improvements in Bolivia

Investments in small community water systems had no major impact on water quality until combined with community-level training, though they did increase the access to, and the quantity of, water. This increase in quantity appears to have been sufficient to generate declines in under-age-five mortality similar in size to those associated with the health interventions.

Over the four year period (1993-97) after the introduction of the water supply improvements a decline of 42% was observed in under-five mortality rates. The cost per death averted averaged $15,200 for the water interventions, compared with $20,000 for the health interventions. It is likely that these benefits would grow, the longer the period of years studied.

This study concurs with the earlier one by Esrey *et. al.*[16] that safe disposal of excreta and proper use of water for personal and domestic hygiene appear to be more important than the quality of drinking water in achieving broad health impacts.

"*An impact evaluation of education, health, and water supply investments by the Bolivian Social Investment Fund". By Newman, Pradhan, Rawlings, Ridder, Coa & Evia*. *World Bank Economic Review*, Vol 16 No 2. (2002)

Cost savings to users (where supply of water in convenient form reduces monetary or economic cost of water collection/use)

By far the largest category of benefits (75%) from empirical studies conducted at the WHO and elsewhere consist of ***savings in time*** spent in household duties, including fetching water and in queuing for public toilets or seeking out secluded spots in the open. Privacy in use of sanitation facilities is a particular issue for women and girls. There are also benefits from increased school attendance, especially for adolescent girls, and gains to national productivity from the greater ease of employing women where proper sanitation facilities are provided. [17]It should be stressed that these are *economic* benefits, only part of which will accrue as financial gains to

[15] Tropp HA, *Investing in water services, infrastructure, policies and management* in *UNEP Opportunities to green the global economy 2010*

[16] "Health benefits from improvements in water supply and sanitation" by Esrey, Potash, Roberts & Shiff. *WASH Reprint Technical Report No 66, Water and Sanitation for Health Project, Arlington, Va.*. www.sanicon.net/titles/title.php3?titleno=103.

[17] OECD 2011, pp 53-4

water users and governments. (This factor explains why water investments which appear so attractive in socio-economic benefit terms may be difficult to finance from commercial sources).

A more direct kind of user cost saving is the differential in the price of water provided through an accessible tap, and the cost of obtaining water from private commercial or informal vendors. There is a large literature on the latter, demonstrating that the price per unit of water bought from private sellers is not untypically 10 times more expensive that the tariff paid for public supplies through household or street taps. [18]

Impact on water-intensive activities (including agriculture, livestock, etc.)

Apart from the direct benefits to agriculture and industry of improved water supply, dealt with in other sections below, there are also direct impacts on productivity of the ill-health of workers, and potential cost-savings on expenditures on treatment of employees with diarrheal disease.

At the household level, the movement for Multiple Water Use Services being promoted by IWMI's Southern Africa Office makes the case for providing water to households in a form and quantity that enables them to use it for activities essential to rural livelihoods such as food processing, livestock watering, subsistence food production, fisheries and aquaculture, brewing, etc. [19]

Summary of Indicative economic benefit-cost analyses

Box 4 Overall global benefits from meeting the MDGs for water supply and sanitation

Type of Benefits	**Breakdown**	**Monetised benefits (US $)**
Time savings from improved water supply and sanitation	20 billion working days per year	$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	$9.9 billion p.a. in total for the 3 categories
Health care savings		$7 billion per year for health agencies $340 million for individuals
Value of premature deaths averted, based on discounted future earnings		$3.6 billion per year
Total benefits		**$84 billion per year**

OECD 2011

A first stage disaggregation of benefit-cost analyses

[18] UNDP *Human Development Report 2006 Beyond scarcity:power, poverty and the global water crisis.pp 80-87*
[19] Various papers by Barbara van Koppen at IWMI, B.vankoppen@cgiar.org. And *Beyond domestic: case studies on poverty and productive uses of water at the household level*, ed by Moriarty, Butterworth and van Koppen. IRC, Delft, 2004.

Examples of a more disaggregated view of economic benefit-cost justification of water supply and sanitation projects are given in an influential and widely-quoted study which estimates benefit-cost results for five types of WASH interventions, in each of five WHO sub-regions[20]. These are quoted here to illustrate the importance of obtaining site-specific and intervention-specific data. The health data relate to infectious diarrhea as the "marker" disease.

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**, given first of all to illustrate **(i) comparative data for one sub-region (Box 5) and (ii) comparative data for the same intervention in different sub-regions (Box 6)** are:

Box 5

WHO Region	Total population (million)	1	2	3	4	5
Sub-Saharan Africa	481	11.5	12.54	11.71	15.02	4.84

Source: Hutton and Haller, Tables 25 and A2.19

Box 6

WHO Region	Sub-Saharan Africa	WHO Region of the Americas - D	WHO European Region - D	WHO South East Asia Region - D	WHO Western Pacific Region - B1
Population (millions)	481	93	223	1689	1488
Intervention 3 (access for all to improved water and sanitation)	11.71	10.59	6.55	7.88	6.63

Source: Hutton and Haller, Table 25

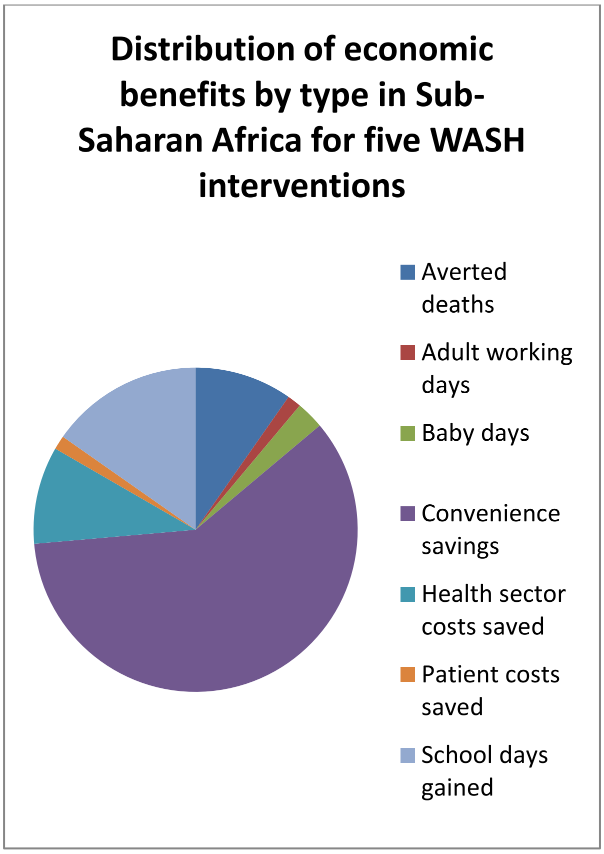
The typology of benefits contained in this analysis identifies the following:

