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Life-cycle costs of rainwater harvesting systems

WASHCost

RAIN Rainwater Harvesting Implementation Network

IRC International Water and Sanitation Centre

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Photo: Under the close supervision of his mother, a boy collects rain water for domestic use (taken by Charles Batchelor and designed by Sandifort id).

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Acronyms and abbreviations

CapEx	Capital Expenditure (hard and soft ware)
CapEx(HH)	Capital Expenditure (by households)
CapManEx	Capital Maintenance Expenditure (on asset renewal, replacement/rehabilitation costs)
CoC	Cost of Capital
DM	District Municipality
EWV	Enterprise Works/VITA
ExpDS	Expenditure on Direct Support costs (for post-construction)
ExpIDS	Expenditure on Indirect Support costs (for macro-level support)
GIS	Geographical Information System
HH	Household
LCC	Life-Cycle Costs
LCCA	Life-Cycle Costs Approach
Lpcd	Litres per capita per day
MVS	Multi Village Scheme
MUS	Multiple Use Services
NGO	Non-Government organisation
OpEx	Operating and minor maintenance Expenditure
O&M	Operation and Maintenance
PPP	Purchasing Power Parity
RAIN	Rainwater Harvesting Implementation Network
RCC	Roller Compacted Concrete
RWH	Rainwater Harvesting
SVS	Single Village Scheme
WASH	Water, Sanitation, and Hygiene

Executive Summary

Rainwater harvesting (RWH) is a centuries old technology that has the potential to play an increasingly important role in improving and sustaining water services delivery in many parts of the world. In the study reported here, the comparative utility and benefits of RWH are assessed from a life-cycle costs (LCC) perspective. In the context of water services delivery, life-cycle costs relate to the expenditure that is needed to ensure that water supply systems deliver sustainable and equitable services, throughout its life-cycle, from planning to implementation, operation, maintenance and replacement. In addition, the study looks into historical trends and drivers of RWH adoption, and the life-cycle costs of RWH systems compared to life-cycle costs of other water supply systems.

Methodological challenges

Comparing the costs and cost benefits of different water delivery systems is notoriously difficult because of the combined influence of factors that include: exchange rate fluctuations; inflation, purchasing power variations; levels of integrity; and, so on. The picture is complicated further by regional and local differences in: service levels; economies of scale; water scarcity, user preferences; and, quality of components (and in relation to lifespan). Given the above, the methodology used in this study centred on identifying and using data that were broadly comparable and, in some cases, could be used to relate costs to service levels (and/or other benefits).

Data limitations

With a few notable exceptions, existing available cost data for RWH and other water supply systems are limited to hardware costs of constructing water delivery systems. Data on software costs related to system design, capacity building, institutional development, establishment of micro-credit systems and so on are difficult to find. It was even more difficult to obtain the data needed to calculate the annualised costs (e.g. lifespan of system components) or, in the case of RWH systems, to estimate the water provided by the systems (e.g. catchment area, rainfall probability, extraction rates during the rainy season). Additionally, limited data was found on capital maintenance (i.e. asset renewal costs) and on direct or indirect support costs, making it impossible to reflect the ideal life-cycle costs that may guarantee sustainability in the analysis. In consequence, a full LCC analysis and comparison of water supply system costs in relation to services provided was not possible. This report therefore recommends for LCC and associated data be documented and shared by organisations involved in promoting and implementing RWH systems.

Comparing one-off capital expenditure on water supply systems

Notwithstanding the caveats listed above, analysis of information on capital expenditure (CapEx) produced findings that include:

- CapEx of RWH systems is relatively high when compared to systems that do not require storage tanks, but is relatively low when compared to, for example, groundwater-based piped water supply. However the most expensive supply systems in terms of CapEx, are not necessarily the most expensive when consideration is given to: 1) the number of users and uses of the system; 2) unit CapEx per capita, per m3 of storage and/or per m3 of water supplied; and, 3) annualised CapEx that takes into account the expected life of the system.
- Typically, CapEx per m3 of storage for RWH systems using jars and tanks is in the range of US$ 40-200 PPP2008, whilst CapEx per m3 of storage for sand dams is more likely to be in the range of US$ 10-30 PPP2008.
- When the systems are used according to their design specification, a borehole and hand pump system has lower per capita costs (around US$ 30-50 per capita PPP2008) than a typical RWH system (around US$ 50-100 per capita PPP2008). This is unlikely to be the case if there are a limited number of users of the borehole and hand pump system;
- CapEx of RWH systems in Africa is approximately double that in Asia and Latin America.

Recurrent expenditure in RWH

As a generalisation, recurrent operation and maintenance expenditure (OpEx) of RWH systems is relatively low when compared to boreholes and piped water supply systems. OpEx is also low when compared to CapEx. However when annualised CapEx is considered, OpEx is typically in the range of 0-20% of annualised CapEx.

Post-construction expenditure in RWH

The RAIN Foundation estimates that total post-construction support costs amount to around 10% of total costs. Intuitively this seems appropriate but clearly this percentage will increase to cover work in remote areas as a result of travel costs and increased staff inputs owing to, for example, added time spent for travelling.

From costing infrastructure to costing sustainable delivery

Historically water service delivery was viewed as an engineering challenge. It was implicitly assumed was that a supply system comprising of a safe water source and appropriate infrastructure would result in improved services. Although this simplistic assumption has become increasingly discredited, governments and international agencies continue to spend vast amounts of money on installing water supply infrastructure. The results in terms of sustainable and equitable services are, in most cases, as predictable as they are disappointing. The simple fact is that good engineering is an important component of a water supply system but the sustainable and equitable provision of services will only be achieved by ensuring that attention and adequate finance is given to the software component of a supply system. Additionally slippage (or slip back) in service levels will only be avoided or managed by ensuring that funds are available for timely capital maintenance (or asset renewal).