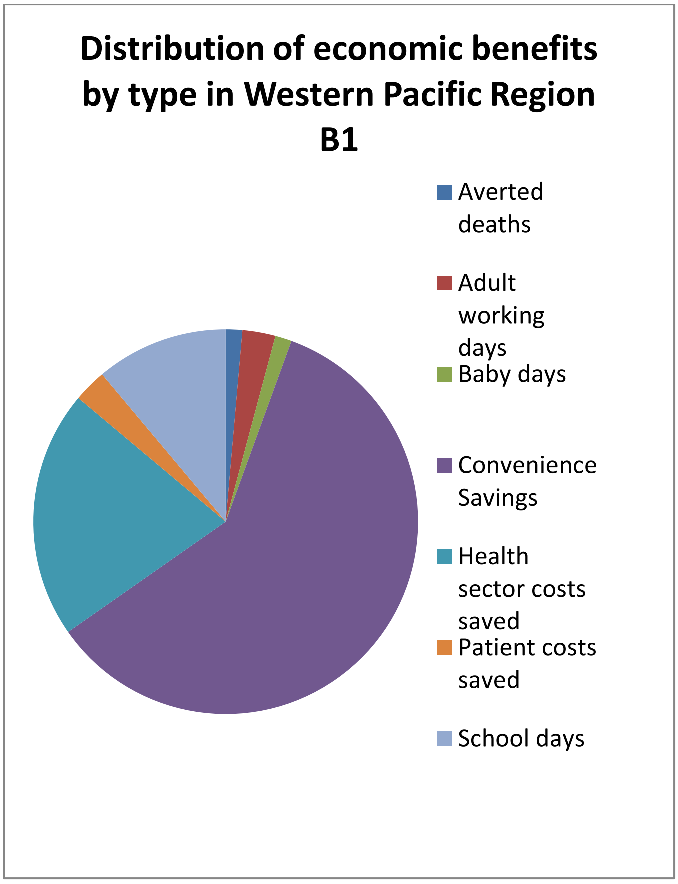
[20] Hutton G, L. Haller, *Evaluation of the Costs and Benefits of Water and Sanitation Improvements at the Global Level* WHO 2004

- Averted deaths
- Adult working days
- Baby days
- Convenience savings
- Health sector costs saved
- Patient costs saved
- School days gained

Comparison of the distribution of benefits shows some variation between regions (Figure 1) below. However, both indicate the overwhelming domination of convenience/time saving benefits (in these cases at least 65% of total economic benefits). Pages 23-38, and Appendices A.2 and A.3 of Hutton & Haller (2004) provide more detail of the benefits under these various categories.

Figure 1





In a separate study [21] Hutton values the health benefits of the various interventions using DALYs rather than loss of lifetime earnings, and also includes the net benefits of disinfecting water at the point-of-use. The results are shown in Table 2

Table 2Global results for three intervention scenarios for water and sanitation

Global benefit-cost ratios	Water supply MDG alone	Water supply & sanitation MDG combined	WS&S universal access + disinfection at point of use
DALY valued at US$1,000	8.6	11.6	10.7
DALY valued at US$5,000	12.1	13.4	14.9
Health valued using human capital approach (lifetime earnings lost/gained)	8.8	11.7	11.0

Hutton (2007) p. 414

[21] Guy Hutton, "Unsafe water and lack of sanitation", chapter 22 in Bjorn Lomborg (ed), *Solutions for the world's biggest problems: costs and benefits*, Cambridge University Press, 2007

Cost analyses

Hutton & Haller (2004) compare cost variations for different improvement options (interventions) on a per-person reached basis, for different regions, as follows (Table 3):

Table 3

INTERVENTION	ANNUAL COST PER PERSON REACHED (US$ YEAR 2000)		
	Africa	**Asia**	**Latin America and Caribbean**
Improved water supply			
Standpost	2.4	4.95	3.17
Borehole	1.7	1.26	4.07
Dug well	1.55	1.63	3.55
Rain water	3.62	2.51	2.66
Disinfected	0.33	0.26	0.58
Regulated piped water in-house (hardware and software)	12.75	9.95	15.29
Improved sanitation			
Septic tank	9.75	9.10	12.39
VIP	6.21	5.70	5.84
Small pit latrine	4.88	3.92	6.44
Household sewer connection plus partial treatment of sewage	10.03	11.95	13.38

Source: Hutton and Haller 2004

However, these data give no indication of standardisation for the scale of investments measured (for example, whether unit costs in the case of regulated piped water, could be lower than shown at higher scale). This is dealt with further in Section 1.6 of this paper.

Outcomes and impacts from improved water supply

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. This is the lesson of a major socio-economic study of the **Niger Basin**, home to 94 million people in this region of West Africa. The proportion of the population in Burkina Faso living below the official poverty line is 70%, in Guinea also 70% and in Niger 66%. Childhood mortality is up to 250 per 1000 live births. In 2004, only 53% of people had access to reliable and safe drinking water and 37% to adequate sanitation. (Ward, et.al., 2009)[22]

In **North West 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%. Increased irrigation development is also correlated with a reduction in child stunting in a number of sub-regions. Lack of education is the other major explanatory factor in poverty. The

[22] Ward, J., D.Kaczan & A.Lukasiewicz, "A water poverty analysis of the Niger Basin, West Africa: Niger Basin Focal Project Work Package 1". CSIRO Sustainable Ecosystems Report to the CGIAR Challenge Programme on Water and Food, 2009.

study concludes: "[for poverty reduction] education and access to improved water quality are the only variables that are consistently significant…across the Niger Basin." (Ward, et. al. 2010).

Given the preponderance of women's time savings in the WHO studies referenced above, a recent study in **Ethiopia** has great policy relevance (Box 7).

Box 7 Impact of village water taps on fertility in Ethiopian villages

This research uses longitudinal survey data collected before and after the installation of village water taps in a sample of otherwise comparable Ethiopian villages. Installing these taps reduced the time and effort that women spend carrying water from 6 hours per day to less than 30 minutes in some cases. This has improved women's' energy budgets and has translated directly into higher fertility. "Women gaining access to taps are now four times more likely to give birth on a given month than those without access to taps." Improved water supplies are also associated with a reduction in child mortality of 50% for every month of life.

The combined result of these impacts has been greater pressure on rural carrying capacity and increased migration of 15-30 year olds to nearby urban centres.

The authors draw the conclusion that in regions of population pressure such as those studied, improvements in village water supply should be accompanied by family planning programmes, or else welfare improvements will be offset by the growth in numbers.

From "Rural to urban migration is an unforeseen impact of development intervention in Ethiopia", by Gibson & Gurmu, PLOS ONE, Nov 2012. www.plosone.org.

Conclusions

Introducing safe water supplies and sanitation to households, at scale, promises various benefits, attested by a large body of literature. Benefits include health, time savings, other user cost savings, convenience, and value-added in productive household activities.

When these benefits are disaggregated, the contribution of improved sanitation and hygiene tends to be larger than improved water supply *per se,* implying that the latter are more cost-effective interventions.

Given that time savings are the largest benefit component, it is important to understand how these are spent, and what complementary interventions would convert these welfare benefits into more tangible gains. One recent study in rural Ethiopia suggests that time savings translate mainly into human fertility rates, which annuls any long term gain in poverty reduction in areas of pressure of population on resources.

Wastewater collection, treatment, re-use & disposal

This topic includes the removal of household wastewater (both domestic "grey water" from washing and cooking, and faeces and urine) and everything that happens to it thereafter in order to render it harmless to other people and the natural environment. It does not cover the removal and treatment of large scale industrial effluent, unless this is discharged into sewers.

Wastewater collection and treatment is a classic "public good", conferring a range of benefits, which can be grouped as follows:

- Public health
- Environmental
- Economic (value-added and cost savings)

Wastewater services typically need to be provided at a certain minimum scale in order to achieve their purpose as well as to attain economies of scale. Providing them piecemeal would allow the continuation of serious public health and environmental risks. Also, sewerage and wastewater treatment is a costly and capital-intensive process requiring minimum levels of throughput and a broad user base to generate the required revenues.

Public health

Untreated wastewater discharges threaten health in the following ways:

- Consumption of untreated wastewater or water contaminated by sewage;
- Consumption of food produced with contaminated irrigation water or from livestock farming using such water;
- direct physical contact with contaminated water through bathing, recreation or work;
- wastewaters are breeding grounds for flies and mosquitoes

  Studies that quantify these impacts are rare, but in one such, the economic cost of pollution of the **Bogota** River in Colombia was estimated to be $4 million p.a. [23] (a minor part of all its pollution costs, estimated to be $111 million p.a.).