User preference

A recent worldwide review of user preference found that the popularity of RWH depended to a great extent on the availability of a public piped water supply system. Because of its convenience, consumers with access to piped water were less inclined to install RWH systems. One caveat, however, was the occurrence or expectation of a crisis. For locations experiencing a water crisis, it was observed that governments were more inclined to promote or mandate RWH installation. Consumers on the other hand were more inclined to invest in the technology. Additionally, a tradition of rainwater harvesting increased the likelihood of adoption of modern RWH systems or technologies.

RWH in areas of increasing water scarcity

Whilst they are not a panacea, RWH systems enable household and communities to manage their own water, thereby reducing reliance on public supply systems which may be unreliable or difficult to access. Arguably in areas of increasing water scarcity, household RWH systems provide a more resilient and cost-efficient means of improving household water security than constructing ever more complex and expensive public water supply systems. If the policy is to improve water security by providing users with more than one source (as is the case of India), RWH systems are likely to provide a more flexible and resilient supply than bulk transfer schemes that are fed from surface and groundwater resources that are, in many cases, already over-allocated.

Clearly RWH will continue to provide an attractive and cost-effective means of water supply in areas that have ground or surface water quality problems (e.g. as a result of pollution or natural contaminants such as fluoride or arsenic). Similarly, RWH systems can continue to play a cost-effective role in the development of multiple use water services (MUS) that ensure access to sufficient water for small-scale productive uses (e.g. livestock, horticulture, backyard gardening and other small-scale enterprises).

This study also found water scarcity an increasingly serious problem, even in areas that are relatively well-endowed with water resources. Household RWH could and should be promoted as a mainstream option for improving water security and, as such, it should be financed by a combination of public and private expenditure. This said, some attention needs to be given to the findings from user preference studies. At one level, to find practical solutions to real issues identified by users (e.g. poor taste, water quality that does not meet national standards) and at another, to make modern RWH aspirational in many developing countries in the same way that it has become aspirational (and trendy) to use RWH in many developed countries. Additionally, RWH is rarely integrated into water management strategies as these usually focus exclusively on surface water and groundwater. Countries could and should integrate rainwater harvesting more fully into their IWRM strategies and water security plans.

RWH and threats from outside the water sector

Many of the threats to sustainable and equitable water service delivery are outside the control of the water sector. These include: climate change, increasing energy costs, economic downturns, population increase and civil unrest. Some of these threats are immediate and predictable (e.g. population increase), whilst others are uncertain in terms of severity, precise nature and timing (e.g. climate change). There are also threats that are completely unforseeable and highly improbable, but may have major impacts.

In response to these potential unknowns, RWH can play a significant role in improving the resilience of water supply systems relative to each of these threats. For example, household RWH systems (e.g. roof water harvesting) are an obvious option for funding under climate-change "no or low regrets" expenditure programmes. With respect to energy costs and reliance on fossil fuels, RWH systems can be designed to operate entirely under gravity. As such, RWH could play an increasingly important role as energy costs increase and as pumped water supply systems become more expensive. With respect to economic downturns, RWH systems may also pose as good options when public finance is in short supply as these systems may be funded in part or wholly by individual households. As far as civil unrest is concerned, since public water supply systems are heavily reliant on timely public expenditure and functional government and/or community-based institutions, these are more susceptible to civil unrest, compared to household RWH.

RWH: equity in access and externalities

Successful RWH systems require software support that include: cash or a source of finance; knowledge, capacity and/or skills for designing, constructing and operating a system; access, entitlements or tenure over a catchment area; a user group of some kind in the case of communal RWH systems and, the time and/or inclination to construct and operate a RWH system. These software requirements can be a major constraint for the poor or marginalised. It is important, therefore, that any RWH programme takes a pro-poor strategy that helps the poor and marginalised overcome software constraints. If doing so is not feasible, steps will need to be taken to ensure that excluded groups have access to alternative water supply systems.

Intensive use of RWH systems, especially when coupled with increased groundwater extraction for irrigation, can and do impact on downstream water availability. Safeguards should be put in place to ensure that intensification of upstream water use does not impact on the primary needs of downstream users and/or the functioning of important aquatic eco-systems.

Looking forward

In conclusion, this study has highlights a number of important issues:

- Current expenditure is primarily and heavily invested on the hardware aspects of RWH systems. Where there may be significant expenditure on software, this is not being documented.
- Cost comparisons of water supply systems in literature also tend to focus on capital expenditure. This may result in findings and recommendations that are misleading. For the future, the authors recommend for studies to compare life-cycle costs per unit volume of water stored and/or provided, per capita and/or per household. In addition comparisons should consider the annualised life-cycle costs required to achieve and sustain a certain service level.
- More comparative studies are needed to better understand the relationship between expenditure and the water services provided by different RWH systems. Given that there is a paucity of comparable and reliable data needed to undertake these studies, professionals working in some capacity with RWH systems should be encouraged to routinely document and share information and experiences.
- Financial planning for RWH systems should set up the necessary budget lines for life-cycle costs expenditure.
- In areas facing increasing water scarcity, a more integrated approach should be taken to planning and implementing RWH systems. Where appropriate, using RWH in conjunction with other water supply systems may be considered.
- Finally, the use of RWH could and should be promoted as a means of improving the resilience of integrated water supply systems designed to cope with climate change and a range of short and long-term threats.

1 Introduction

1.1 Role of rainwater harvesting systems

Rainwater harvesting (RWH) systems enable people at the household and community levels to improve and manage their own water supplies, thereby reducing reliance on public supply systems which may be difficult to access and/or are unreliable. Well-designed RWH systems can be used to provide safe water in areas that have ground or surface water quality problems as a result of pollution or natural contaminants such as fluoride or arsenic. RWH systems can also play a role in ensuring access to sufficient water for small-scale productive uses (e.g. livestock, horticulture, backyard gardening and other small-scale enterprises).

In many areas of increasing water scarcity, RWH systems are being promoted as a means of improving water security. In these areas, RWH systems are considered as back-up supply that can be used when public supply systems fail, and/or are used as a means for reducing overall demand on public supply systems that are struggling to cope with rapidly increasing demand and inter-sectoral competition for water resources.

1.2 Design of RWH systems

A typical RWH system comprises the following components:

- A catchment surface where the rainwater runoff is collected
- A storage reservoir where water is stored until required
- A reticulation system for transporting water from the catchment to the storage reservoir (e.g. gutters, channels and pipes)
- A means of extracting water from the storage reservoir and conveying it to where it will be used (e.g. a rope and bucket, a pump, pipes and taps)

The overall objective of RWH systems is to make available a desired volume of water of acceptable quality, when and where it is needed. This said, RWH systems come in an impressive variety of designs. Some of these designs are traditional and are based on many centuries of use and adaptation. At the other end of the spectrum, a number of modern designs aimed at meeting the increasing demand for environmentally-friendly technologies or *gizmos* may be found. As will be discussed later in this report, the life-cycle costs, level of service provided and overall utility vary enormously with design.

The design of a RWH system is often based on whether or not it will be used as the primary supply system. If intended to be used as the primary system, specific attention should be given to ensuring that the system will provide a reliable supply during dry seasons and prolonged periods of drought. The reality, however is that the majority of users of RWH systems worldwide do not rely entirely on RWH to meet their demands for water. In most cases they have livelihood and farming systems that are based on a number of different water sources and supply systems. For example, a family may have access to a piped supply system, but use RWH as a complementary or back-up source.

RWH systems can be categorised according to a number of criteria. The most common approach is to subdivide systems according to the type of catchment surface used (e.g. roof, ground or rock). Categorisation can also be based on the storage tank used (whether surface or sub-surface) or the purpose for which water is being collected (e.g. domestic, MUS[1], irrigation, improved rain-fed farming etc.). Finally some systems are categorised according to their ancillary benefits (e.g. flood control, reducing pressure on public water supply systems, etc.). Figure 1 categorises RWH systems according to catchment surface and main uses. The shaded area in Figure 1 (small-scale and medium-scale) indicates the main area of focus of this report.

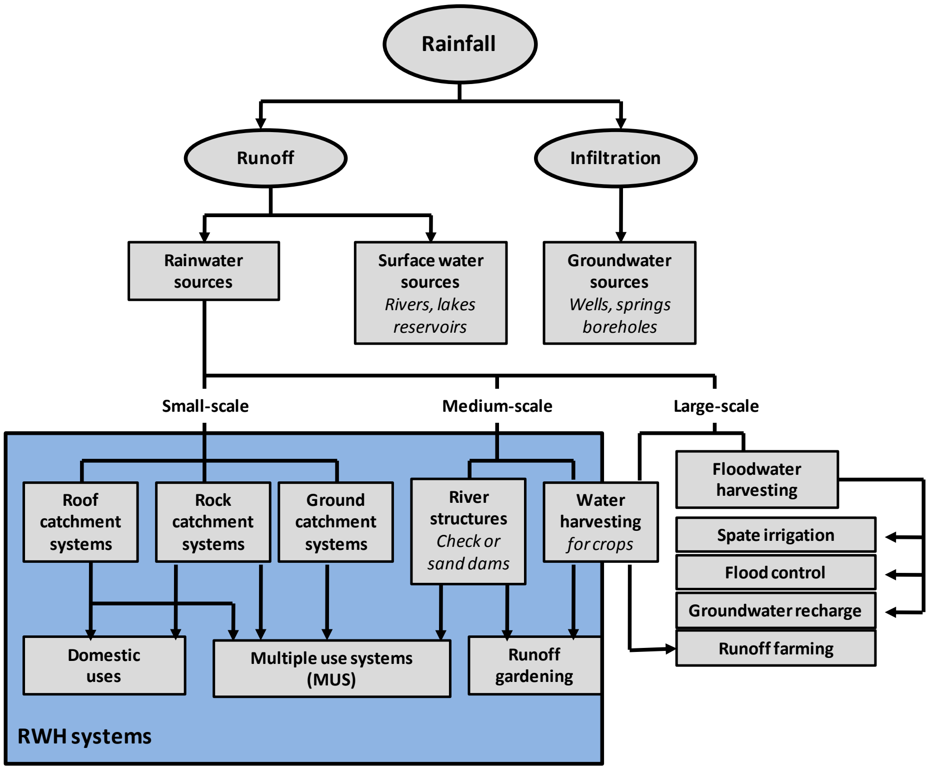

Figure 1 **RWH systems categorised by catchment type and main users/uses**

Source: Gould and Nissen-Petersen, 1999.

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[1] See Van Koppen et al (2009) for more information on Multiple Use Systems.

1.3 Objectives of the study

The objectives of this study are:

- To determine the life-cycle costs of using RWH systems to deliver adequate, equitable and sustainable water services to a population in a specified area.

- To give an overall judgement of the benefits versus the costs of the different RWH systems, and in comparison to other water supply, bearing in mind the fact that benefits could be social, economic or environmental and, in some circumstances, RWH can impact negatively on "downstream" users[2].

- To provide insights into the trends and status of rainwater harvesting in the light of user preferences and predicted water scarcity in 2030.

The focus of the study is on rural water supplies (i.e. limited attention is given to sanitation and hygiene and to water service delivery to urban or peri-urban users).

1.4 RAIN Foundation

This study was commissioned by the RAIN Foundation[3]. RAIN is an international network with the aim to increase access to water for vulnerable sections of society in developing countries - women and children in particular - by collecting and storing rainwater. RAIN is currently promoting the catchment and storage systems listed in Box 1.