  The costs to public health of water pollution in the **Sebou Basin of Morocco** were estimated to be US$97 million (in present value terms for total costs over a 25 year period, in 1996 prices)[24]. These were due to the cost of treatment and losses in productivity from diarrhea, cholera and typhoid.

  The impact of a sewerage project in **Salvador, North-East Brazil** on public health has been assessed on a before and after basis. Between 1995 and 2004 the spread of connections to public sewers increased from 26% to 70%, and is now 90%. Over this period the prevalence of childhood diarrhea fell by 22% on average and by 42% in areas

[23] Cited in OECD (2011, p. 76)
[24] *The price of dirty water: pollution costs in the Sebou Basin* by Claudia Sadoff. World Bank, June 1996

with a high prevalence prior to the project. There was an even bigger impact on other diseases. No economic assessment was done of these impacts. [25]

Environmental effects

The release of untreated or inadequately treated wastewater into natural water courses can damage natural habitats and environmental processes:

- nutrients in sewage can cause eutrophication, involving the development of algal bloom, affecting fauna (e.g. fish) and flora and leading to reduced biodiversity.
- Additionally, phosphorus, nitrogen, toxic chemicals, endocrinal disruptors and other residual elements can alter or destroy the balance of ecosystems, as well as feed back into the human food chain.

The predominant form of economic evidence on the environmental impact of wastewater is that derived from willingness-to-pay (WTP) studies, the overwhelming bulk of which is obtained from developed countries[26]. Values produced by these WTP studies depend greatly on the type of elicitation method, the design of the questionnaire, the assumed payment vehicle, and the income level and environmental awareness of the surveyed population, amongst other factors.

In one of the few such studies for a developing country, the WTP of the population in **Chandemagore Municipality, India** was investigated in relation to improvements in wastewater treatment for discharges into the River Ganga. This revealed an average WTP of Rs 16.46 (US$0.35) per month per household (= $4.25 p.a.) for additional municipal taxes spent on improved wastewater treatment.[27]

Impact on economic sectors

Wastewater treatment avoids the extra costs that would fall on downstream users arising from the need to treat this water before use, or even develop alternative water supplies. This is obviously very location-specific: in some cases it will involve the addition of new capacity or technology to a water treatment plant, in others it will entail relocating intakes further upstream or even into other watersheds. In one study of the city of **Fes in Morocco**, the extra treatment costs incurred in response to water pollution from the olive industry amounted to US$0.73/m3, more than three times the actual tariff (OECD, 2011, p. 69).

In some cases, the extra costs of water pollution from urban wastewater and industrial effluent are reflected back onto the polluting agents, in the form of tighter regulation which raises their costs. This is the case for the Paldang Reservoir which supplies **Seoul in Korea**.

[25] Cited in OECD, 2011, pp 49-50..

[26] A large number of these are reviewed in *External economic benefits and costs in water and solid waste investments: methodology, guidelines and case studies.* Authors: van Beukering, van Drunen, Dorland, Jansen, Ozdemiroglu and Pearce. Institute for Environmental Studies, Free University, Amsterdam, 1998. See also the website.....A more recent study in the same vein is “The value of a tidier Thames: WTP to reduce sewage overflows” by Ozdemiroglu, Newcombe, Mourato, Atkinson and deGaris. Paper presented to Applied Environmental Economics Conference, March 2004, Royal Society, London. See also *The economic, social and environmental value of ecosystem services: a literature Review.* Final Report by eftec for the UK DEFRA, Jan 2005.

[27] Cited in OECD, 2011, p. 68

Many industries depend on water as an essential element in their production process. Some require water in large quantities (thermal and hydro power generation, cooling, paper, food processing, etc.) others need it to be of high quality (e.g. electronics, specialty food, brewing). Where water does not satisfy industrial requirements, users turn to alternative supplies or greater use of internal treatment and recycling. Tourism is also sensitive to water: hotels and restaurants need sufficient water to cater to their visitors, while there are many cases of losses incurred where beaches and lakes are closed to tourists due to an outbreak of water-related disease, or to the onset of algal bloom. Fisheries are also seriously impacted by water pollution: the loss of fish from stretches of the **Bogota River** due to pollution has been estimated to be c. $1 million. (OECD, 2011, p. 76)

In warmer climates, agriculture is one of the most sensitive sectors in respect of water quantity and quality, accounting for c. 70% of global freshwater withdrawals, a high proportion of which is for consumptive use. There is growing recourse to the use of recycled wastewater for agriculture (in the Mediterranean region 30% of wastewater is re-used in this way). **Re-use** schemes in **Spain, Mexico** and elsewhere can be justified in benefit-cost terms, if their net impact on industry and urban services is taken fully into account (FAO, 2010)[28] .

Conclusions

Water pollution from untreated wastewater can pose serious economic costs through its impact on health, environmental quality and productive economic sectors. Such losses avoided by the construction of wastewater collection, treatment and reuse schemes are the basis for a number of benefit-cost studies, some of which are cited above.

Water for irrigation and other productive sectors

Irrigation accounts for c. 70% of water withdrawals at a global level, a high proportion of which is for consumptive use (i.e. effectively lost to other potential users). Irrigation underpins the agricultural economies of many populous countries, and its modernization and expansion is considered essential to cope with the growing food demands of a rising population. However, irrigated farming increasingly competes for water with fast growing cities, it is a relatively low value water user, and its impacts on the natural environment (e.g over-abstraction and water pollution) are becoming unsustainable.

The future direction of irrigation development has been authoritatively set out in the *Comprehensive Assessment of Water Management in Agriculture.*[29] The CA draws a distinction between the large public surface irrigation schemes which dominate the landscape in South Asia and a few other regions, compared with smaller projects, typically owned and financed by farmers themselves, many of which rely on groundwater. The CA, as well as the World Bank's AICD[30], portends new development consisting predominantly of the renovation and re-engineering of existing public schemes, alongside smaller developments owned by farmers themselves. In both cases, there is likely to be a larger role for private companies as investors, managers and suppliers (CA, p. 363).

[28] E.g. by "releasing" flows of water that would otherwise have to be provided from clean supplies. Winpenny, Heinz, Koo Oshima *et.al.*, *The wealth of waste: the economics of wastewater use in agriculture.* FAO, 2010.
[29] *Water for food, water for life*, ed. David Molden. IWMI, 2007.
[30] Africa Infrastructure Country Diagnostic, *Africa's infrastructure: a time for transformation.* 2010

Although irrigation has a poor reputation for profitability and economic performance, rates of return on recent new projects have been respectable compared with those in other sectors of infrastructure (Box 8). To qualify these figures, in irrigation there is often a gap between financial and economic rates of return, due to artificially depressed output prices, and the externalities of irrigation are rarely reflected – e.g. contamination of groundwater and surface water with agrochemicals, and waterlogging and salination of soils.

Box 8. Economic Rates of Return for infrastructure projects in sub-Saharan Africa (%)

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

AICD, (2010) p. 71

AICD have estimated rates of return for projected investments in two kinds of irrigation: on the one hand, large scale and dam-based projects, and on the other hand small-scale irrigation based on small reservoirs, farm ponds, treadle pumps and water harvesting structure collecting local runoff. The results are shown in Table 4 (a further regional breakdown of these data within SSA is given on p. 291 of AICD):

Table 4: Investment needs and rates of return for investment in large- and small-scale irrigation in sub-Saharan Africa.

----------- - large scale---------------------			----------------small scale---------------		
Increase in irrigated area (mn ha.	Inv. Cost ($ mn)	Av. IRR (%)	Increase in irrigated area (mn ha.)	Inv cost ($mn)	Av. IRR (%)
1.35	2,640	17	5.44	17,790	26

AICD, 2011, p. 291

The AICD analysis suggests that new dam-based, large-scale irrigation would be profitable on 1.35 mn ha. if its scope was limited to projects passing the 12% IRR threshold. This would necessitate associated on-farm investment of double this amount. The larger schemes would, however, only be profitable if their major costs could be recovered from hydropower sales.