Box 1 RWH catchment and storage systems promoted by the RAIN Foundation

RWH catchment systems

- Roof catchments (e.g. galvanised and/or corrugated iron)
- Paved surface catchment (e.g. cement or stone)
- Surface catchment (e.g. soil catchment)
- Riverbed catchment (e.g. an ephemeral stream)

RWH storage systems

- Above ground storage tanks (e.g. ferro-cement tanks, stone masonry tank and rain jars)
- (Partially) below ground storage tanks (e.g. circular stone masonry tank, hemispherical cement concrete tanks and rectangular reinforced cement-concrete tanks)
- Subsurface sand dams

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[2] See UNEP and SEI (2009) for information on the potential downstream impacts or negative externalities of RWH systems.

[3] Visit *www.rainfoundation.org*

2 Methodology

2.1 Life-Cycle Costs (LCC) terminology

What are life-cycle costs?

In the context of water services delivery, life-cycle costs represent the aggregate costs of ensuring sustainable[4] and equitable delivery of a certain level of water supply services to an individual household or towards a population of a specified area. Life-cycle costs include the disaggregated or unit costs of design, construction and maintenance of a water delivery systems along with all the non-engineering costs that are often overlooked or ignored when budgets and financing are discussed and finalised (e.g. costs relating to institutional development, capacity building, source protection, pro-poor planning and capital maintenance).

What are water services[5]?

Water services focus on the delivery of water to users who will use this water for a range of different uses (e.g. drinking, cooking, bathing, washing and small-scale productive uses). As such, a distinction is made between:

- **Services** which are defined by the volume of water of an acceptable quality that is accessible to users along with attributes such as the predictability, reliability, sustainability and equity of provision of these services; and
- **System** hardware and software that is used to deliver these services.

In practice, water services and water supply systems are often closely related. For example, a borehole and a hand-pump operated at the village level provides one type of service. Whilst professionally-managed water supply network with household connections provides another. However, the difference between a system and a service is critical. By focusing on systems and, more specifically the capital costs of rolling out new water supply infrastructure, engineers and planners run the risk of losing sight of what they are or should be trying to achieve. By focusing on water services, planners and engineers are more likely to ensure that users receive a level of service that is acceptable and that meets a set of key indicators (or national norms).

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[4] In the LCC context, the concept “sustainable” is widely used to refer to environmental, institutional, social and financial sustainability.

[5] See Moriarty et al (2010) for a more detailed discussion on water services.

Why is a good understanding of LCC fundamental to water services delivery?

A good understanding and knowledge of LCC is essential to:

- **Improving the design and management of water delivery systems.** Despite, huge investments in the WASH sector, service levels remain stubbornly low in many parts of the world. This indicates that this challenge of improved services will not be solved by just increasing capital expenditure. Clearly, sustainable services and value for money will only be achieved if all the components of a water delivery systems are financed adequately.

- **Tackling slippage (or slip back).** Service levels provided tend to slip back over a period of time especially when, as often is the case, expenditure is heavily skewed towards construction and technical aspects of service provision neglecting maintenance and renewal.

- **Improving the resilience[6] of water delivery systems to shocks and extreme events.** WASH systems that are financed on the basis of LCC tend to be more resilient and able to adapt to challenges thrown up by climate change or other uncertain events. One reason being that adequate finance for participatory planning and institutional development ensures that systems are properly managed and maintained.

- **Ensuring the poor have equitable access to water services.** Experience has shown that explicit actions have to be taken if the poor, particularly poor women are to participate actively in the planning and management of water delivery systems. For example, decisions on tariffs or connection charges must take full account of the needs and constraints of the poor and the risk that the benefits of a delivery system will be captured by elites to the detriment of the former.

- **Adaptation to climate change.** "No or low regrets" expenditure [7] is seen by many as an important plank of climate change adaptation strategies. This makes good sense especially if "no or low regrets" expenditure is based on LCC assessments and the focus of resulting activities is on improving the overall resilience of WASH delivery systems and not solely on construction works.

- **Benchmarking.** Benchmarking is being used increasingly in the WASH sector to monitor and compare water delivery systems and service levels achieved by these systems. Clearly, benchmarking processes are to be improved if they are to take into account the LCC required in order to achieve a certain level of service in any given context.

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[6] *Resilience* refers to the ability of a social or natural system to withstand disturbances while retaining the same basic structure and ways of functioning.

[7] *No or low regrets* expenditure programmes design policies, plans, or actions that can potentially generate net social benefits whether or not climate change occurs.

What is the LCC approach?

The Life-Cycle Costs Approach (LCCA) promoted by the WASHCost project[8] goes beyond achieving the technical ability to quantify and make cost information readily available (Fonseca et al., 2010). It seeks to influence sector understanding of why life-cycle costs assessment is central to improved and sustained water services delivery and to influence the behaviour of sector stakeholders so that life-cycle unit costs are mainstreamed into WASH governance processes at all institutional levels from local to national to international. The LCCA also aims to increase the ability and willingness of decision makers (both users and those involved in service planning, budgeting and delivery) to make informed and relevant choices between different types and levels of WASH service

What are the main LCC components?

Leaving aside costs relating to externalities, the main generic financial components or categories of LCC are described in Table 1.

Table 1 Life-cycle costs components for water services delivery

Life-cycle costs	Description
Capital expenditure – software and hardware (CapEx)	Capital invested in planning (i.e. software) and constructing (i.e. hardware) a water services delivery system
Operating and minor maintenance expenditure (OpEx)	Recurrent expenditure on operating, managing and maintaining a water delivery system
Capital maintenance expenditure (CapManEx)	Expenditure on asset renewal, replacement and rehabilitation of a water delivery system
Cost of capital (CoC)	Cost of financing a water service delivery system, taking into account loan repayments and/or the cost of tying up capital
Expenditure on direct support (ExpDS)	Unit costs of post-construction support activities to users of a water delivery system
Expenditure on indirect support (ExpIDS)	Unit costs of macro-level support, planning and management of a water services delivery system. Includes also the costs of inter-sectoral dialogues and planning alignment

Source: Fonseca et al., 2010.

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[8] For more information, visit *http://www.washcost.info*.

What are the main sources of LCC finance?

The main sources of LCC finance include: public expenditure, international agencies, non-governmental organisations (NGOs) or the users themselves (i.e. household expenditure). As is often the case, LCC financing for any given water delivery system is derived from a mix of different sources.

2.2 Sources of information

The comparison of life-cycle costs data across different regions and over time is far from easy to achieve because of the combined influence of factors that, according to Gould and Nissen-Petersen (1999), include the following:

- Limited availability of comparable cost information especially post-construction cost information
- Lack of empirical information on the lifespan of system components[9]
- Limited availability of user in-kind, cash and/or opportunity costs
- Fluctuations in exchange rates, purchasing power parity (PPP) and inflation, not least because inflation (and sometimes deflation) in the cost components of RWH systems is far from uniform

The picture is complicated further by the fact that relative costs are influenced by regional and local differences in service levels, economies of scale, quality of construction, quality of components and extent of operational maintenance (and hence the lifespan of system components), whether or not work is carried out by contractors; and, levels of integrity.

Given the above, any comparison between the LCC of RWH systems and between RWH systems and other water supply systems and/or technologies should be undertaken with caution. Nevertheless such analysis is fundamental to understanding the relative benefits and value for money of different water supply systems.

For the purpose of this study, information was drawn from three main sources: primary and secondary data collected as part of the WASHCost Project; cost information provided by the RAIN Foundation; and, information from easily-accessible websites. As far as possible, data was selected, and those that may

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[9] In this study, technical lifespans were used. The **technical lifespan** of a system component represents the period of time during which it operates satisfactorily in a technical sense. The **economic lifespan,** on the other hand, refers to the period of time during which the component can operate before the costs of continued use are higher than the costs of replacement. The economic lifespan is never longer than the technical lifespan and, in some cases, it is much shorter.

be easily compared – analysed. Similarly, cost data was adjusted to 2008US$ on the basis of purchasing power parity (PPP). A one-off expenditure such as CapEx and CapManEx was annualised in order to facilitate easy comparison with a recurrent expenditure such as OpEx. Annualising a one-off expenditure also provided a reasonably sound basis for comparing technologies that have different life spans.

2.3 Life-Cycle Costs (LCC) framework for RWH systems

Table 2 on next page presents the framework used by this study for analysing and aggregating the LCC of RWH systems. In this framework, a distinction is made between "provider" and "user" costs. This implies that if a RWH system is constructed and operated entirely by the user, such will not require "provider" costs. However "provider" costs may be charged if a RWH system is funded or promoted by government or a NGO programme.

Table 2 LCC framework adapted for RWH system analysis

LCC components	**Resources** *Costs involved in sustainable provision or augmentation water resources of required quantity and quality*	**Infrastructure** *Cost related to constructing, operating and maintaining water supply infrastructure*	
		Provider costs	**User Costs**
CapEx Software *One-off work prior to construction*	**Water resource assessment:** costs of accessing and analysing rainfall data. If relevant, costs of estimating runoff, potential losses from structures, water quality analysis, risk and vulnerability assessments, GIS mapping, etc.	**Engineering design**: costs of design of rainwater harvesting system (including costs of field visits, interactions with government staff etc.)	**Engineering design**: costs of design of rainwater harvesting system (including costs of accessing specialist advice)
CapEx Hardware *Capital investment in construction fixed assets*	**Source protection or augmentation**: any hardware costs related to protecting or augmenting the quality or quantity of water (e.g. interventions aimed at protecting downstream flow to a sand dam)	**Construction:** costs of materials, labour costs, hire of masons, transport of materials construction of RWH system, storages, water treatment equipment etc. **Additional pro-poor costs**: related to pro-poor sitting/construction of RWH system, additional hands-on support etc.	**Construction:** costs of materials, labour costs, hire of masons, transport of materials construction of RWH system, storages, water treatment equipment etc. **Additional pro-poor costs**: any additional costs that might be incurred by poor or marginalised households (HH)
OpEx *Operating and minor maintenance expenditure*	**Costs of operating and maintaining source protection or augmentation infrastructure**	**Cost of operating and maintaining infrastructure listed above:** repairs, spare parts, cleaning tanks, replacing filters, hire of plumbers, chemicals, etc.	**Cost of operating and maintaining infrastructure listed above:** repairs, spare parts, cleaning tanks, replacing filters, hire of plumbers, chemicals etc.
CapManEx *Asset renewal and replacement cost*	**Costs of rehabilitating or replacing source protection or augmentation infrastructure**	**Costs of (or subsidies for) rehabilitating or replacing RWH infrastructure, storages, filtration equipment**	**Costs of rehabilitating or replacing RWH infrastructure, storages, filtration equipment**
CoC *Costs of capital*	**Costs of interest payments:** interest on bank loans, micro-credit charges	**Cost of interest payments:** interest on bank loans, micro-credit charges	**Cost of interest payments:** interest on bank loans, micro-credit charges
ExpDS *In-country post-construction direct support costs*	**Direct support costs:** any direct support costs related to source protection or augmentation activities or interventions	**Direct support costs:** staff costs, DSAs, travel costs for routine site visits, overhead costs, training and capacity building course actual costs (incl. unit cost of running training centre), water quality analysis etc.	**Direct support costs:** any user fees or contributions to support organisations
ExpIDS *Indirect support costs at the international level*	**Engineering design**	**Indirect support costs**: Staff inputs and management overheads of international staff, any ancillary costs	**Indirect support costs:** any user fees or contributions to support organisations

Source: Fonseca et al., 2010

2.4 Water supply service levels required to analyse costs

As discussed earlier, comparison of the costs of different supply systems is fraught with difficulties not least because systems are rarely compared based on a like for like terms for the services provided. Hence for any comparison to have any value it is important to have good understanding of the service levels that can be achieved and sustained with different types of water supply systems. This is an approach different from the mainstream approach that derives financial and economic benefits commonly used in cost-benefit analyses.