Small-scale irrigation offers larger potential since extensive rain-fed areas could be converted to irrigation, though on-farm water storage would be required. For all types of irrigation, viability would depend on cultivating high-value crops. Only in a minority of cases would the irrigation be viable for growing low-value food crops.

Rates of return for irrigation projects are highly sensitive to investment costs, which vary according to location, amongst other key factors. For small-scale irrigation, for example, the AICD notes: “raising the investment cost from the baseline case of $2,000 per ha to $5,000 /ha would all but eliminate the economic case for small-scale irrigation” (p. 193).

It should be noted that the above cost yardsticks are low compared with historical outturns. In a study of 314 irrigation projects of all types and in all regions of the world funded by the

World Bank, African Development Bank and IFAD completed during the period 1965-2003 the average global cost of new construction irrigation projects was $14,455/ha for sub-Saharan Africa, and $6590 /ha for all other regions. For rehabilitation projects the corresponding figures are $8,233/ha and $2,280/ha. (all at 2000 prices). Not surprisingly, when the projects were sorted into "success" and "failure" categories, the former tended to have much lower unit costs than the latter.[31]

One possible conclusion to be drawn from the discrepancies in irrigation costs used by the two studies reported above is that irrigation projects supported by the agencies in the past have been high cost and that if this type is to be expanded in future it will have to be modified to be lower cost in order to be viable on its own.

In the study by Inocencio et.al. , other things equal, project size was correlated with success. A 10% increase in irrigated area was associated with a 7% decrease in unit cost and a 3% increase in economic returns. However, the study found that too much project "complexity" reduced performance. Other key factors in successful performance were: availability of water; conjunctive use of surface and groundwater; and limited overruns on cost and time.

Conclusion

Irrigation accounts for the majority of global water withdrawals, and much of it is used for relatively low-value purposes. Many new irrigation projects undertaken in the past have had disappointing economic returns. Even in well-performing projects there is usually a significant difference between economic and financial rates of return. In future, there will remain a pressing need for more output from irrigated farming, but it will need to be more cost effective than in the past, and focused on the new agenda set out in the IWMI Comprehensive Assessment.

Delivering at scale in the provision of Water Services

Given the size of the service deficit, worldwide, governments and development agencies have an obvious interest in providing water services on a scale proportionate to the size of the un-served population. The overriding motives for this are:

- a humanitarian desire to provide for basic human needs, ,
- to restore equity between the fortunate recipients of services and those without,
- a desire to capture the potential economic and social benefits from expanded water services, and
- keenness to capture the cost dividends from economies of scale and critical mass.

The first two motives above need no comment. Evidence for the third is provided in earlier sections of this paper. The current section deals firstly, with potential economies of scale in water services, secondly with the obstacles needing to be addressed in order to scale up ("roll out") services, and thirdly, alternative business models that need to be considered in order to maximize coverage of the services concerned.

[31] "An analysis of unit costs & performance of irrigation projects: lessons from the WB, AfDB and IFAD" by Inocencio, Kikuchi, Merrey, Tonosaki, Maruyama, de Jong, Sally & de Vries. IWMI, 2005.

Evidence of economies of scale and scope, and critical mass, in water services

Scale economies exist when output can be increased with a less than proportionate increase in costs. *Scope economies* are present when the production costs of two or more products jointly produced are lower than when they are produced separately. *Critical mass* refers to the minimum size of effort required to make an initiative effective or worthwhile: this is important in securing the health benefits of water supply and sanitation, and in planning the scale of wastewater collection and treatment.

A recent paper by Carvalho, Marques and Berg[32] provides a summary of the worldwide literature on water utility benchmarking, specifically that relating to economies of scope and scale in the provision of water services. They note that historically there has been a dearth of water sector studies focused on measuring performance and identifying factors affecting costs. Recent upsurge in interest in this area has resulted in the identification of more than 250 studies by end 2010 (compared with 190 identifiable studies by end 2009).

The authors conclude that there is no consensus in the literature regarding (1) the optimal scale of water utilities and (2) the existence of scope economies between different types of services (e.g. water and wastewater services). Nor do they find any consensus regarding economies of vertical integration (i.e. economies between the various stages of the production chain). Quite distinct arrangements can be found around the world such that, even within a single nation, suppliers can range from very small water utilities producing services to small villages, to large utilities providing services to many customers in a large municipality or a region. In some countries (e.g. the Netherlands) the drinking water supply is provided as a single service; in others it is provided together with wastewater (e.g. France) and also with other services such as urban waste, electricity or gas (Germany). There are also vertically integrated water utilities responsible for wholesale and retail (distribution) segments (e.g. Spain) and others that deal with these elements separately (e.g. Portugal). Developing countries have a similar range of institutional arrangements.

Most early studies refer to the US and the UK, and give a wide variety of conflicting results. More recently Nauges and van den Berg (2008) have found economies of scale in Colombia, Moldova and Vietnam for small and medium utilities, but not in Brazil. Other studies quoted in the meta-analysis mostly found economies of scale of provision of water services in countries such as Portugal, Germany, Latin America, Peru, Spain and Canada.

As regards economies of scope, results are similarly mixed. Of the studies examining scope economies between water and wastewater services, a large number find scope economies, whilst others have concluded the opposite.

There seems to be consensus that:

(i) small water utilities providing only one service or that are not vertically integrated have significant unrealised scale and scope economies due to relatively low levels of output;

[32] Carvalho P, RC Marques, S Berg "A Meta-Regression Analysis of Benchmarking Studies on Water Utilities Market Structure" August 2011

(ii) large or vertically integrated utilities seem to have scale and scope diseconomies (disproportionately high costs) at the levels of output they produce

The balance seems to be between the savings from the use of shared resources, reduced administrative and procurement costs per customer, on the one hand, and the greater costs associated with network complexity and increasing bureaucratisation, on the other.

The literature reports a wide range of maximum number of connections where economies of scale were not exhausted, ranging from 100,000 to one million in studies of Italy. In the wastewater sector, there is more consistency of results suggesting the existence and importance of economies of scale.

Much of the literature drawn on above relates to conditions in *developed* countries. In *developing* countries some qualifications need to be made, reflecting financial, economic and institutional realities. This is the subject of section 1.6.3. below.

Drivers influencing cost

A study carried out in Australia[33] concludes that it is contextual features which determine the cost advantages of any water supply option, and that there is no simple, universal, cost ranking which can be applied to each and every situation. The exception to this is the costs of pipelines and pumping water over long distances, which have a dominating influence on cost.

Key drivers appear to be the physical characteristics of different regions (geographic, hydrological and topographic circumstances); and to the legal and regulatory framework for providing water services. Other factors include density, customer income levels and distance of customers from water sources. Country GDP may also be a factor, suggesting that countries with higher GDP are more likely to exhibit diseconomies of scale. By implication, in countries where the standard of living is lower, there are probably many utilities with significant economies of scale to be exploited (although this conclusion needs to be interpreted with care, as developed countries tend to meet WHO standards for water quality and treatment levels for wastewater, whereas neither is the case for low income nations).

Regulation has been found to be a major driver of cost.

The WASHCost programme of the IRC in Delft is generating important cost data on the life-cycle cost of water supply, sanitation and hygiene interventions in different developing country contexts (www.irc.nl/washcost).