Increasingly, the WASH sector is differentiating between the water supply service received by users and the infrastructure used to provide this service. For example, until recently the Government of India used infrastructural coverage as the main indicator of whether or not expenditure on water supply was achieving its desired normative outcomes. The 2010 National Rural Drinking Water Programme Guidelines (Government of India Department of Drinking Water Supply, 2010) have signalled a major shift in policy by emphasising that access to infrastructure does not equate to having a service. Most importantly, these new guidelines recognise the day-to-day reality of rural water supply users who are unable to access water of an adequate quantity and quality to meet their demands owing to poorly maintained infrastructure, or because sources are dwindling and/or polluted.

The most common service level indicators against which the quality of service can be assessed include: **quantity** - measured in litres per capita per day (lpcd); **quality** - typically comprising of a set of permissible limits for chemical and biological pollutants; **reliability or security** - typically defined as the proportion that a specified service level is achieved; and, **accessibility** - typically defined in terms of distance to a water point or the level of crowding around a water point.

Table 3 on next page compares the services provided by RWH and groundwater based water delivery systems. A conclusion that can be drawn from this general overview is that there is no such thing as a perfect water supply system in terms of the services that are provided. Put another way, all water delivery systems have their pros and cons. An important element of selecting and designing effective delivery systems is, therefore, to recognise the inherent strengths and weaknesses of different systems.

Table 3 **Comparison of the services provided (pros and cons) by RWH and groundwater-based delivery systems**

		Private RWH System *(e.g. roof water harvesting system supplying a single household under gravity)*	**Private Groundwater System** *(e.g. a borehole and pump supplying water to one household)*	**Public RWH System** (e.g. a sand dam feeding a piped water supply to a village under gravity)	**Public Groundwater System** *(e.g. a borehole(s) and pump feeding a piped-water supply)*
Quantity	**Pros**	If designed correctly and no major design constraints, will provide sufficient water to meet most demands	If designed correctly, will provide sufficient water to household and MUS demands	If well sited and aggregate demand is appropriate, can meet household and MUS demands	In most settings, the supply system of choice because supply will meet household and MUS demand
	Cons	If there are major design constraints (e.g. limited catchment area, low rainfall), may not be suitable as primary water source to rely on	CapEx and OpEx per m^3 will generally be higher than for a private RWH system	If stream flow variability is high, may not be suitable as a primary source. Users at the tail-end of pipelines may receive less water	Users at the tail-end of pipelines may receive less water
Quality	**Pros**	Generally the quality of water is better than unprotected water sources	Quality will generally be higher than for RWH systems	Quality may be higher than many unprotected sources and taste may be better than stored water	Quality will generally be higher than for RWH systems
	Cons	It may be necessary to treat or disinfect the water and there may be cultural objections to drinking stored rainwater	May not be a good option when aquifer is affected by pollution, salinity, arsenic, fluoride etc.	Quality will depend on presence of pollution sources upstream	May not be a good option when aquifer is affected by pollution, salinity, arsenic, fluoride etc.
Reliability	**Pros**	Under the control of the HH; unaffected by irregular power supplies; cheap and easy to maintain	Under the control of the HH and unlikely to be affected by prolonged meteorological drought	Can store relatively more water than RWH systems at similar annualised CapEx per m^3	Unlikely to be affected by prolonged meteorological drought
	Cons	Can be affected by a prolonged drought, a small catchment areas or excessive demand	In many settings, groundwater levels will decline If all households install boreholes	May be affected by upstream storages and land uses that reduce base flows. May also be affected by functionality of WUG	May be affected by the functionality of the WUG and/or groundwater overdraft
Access	**Pros**	Only available to households with a house, adequate roofing, and ability to pay for a system	Only available if favourable hydro geological conditions prevail and if households are can afford the CapEx & OpEx	Will be a better source of water than fetching and carrying from some distance	Will be a better source of water than fetching and carrying from some distance
	Cons	Unlike a piped water supply, supplies cannot be affected by other users or illegal connections	Similar to RWH access to water unlikely to be affected by (in)actions of others or water user committees	Access may be affected by design of piped water system, illegal connections and system losses. Sand dam may impact of downstream water users	Access may be affected by design of piped water system, illegal connections and system losses

Source: Own elaboration, 2011.

3 Results and discussion

This section starts with a comparison of the costs of different RWH systems albeit not their respective full life-cycle costs. This is followed by a comparison of the costs of RWH systems with other water supply technologies, taking cognisance of differences in economies of scale and inter-regional costs. It concludes with a recommendation to also consider the importance and scale of post-construction support costs.

3.1 Costs relative to the supply system

Using data from RAIN Foundation case studies, Table 4 compares the CapEx and OpEx of a number of different RWH systems in Nepal, Mali, Kenya and Ethiopia. The table illustrates clearly that most expensive systems in terms of CapEx are not necessarily the most expensive when unit costs are considered. For example, a sand dam in Kenya, while having the highest CapEx cost, is found to have a relatively low CapEx per m3. Similarly, of the four Nepalese RWH systems, the RCC tank system is recorded as having the highest total CapEx, but the lowest CapEx per capita. Similarly, this also applies to OpEx. Annual OpEx for the RCC tank system is highest but annual OpEx per capita is the lowest of the four Nepalese RWH case studies.