There is no clear message from the above-cited literature survey that lower costs are associated with private ownership of production. However, if the sample is limited to developing countries, the conclusion of the most recent and comprehensive analysis of public-private partnerships in urban water utilities concludes that "operational efficiency appears to be the area in which the positive contribution of private operators has been the most consistent". This is based on their

[33] Marsden Jacob Associates (2006)

superior performance, compared with their public counterparts, in combating water losses, improving bill collection and raising labour productivity.[34]

OECD Studies

OECD work in this area[35] notes that, whilst populations in most OECD countries enjoy high levels of access to networked systems of water supply and sanitation, the maintenance of these systems is becoming more difficult due to ageing infrastructure and the high costs associated with water transport and network maintenance, including work on roads to repair underground infrastructure. There is also the need to meet more stringent environmental requirements. An additional issue concerns the impact of climate change, with the concomitant need to adjust to more variable supply of water, make better use of available resources and adjust water quality to specific needs.

These new drivers have been grouped under four headings: socio-economic, technological, environmental and political[36].

Socio-economic changes are expected to increase total and unit costs of water service infrastructure into the foreseeable future due to population growth, changing demographic profiles (e.g. ageing and more sophisticated lifestyles), demand for increased service quality, etc.

Technological change is expected to work the other way, attenuating the overall increasing costs of water services. Developments in this area include increasing use of information and sensoring technologies, and green infrastructure technologies (e.g. natural or engineered systems which use soils and vegetation to capture, cleanse and reduce storm water and other excess flows).

Environmental stresses will be a key driver, particularly those which result from rising abstraction levels and from mismanagement of the water resource, leading to increased competition for water use. This will be compounded by climate change and its expected impact on reliability and predictability of future water resources, which will generate additional demand for security of water systems.

Political forces - mainly increasing regulatory stringency - are likely to increase the relative costs of future water service delivery.

As a result, conventional wisdom on the traditional view of economies of scale attached to piped water supply, single water use and water-borne sewage treatment in centralised systems are all being called into question. There is growing emphasis on improving the productivity of water use, rather than seeking new sources of supply, and applying economic tools (such as pricing for

[34] *Public-private partnerships for urban water utilities: a review o9f experiences in developing countries*, by Philippe Marin, World Bank/PPIAF, 2009. P.5. A similar result is found in *Does private sector participation improve performance in electricity and water distribution?* By Gassner, Popov and Pushak, World Bank/PPIAF, 2009, p. 42

[35] OECD " Alternative Ways of Providing Water Emerging Options and Their Policy Implications" Advance Copy for the 5th World Water Forum (2009)

[36] Ashley and Cashman

demand management) with the objective of encouraging efficient use and equitable distribution of the resource, thereby improving its sustainability.

There is a new emphasis in particular on *alternative water systems*, defined (i) as reuse of (treated or not treated) grey or reclaimed and (ii) systems based on decentralised infrastructures, producing water where it is consumed. From an environmental perspective, water reuse can reduce demand for fresh water resources, diversify water sources and enhance reliability of access to resource. It can reduce the volume of wastewater discharged into the environment.

Decentralised systems can reduce energy required to transport water from the point of production to the point of use, and reduce greenhouse gas emissions due to energy savings. Decentralised capacity can be built house-by-house or cluster-by-cluster in a "just in time" fashion which often results in a more economical approach than building centralized treatment capacity or extending sewers.

They do, however, carry risks. For example, they tend to preclude cross-subsidies (rich in favour of poor consumers), and beg questions about what happens if service providers go bankrupt, how will tariffs be set, and who will undertake water quality testing? Another issue is that water and sanitation cover a range of services each of which can be organised at different scales - potable water supply, supply of water for non-potable uses, rain water harvesting and flood mitigation, wastewater collection, treatment, etc.

Alternative water systems have been used in rural areas for decades, and are an option in urban areas where no central infrastructures pre-exist and in extra-urban areas, as well as in areas with decaying water infrastructures. In Japan, for example, in 2003, more than 1,000 on-site individual buildings and block-wide wastewater recycling systems generated water for non-potable urban applications (toilet flushing in commercial buildings and apartment complexes)[37]. However, some of the most promising areas for wastewater reuse are irrigation or industrial uses.

An important pre-requisite for their use is likely to be reform of prevailing regulatory systems. In addition, regulators need to be able to monitor water quality from a variety of different sources (e.g. fresh water abstraction, harvested rainwater and water treated) in multiple settings (central plants, commercial and industrial buildings, and private houses).

Scaling up water service provision; obstacles and solutions

Critical mass

This issue arises in household water supply and sanitation, sewerage and wastewater treatment, among other water service issues.

For household water supply and sanitation, unless 100% coverage of a community can be assured, the full benefit of these services is not guaranteed. A single household or water point

[37] Funamizu et al 2008

can trigger an epidemic of cholera (such as the notorious Broad St pump, contaminated with sewage from a nearby leaking sewer pipe, which was traced as the cause of a cholera outbreak in London in 1854[38]).

In the same vein, the movement for Community-Led Total Sanitation in parts of South Asia and Indonesia aims at 100% abolition of open defecation in villages that enlist: anything less exposes residents to faecal contamination, and prevents their residents claiming the status that goes with 100% compliance (which can include the marriagability of their girls)[39].

Scaling up

In the provision of conventional sewerage, a minimum number of connections and minimum flow of sewage (and other forms of household wastewater) is necessary for the viability of the system, otherwise blockages occur. Likewise for conventional wastewater treatment plants, which are designed for a particular throughput and which fail to function effectively at less than this.

Many innovative solutions in water services start off as small-scale pilots in specific localities. When they appear successful, their sponsors (typically NGOs) seek to "roll out" their schemes to other communities and regions, and even try to get them adopted as a national model ("mainstreamed").

Scaling up tends to be a fraught process. Often, the pilots are successful because they enjoy favourable conditions (donor funding, intensive attention and inputs, etc.) which it is unrealistic to expect in larger programmes. Sometimes the very success of isolated pilot projects is due to their invisibility: Davis and Iyer report one consultant in Brazil who commented "[the Government] wants the funding and will agree to anything as long as it's small enough to be off the political radar....The pilot could be very successful, but it will never go any further than that."[40] (presumably because its wider replication would be difficult or awkward, for various reasons). It is not uncommon for a pilot project to be successful precisely because it has its own modalities and sources of finance, totally separate from that of the mainstream administration.

Davis and Iyer highlight several potential blockages between the pilot and the scaling up:

- Resistance from beneficiaries who do not want the proposed service or think they could not afford it on the terms proposed.
- Resource constraints (finance, people, weak supply chains, organisational capacity, etc.), not helped by the common situation that pilots use "gold plated" solutions. As Sinclair states, "Experience has shown that many projects implemented on a small scale require a level of financial and human resources that makes them completely impracticable on a larger scale".[41]

[38] Sandra Hempel, *The Medical Detective: John Snow, Cholera and the Mystery of the Broad Street Pump.* 2006
[39] Kamal Kar, *Subsidy or self-respect? Participatory Total Community Sanitation in Bangladesh.* IDS Working Paper 184, Sussex, Sept 2003
[40] Jennifer Davis and Param Iyer, "Taking sustainable rural water supply servies to scale: where are the bottlenecks?" *WaterLines.Vol 23, no 2, Oct 2004*
[41] Peter Sinclair, "Scaling up water supply – a WaterAid perspective", *WaterLines* Vol 23 No 2, 2004

- Lack of a “shared understanding” amongst key stakeholders of the aims and components of a scaled up programme.
- Resistance from officials and others whose role is diminished by the scale-up, and the need to have a credible champion for change.
- Untypical pilot conditions. Pilot sites are often selected because they seem favourable for the project in question. They may not be typical of the wider community.

Condominial sewerage and the Total Community-led Sanitation movement are both examples of scaling down technology in order to scale up coverage of services.

Condominial sewerage, expanding in Latin America, involves the construction of small-bore sewers at shallow depths in areas with no road traffic. This solution has advantages in irregular urban settlements, on steep slopes and rocky terrain. Its cost savings, compared with conventional sewerage, is illustrated in Table 5.

Table 5 Estimated costs savings per connection for condominial sewerage compared with conventional type (US$ 2006)

Bolivia: La Paz-El Alto	Cost of conventional sewerage	Cost of condominial sewerage	Savings %
Villa Ingenio	276	119	57
German Bush	276	176	36
South Africa: Durban			
Emmaus	1007	444	56
Briardale	390	253	35
Paraguay: small towns			
Villeta	1250	279	78
Peru: Lima			
Kawachi	430	242	44
Virgen del Pilar	576	325	44

Vargas-Ramirez & Lampoglia, “Scaling up using condominial technology. WaterLines, vol 25 no 2, Oct 2006. Table 1.

In condominial systems, users are responsible for maintaining (and often, constructing) lines in their vicinity, which requires technical training, as well as education in household waste disposal. They also call for technical back-up from the public utility, e.g. in removal of blockages. Condominials depend on having adjustments to national standards of engineering design, materials and other items, which in the case of Bolivia and Peru have been permitted though changes in national norms.

Although condominial solutions offer financial savings, which enables greater roll-out, they also entail sizeable social costs – of mobilizing communities and encouraging them to cooperate in creating solutions, and contributing to their technical and financial upkeep. Once created, these community organizations represent an externality which can be useful in other social realms. However, Vargas-Ramirez and Lampoglia caution that these social costs can be onerous for small systems, and scale economies do apply in this case.

Total Sanitation is an approach to providing community-wide sanitation that is rapidly spreading across rural areas of Bangladesh, India and Indonesia – though has failed to gain traction in sub-Saharan Africa.[42] It is community-led, requiring minimal (or zero) hardware subsidies, entails collective changes in behavior in hygiene, and uses simple technologies mostly of local origin. It builds on peer pressure, naming and shaming, and may involve fines and other forms of social sanction. In some projects, toilet use and hygienic practices dropped off following initial enthusiasm, and this was sometimes due to the new toilets or latrines becoming dysfunctional for various reasons.

One of the conditions for success for TS is that local governments continue with monitoring, support and technical help where required. It is also important that hardware subsidies[43] be discontinued, since their continuation can de-motivate communities adopting TS.[44] Robinson notes that TS, quintessentially a local movement, is compatible with large scale hygiene and sanitation marketing approaches (e.g. by governments and NGOs) – an example of scale economies in some components of this concept.

Alternative business models.

The sheer cost of certain kinds of water infrastructure, allied to the managerial sophistication required in its operation, will limit the spread of the more advanced technological options. The heavy cost of water treatment, mains sewerage and wastewater treatment plants would, for instance, quickly exhaust the financial means of many urban authorities, and would lead to a bi-polar model of service provision in which many people would remain without safe public services.

This suggests a rather counter-intuitive conclusion: in order to promote the widest spread of water services affordable to the majority of people, the search for technological economies of scale may have to be complemented – or even superseded in some cases – by a drive to *reduce the diseconomies of small scale*. Models based on non-conventional, cheaper and decentralized solutions to water treatment and distribution and sewerage and wastewater treatment may be more feasible in the conditions prevalent in many developing countries. This may entail greater reliance on private companies operating under delegated management[45] , or the empowerment of individual or community initiatives. “Self-supply” is another promising mantra.[46]

An OECD Expert Meeting held in 2007 considered potential innovative business models for water services. [47] It was concluded that the tasks facing water supply and sanitation services left

[42] Robinson, “Total Sanitation: reaching the parts that other approaches can’t reach” *WaterLines* Vol 25 no 2, Oct 2006
[43] In Maharashtra State, India, between 1997 and 2000 these amounted to $55-80 per household (Robinson, ibid)
[44] Robinson, ibid
[45] E.g. two papers from the World Banks WSP, *Improving water utility services through delegated management – lessons from the utility and small scale providers in Kisumu, Kenya (May 2009) and Private operator models for community water supply- a global review of private operator experiences in rural areas* (Feb 2010)
[46] E.g. *An introduction to self-supply: putting the user first. Incremental improvements and private investment in rural water supply.* World Bank WSP, Feb 2009
[47] OECD Expert Meeting on Sustainable Financing for Affordable water services: from theory to practice.” Paris, November 2007. From Rapporteur’s Summary by J.Winpenny.

room for a variety of responses, e.g. demand management, adaptation of scale, public involvement of various kinds, and financial and technical innovation. There is no “silver bullet” and there are likely to be complementarities between different options and models. Two of the presentations made are summarised in Box 9

Box 9 Business models for water services at different scales

Harald Hiessl (Fraunhofer Institute, Germany) presented alternative scenarios of urban water infrastructure systems. He drew attention to some strains and emerging problems in the existing conventional model – the age of existing systems, adaptation to climatic change, vulnerability to terrorism and natural disasters, growing scarcity and cost of fossil fuels and phosphates, more stringent pollution requirements, etc. Two small German municipalities have been used in the development of long term scenarios testing different degrees of decentralisation. The imminent need of major rehabilitation of aging systems presents an opportunity to try new sustainable models. Managing the transition will call for long term thinking and management of change. Changes are opening up in technology, organisations and institutions which call for more flexible systems than in the past and the ability to realise synergies between different utility sectors.

Jon Freedman and James Hotchkiss (General Electric Water & Process Technologies) explored the technological options more thoroughly. They contrasted the existing centralised system with a decentralised paradigm, the latter taking advantage of new safe, reliable and cost effective technologies, emphasing plant rather than pipe, offering the same level of water quality to rural and urban regions, with more on-site water re-use and greater accountability for water use and re-use. Such systems could also be operated with less need for specialised expertise. In their view, the centralised option might continue to be preferred for large urban areas where municipally managed recycling is possible. But for extra-urban, low-impact urban infill and many industrial applications, on-site and decentralised water management may be the preferred option. The role of governments will be to create an enabling environment in which the above changes can play out, with policies encouraging re-use, clear standards on water quality, and financial recognition of the benefits that on-site solutions can give to communities.

Elaborating the above points, they cited a recent case in Atlanta where a private company took raw sewage from the municipality, and treated and recycled it for non-potable use. On-site recycling makes waste recovery feasible, which is not always possible with centralised plant. Although recycling and re-use is likely to have a higher capital cost, it is likely to be cheaper on a full life-cycle basis, especially if savings in the cost of sewer pipes are factored in.

OECD, 2007. Loc.cit. From Rapporteur’s Summary

2. Potential economic benefits and costs of research into increasing the sustainability of water system services

Our terms of reference require: *a written review of the quantitative data estimates on potential economic benefits and costs of research investments that increase the sustainability of water system services (e.g. investments in research on water resources management, investment in research on climate change adaptation, etc.).*

A report by Guy Hutton "Economic benefits of supporting deployment of global knowledge and innovation for the delivery of water and sanitation services"(April 2011) states:

> "Investing in knowledge and innovation is a large part of what DFID's water policy team does. We need to do an analysis and make the economic case for investing in the development and deployment of knowledge and innovation in water and sanitation. This requires analysis and a narrative argument on the possible returns (with a view to attempting to quantify) of investing in the knowledge part of the supply chain. This is a generic argument that can be used for justifying investments in this area".

We have undertaken an extensive literature search in this field which has produced nothing providing quantification of returns to investment in research in provision of sustainable water system services. Accordingly, the following offers a more qualitative assessment of potential benefits, drawing on frameworks developed in comparative work in the UK health sector and the UK Research Councils.

It may be worth re-rehearsing the economic arguments for public investment in research activities. Research is classically an area of economic activity subject to fundamental market failures, principally the problem that private investors may be unable to capture the returns from their investments on knowledge products. The creation of temporary monopolies in the form of devices (patents, etc.) to protect intellectual capital created by research activities goes some way towards dealing with the problem. Even so, without government intervention, research activities are likely to be below their "optimal" level. There are also issues of risk management and affordability which the public sector is more likely to be able to manage.