Figure 2 (see next page) compares the costs of several types of water supply system in Kenya. Although the costs presented are not full life-cycle costs, nor are they annualised[10], they do include labour and material inputs. Notably, all these costs were assessed at the same time, in the same country, using the same methodology. Figure 2 shows that RWH systems that require storage tanks are relatively expensive as compared to rock catchment dams, hand-dug wells and piped water schemes. Figure 2 also gives an indication of the range of costs for RWH systems using storage tanks (i.e. approximately US$ 25-160 PPP2008 per m3 supplied).

Table 4 Comparison of CapEx and OpEx of different RWH systems

RWH System	CapEx (US$ PPP 2008)				OpEx (US$ PPP 2008)			TotEx (US$ PPP 2008)	
	Total	Annualised	Annualised per m^3	Annualised per capita	Annual	Annual per m^3	Annual per capita	Annual per m^3	Annual per capita
Nepal									
Stone masonry (10 m^3)	680	34	3.4	4.8	4.4	0.5	0.6	3.9	5.4
Ferrocement jar (6.5 m^3)	638	31.9	4.9	6.4	5.6	0.9	1.1	5.8	7.5
RCC tank (60 m^3)	5730	287	4.8	0.5	8.9	0.2	0.02	5.0	0.5
Ferrocement tank (20 m^3)	4082	204	10.2	1.1	6.7	0.3	0.03	10.5	1.1

(Table 4 continued on next page)

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[10] These data were not annualised because lifespan information was not documented.

RWH System	CapEx (US$ PPP 2008)				OpEx (US$ PPP 2008)			TotEx (US$ PPP 2008)	
	Total	Annualised	Annualised per m^3	Annualised per capita	Annual	Annual per m^3	Annual per capita	Annual per m^3	Annual per capita
Ethiopia									
Sand dam (400 m^3)	12144	607	1.5	-	-	-	-	-	-
Kenya									
Sand dam (1750 m^3)	17966	898	0.5	6	89.8	0.05	0.6	0.55	6.6
Mali									
Ferrocement jar (13.6 m^3)	1388	69	5.1	-	-	-	-	-	-

Source: RAIN Foundation, unpublished.

Notes: A lifespan of 20 years was used for all systems when annualising CapEx; Annualised costs per m^3 are based on the volume of storage rather than volume of water supplied; The RWH system CapEx does not include costs of roof construction or guttering; The Kenya sand dam OpEx was estimated as 10% of annualised CapEx by Tuinhof*,* van den Ham and Lasage, 2011.

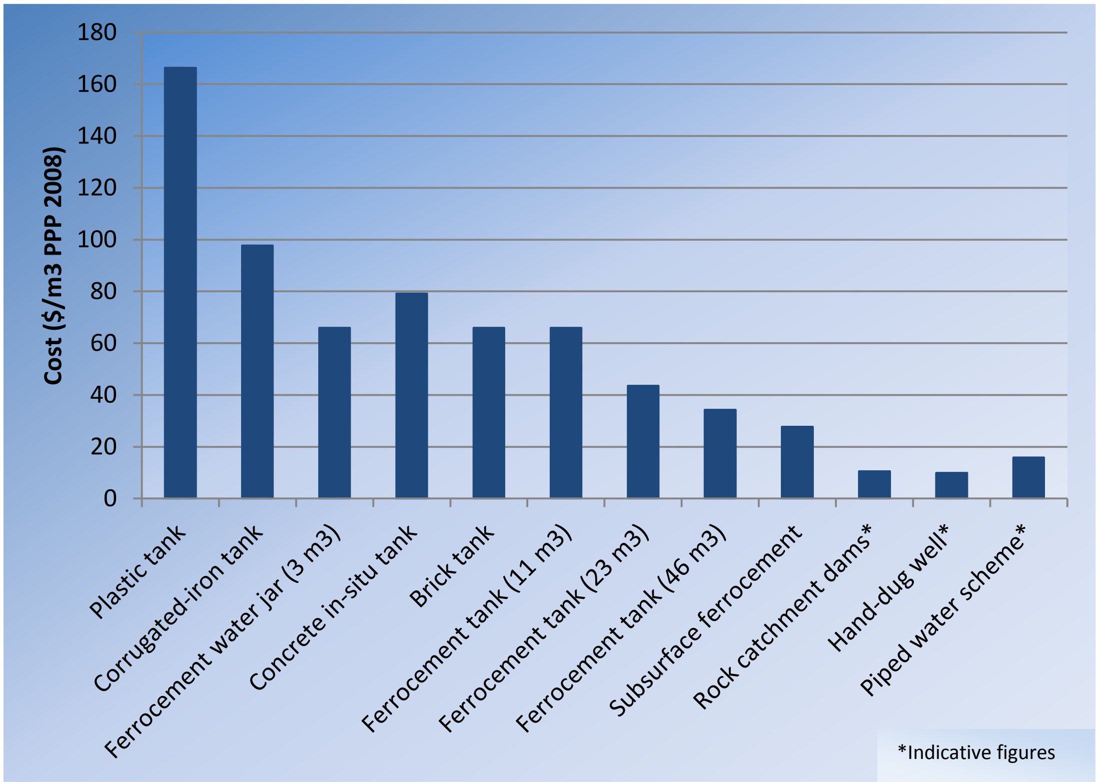

Figure 2 **Comparison of costs of water tanks (including labour and materials), Kenya**

Source: Gould and Nissen-Petersen, 1999.