Investments in research activities are not homogeneous. "Blue skies" research is necessarily speculative and high risk with regard to the utility of possible outputs. Many research discoveries, classically those in biomedicine, are "accidental" and some pertain to uses which were originally not expected or intended (e.g. asprin, viagra) in the original research. More closely targeted research is likely to investigate (successfully or otherwise) tightly specified hypotheses.

Assessing payback in health research

There have been attempts in various economic sectors, to identify and to quantify the economic value of research activities. We are aware of work by Brunel University[48] which distinguishes between *ex ante* and *ex post* assessment of economic payback on research investments. The *ex-ante* approach would provide an analytical framework with the purpose of achieving greater clarity (but not quantification) about

- what the benefits of research in the proposed topic might be
- how the world might change without the research
- how the research might be expected to change policy or practice

The main purpose of imposing such a framework is to strengthen the justification for spending resources on research; contributing to methods for prioritising future investments in research; and improving the conduct of research so as to enhance subsequent payback.

Ex post assessment is inevitably based on individual case studies, which measure the benefits of successful research against the overall cost of the research effort (as well as the relevant individual research project costs). This particular work identifies a number of categories of payback (Table 6):

Table 6

Category	
(a)	**Knowledge**
(b)	**Benefits to future research and research use**
(i)	Better targeting of research
(ii)	Development of research skills
(iii)	A critical capacity to utilise existing research (including international)
(iv)	Staff development/educational benefits
(c)	**Political and administrative benefits**
(i)	Improved information bases on which to take political and executive decisions
(ii)	Other political benefits
(d)	**Health sector benefits**
(i)	Cost reduction in the delivery of existing services
(ii)	Qualitative improvements in service delivery
(iii)	Increased effectiveness of services
(iv)	Equity, i.e. improved allocation of resources
(v)	Revenues from intellectual property rights
(e)	**Broader economic benefits**
(i)	Wider economic benefits from commercial exploitation of innovations
(ii)	Economic benefits from a healthy workforce and reduction in working days lost

Source: Ed Buxton and Hanney, 2nd report Vol 1, p 19 Figure 1.1

[48] Ed Hanney and Buxton, "Assessing payback from Department of Health Research and Development, 2nd report vols 1 and 2", Health Economics Research Group Report No 24, 1997

Assessing the economic value of UK public funded research activities
More recently, the UK Research Councils have commissioned work to investigate the economic benefits of their research portfolios[49]. This report proposes an "Economic Impact Reporting Framework, comprising the following categories of impacts (benefits):

Figure 2

Overall economic impacts	Innovation outcomes and outputs
Increased productivity	Technological innovation Other innovation
Improved welfare	Human capital Stock of publicly available knowledge

Source: See footnote 50

Again, it is predominantly through qualitative comment in ex post case study material that the impact of research is compared with its costs. For example:

Figure 3

> "The National Environmental Research Council (NERC) funds some of the world's most powerful climate prediction experiments, for example the high resolution atmospheric model known as HiGEM (www.higem.nerc.ac.uk). The polar regions are highly sensitive to climate change and polar research enables better understanding of how melting sea-ice and reduced snow cover can make the planet's surface less reflective and hence absorb more sunlight. This research has informed the work of the United Nations Intergovernmental Panel on Climate Change."
>
> Taken from: "Adding value: how the research councils benefit the economy" RCUK

Sometimes quantification may be possible. For example, NERC's Oceans Margin LINK programme has the objective of better understanding the effects in deep water oceans. NERC input 2000-2007 was approximately £9 million. Actual impacts include leverage of £9 million from the private sector, as well as expected improvements in risk mitigation and site prediction in oil drilling of £100 million. Wider impact includes the application of analytical techniques to drug testing in sport - put at £10 million annually[50].

[49] PA Consulting Group/SQW Consulting "Study on the Economic Impact of the Research Councils" (September 2007). http://www.rcuk.ac.uk/documents/keireports/EconomicImpactResearchCouncilsPart1Summary.pdf
[50] "Adding value: how the research councils benefit the economy" RCUK

Guy Hutton[51] includes examples of such quantification in the water sector, although the assumptions involved in arriving at estimates are sometimes heroic (Box 10).

Box 10

Quantitative assessment has been made of gains from research and policy support by the World Bank's Water and Sanitation programme in Himachel Pradesh (HP) and Madya Pradesh (MP), India. Overall, the WSP has spent US$ 1.9 million, and has leveraged $7dollars from the state government and $20 from the population for every WSP dollar spent. The average cost per person of research funding was $9, compared with a cost per latrine of $45, for the 3 million population estimated to have gained access.

In Ethiopia, between 2010 and 2015, an estimated 32.2 million rural people are expected to gain access to sanitation. Cost per person per annum has been estimated at $10 (2010 prices), giving a 5-year cost of US$1.6 billion. On the assumption that a WSP contribution to the enabling environment is 25% of its total budget of $8.4 million, the WSP leverage has been calculated as 48.

The study goes on to apply a global benefit-cost ratio of 8, giving total benefits from this project of 384 per unit invested by WSP.

Source: Hutton G, (2011)

In environmental economics, the concept of *quasi-option value* refers to the expected value of having better information about a project's future environmental impact. Research producing such information has this value.

In a similar vein, *Value-Of-Information* analysis seeks to identify specific areas for which it would be most valuable to have more information. This could be based on standard *sensitivity analysis* in benefit-cost studies, which identifies variables in a project to which its economic return is most sensitive.

Progressing the logic of the above, if we are confronted with potentially large economic returns from specific water investments (e.g. in the WHO studies of the benefits of implementing the MDGs) but where these depend on the removal of constraints or the presence of complementary programmes, further research into what these constraints are[52] and how they could be overcome would have a major benefit *per se*, especially if the earlier work developing such investment programmes could be regarded as a sunk cost.

The following survey of evidence and knowledge gaps which further research might address draws out key messages from the most recent UN World Water Development Report (WWDR4) (2012) "Managing Water under Uncertainty and Risk", Volume 1, Chapter 6 of which is devoted

[51] Hutton G, "Economic benefits of supporting deployment of global knowledge and innovation for the delivery of water and sanitation services". April 2011

[52] Why are there more African households with mobile phones than toilets?

to this issue. The context of the analysis is the view that climate change has forced a major change in the risk profile of water resources management. Whereas parameters such as water availability were previously considered essentially fixed and statistically predictable based on historical records and trend extrapolation, this is no longer the case.

Some key policy research issues

Technological developments in the water sector

Technology is making a big contribution to the management of water resources and security. An example is the development of techniques that enable evapo-transpiration from crops to be measured directly at a variety of scales, including by remote sensing. Signal attenuation between mobile phone towers can help to provide accurate estimates of precipitation. The GRACE family of satellites has enabled the application of remote gravimetric measurement to determine changes in the total stock of water in specific geographical areas. Although still only experimental, this technology has already demonstrated the potential to monitor changing groundwater reserves in large alluvial basins.

Global food production

The ability to produce sufficient food for growing and increasingly affluent populations is a global concern and water is an essential resource in food production. Agriculture accounts for 70% of water abstraction, much of which is for consumptive use. The potential research agenda of water in agriculture is vast, though its most urgent directions have been signaled in the authoritative *Comprehensive Assessment of water management n agriculture – Water for Food, Water for Life* [53]from the International Water Management Institute (IWMI). The collection of Abstracts of papers presented to the Stockholm World Water Week, August 2012 on the theme *Water and Food Security* is an indication of the wide range and richness of research proceeding in this area

Urbanisation

Population growth and increasing urbanisation raises issues for government planners about the availability of water resources to support such developments, and about the wastewater impacts they generate. The collection of (several hundred) abstracts of papers presented to the Stockholm World Water Week in 2011 on the theme of *Water in an Urbanising World* is a fertile source of ideas in this domain.

Climate Change

Threats posed by vulnerability to extreme weather events are prompting a review of measures to building resilience to disasters such as floods. While most of the Research and Development proposals contained in the influential *Stern Review*[54] are in the field of mitigation, specifically in energy policy, there has since then been a rebalancing of international focus to include

[53] Ed. David Molden. Earthscan, 2007
[54] *The economics of climate change: the Stern Review.* By Nicholas Stern, CUP, 2007

adaptation, which brings water back into play. Typical of this is the initiative on *Water security and climate resilient development* of the African Ministers Council on Water, the Climate and Development Knowledge Network and the Global Water Partnership[55].

Industry and Commerce

Water availability and quality has been identified as a major risk to sustainable business activities, as witnessed by the growing research and advocacy conducted by the World Business Council on Sustainable Development, the Global Economic Forum, the Water Footprint Network, and the report[56] by McKinsey & Co for the 2030 Water Resources Group. The latter's development of the *water cost curve* is an enlightening approach to the analysis and ranking of options for dealing with a country's water futures. Extending this methodology to other countries and situations would be an interesting research agenda.

Environment

Environmental stakeholders recognise that water resources are an ecosystem in their own right, as well as being essential to the health of other ecosystems. It is important to monitor the status of acquatic ecosystems in order to assess the effectiveness of national and international environmental regulation.

Research into "enabling factors" and constraints

Part 1 of this paper contained empirical evidence of the size of net benefits (or Value for Money, from another viewpoint) of many projects to improve water services. Some of the Benefit-Cost ratios are huge. The question arises, if the benefits are so self-evident, why are such projects not more widely implemented?

The answer to this conundrum may lie in the questionable methodology of some studies, the choice of pilot projects in favourable and unrepresentative situations, the fact that benefits do not accrue in a form of interest to policy-makers, etc. In reality, many factors hinder the implementation of attractive-sounding projects – the perceptions and preferences of users, funding constraints, corruption, institutional and managerial weakness, rent-seeking by key agents, sheer geography, and others. Research into these constraints would enable more of the putative benefits to be realised – the economic case for the research is in such cases *derived* from that of the underlying project.

[55] The three main outputs of which are the *Strategic Framework, the Technical Background Document,* and the series of *Policy Briefs*, all appearing in 2012 (www.gwp.org and www.amcow-online.org

[56] *Charting our water future: economic frameworks to inform decision making.* Report by McKinsey & Co to the 2030 Water Resources Group, 2009.

Knowledge Gaps

In the above cited paper, Hutton notes as potential areas for research as an enabling factor: *policy development, resource mobilisation and resource allocation, service delivery via programmes and projects and via the private sector, resilience to climate change, and finally monitoring and evaluation of service coverage and development outcomes*. Many of these research functions relate, in fact, to stages in the project and programming, financing and investment implementation cycle. However, as the earlier part of our paper has indicated, many of the studies undertaken generate results which are highly site and project specific. One possible solution to this, adopted in value-for-money work which we undertook for DFID Nairobi to map the cost-effectiveness of humanitarian interventions, would be to develop a database of results, drawing on the very many individual studies which are recorded in the formal and the grey literature, mapped by intervention, by geographic area, by scale, etc. and informed by supplier expertise where possible.

A particular challenge is to maintain a regular flow of comparable data that can be used to monitor trends in different parameters over time. For example, the following summary is a dashboard of data availability in the countries of the Southern African Development Community (SADC) for 2010.

SADC Country	Surface and groundwater	Infrastructure	Water supply sources and returns to the environment	Water uses and allocation	Wastewater	Water efficiency	Water charges	GDP	Water financing and production costs
Angola	🟡	🔴	🔴	🔵	🔴	🔴	🔵	🟡	🔴
Botswana	🟡	🔵	🔵	🟡	🟡	🟡	🟡	🟡	🟡
DRC	🟡	🟠	🔵	🔵	🔴	🟠	🔵	🟡	🟠
Madagascar	🟡	🔵	🟠	🔵	🔴	🔴	🔵	🟡	🟠
Malawi	🟡	🟠	🔵	🟠	🔴	🔴	🔵	🟡	🟠
Mauritius	🟡	🟠	🔵	🟠	🔵	🟡	🟡	🟡	🟠
Mozambique	🟡	🔵	🔵	🟡	🟠	🟠	🟡	🟡	🔵
Namibia	🟡	🟠	🔵	🟡	🟠	🟡	🟡	🟡	🔵
Seychelles	🟡	🟠	🟠	🟡	🟠	🔵	🟡	🟡	🔵
South Africa	🟡	🔴	🔵	🟡	🔴	🔴	🟡	🟡	🟠
Swaziland	🟡	🔴	🔵	🟡	🟠	🟠	🟡	🟡	🔵
Tanzania	🟡	🟠	🔵	🔵	🔴	🔵	🟡	🟡	🟠
Zambia	🟡	🔵	🔵	🔵	🟠	🟠	🟡	🟡	🔵
Zimbabwe	🟡	🟠	🔵	🔵	🔴	🔴	🟡	🟡	🟠

Key:
🔴 No response received
🟠 Little Information
🔵 Some, but limited information
🟡 Substantial information

Source: UN World Water Development Report 4, Vol 1 Figure 6.

Getting research into practice (GRIP) and the importance of knowledge transfer

The emerging market for data - ensuring research investments are complementary

An important message of WWDR4 and other similar publications is that knowledge transfer, and ensuring the uptake of research findings, is as important a set of activities as generating knowledge in the first place. A large number of initiatives are underway to make good these gaps, in what WWDR4 describes as "the emerging market for better data and indicators". This is borne out by earlier references in this paper to an exponential growth of academic and research interest in aspects of the water sector. One potential downside of these efforts, however, is the need to ensure that research interests and activities are complementary, rather than overly competitive and wasteful of scarce research resources. Donors such as DFID may be particularly well-placed to require, or provide, the kind of coordination and dissemination of research findings which would help to ensure that results are properly disseminated and taken up, an integral part of realising and exploiting the benefits of research, and an important adjunct to scarce research resources in developing countries.

Part 3: Summary and Conclusions

This paper stresses the interrelatedness of components of the water cycle. Management of water resources requires attention to all aspects of the water cycle. Demand drivers such as global population growth and growing real incomes, combined with increasing unpredictability of future precipitation flows due to a changing climate, are placing water resources under increasing pressure. At the same time, there are great inequalities in provision of water, sanitation and wastewater services, and for many of people little or no access to these basic services.

The paper cites evidence from the academic literature (meta-analyses where we have been able to find these) and from international policy making institutions such as the World Bank, WHO and OECD, to support the view that there are major economic returns to be achieved from investment in water in its various uses. The size of the benefit-cost ratios depend on the baseline situation and the type of investment, as well as site-specific factors.

We suggest DFID gives further consideration to compiling a "library of results" which tracks and archives this kind of evidence.

A separate discussion in this paper rehearsing such quantitative estimates as have been attempted suggests that there is no ready consensus on the question of where scale economies are to be located, nor on the question what constitutes an "optimal scale" of operation. This section also rehearses the qualitative arguments on both sides on how to scale up a successful initiative, and what this costs. The constraints may be financial, logistical, managerial or institutional, rather than economic.

In the face of increasing unpredictability of climate conditions, the paper argues that research evidence, whether for project programming, or to address broad strategic issues, is an essential component of future water resource management, and that without it, the full exploitation of benefits may be missed. This includes attention to contextual issues which may hinder the take up of economically beneficial investments.

We suggest that DFID give further thought to the possible role of donors in helping to fill research gaps and to coordinate and disseminate the results of research.

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