Although a useful starting point for comparing different water storage options, Figure 2 has its limitations and only tells half of the story (Gould and Nissen-Petersen, 1999). This is because key information that may provide a more accurate picture of the actual life-cycle costs of services that are provided are lacking. Missing information includes:

- Number of users of the tank (e.g. number of people or households) and range of uses of the tank water (e.g. domestic, livestock, etc.)
- Expected frequency that the tank will fill (e.g. fills per year). This needs to take into account inter and intra rainfall variability, size of the catchment area and the size and frequency of rainfall events
- The rate at which water is used (e.g. l/day) because rate of extraction from the tank influences the total water caught by the tank
- Lifespan (or expected life) of the tank. The concepts, lifespan and expected life are relatively simple in that they refer to a period of time between installation of a system component and its replacement (or abandonment). However, putting absolute figures of life spans is not easy because: 1) published information on lifespan is often based on conventional wisdom or beliefs rather than empirical data; and 2) the functionality and/or utility of system components often dwindle over a period of time (e.g. the discharge of a pump declines, the distribution losses from a piped system increase) and, as a result, the services provided by a system slip incrementally rather than remaining at a constant level up until the time that a component fails catastrophically. An implication of the this process of slippage is that OpEx per m3 can increase over time because the total volume of water supplied by a system declines whilst total OpEx remains the same (or possibly increases)
- Information on support and capital maintenance costs

Figure 3 on next page compares the per capita CapEx costs of RWH systems with other types of water supply systems commonly used to provide water services in rural areas. The data used in Figure 3 is derived from a literature review focusing on the most quoted unit costs during the period 1990-2010. Given that different methodologies have been employed to calculate costs in these studies, some caution is warranted when considering both the absolute and comparative costs. This said, at approximately US$ 100 per annum, the CapEx cost of RWH systems is: 1) higher than many of the technologies presented in this figure (e.g. hand-dug wells, protected springs); and 2) broadly similar to annualised CapEx costs of the RWH systems presented earlier in Table 4[11]. However, the unit cost of RWH is considerably lower than that of medium piped water supply or, somewhat surprisingly, shallow wells with a hand pump in Africa.

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[11] Note the annualised per capita CapEx data in Table 4 can be converted to per capita CapEx data by multiplying by 20 (i.e. the assumed lifespan of these RWH system components).

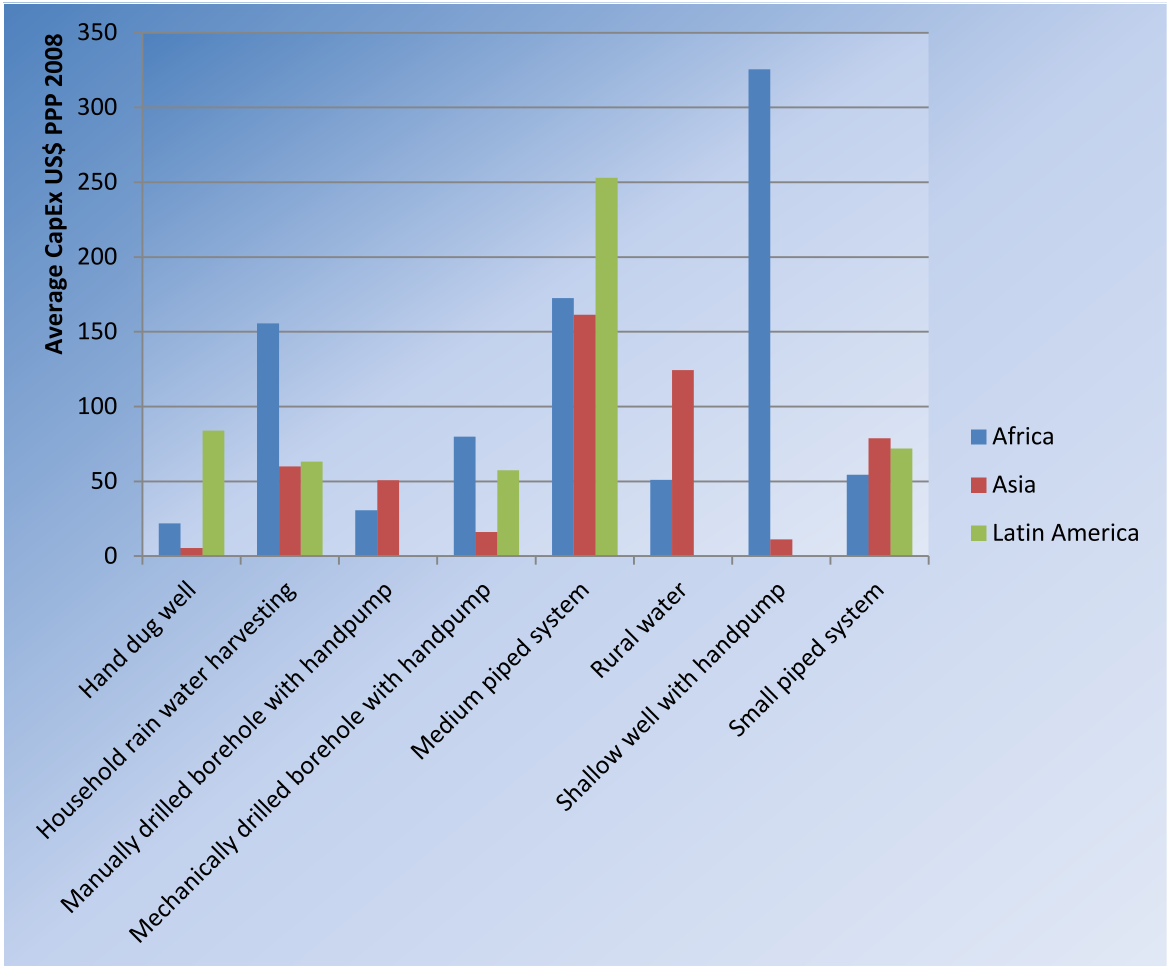

Figure 3 **Average per capita CapEx (US$ PPP 2008) of water supply systems**
Source: Fonseca, forthcoming.

3.2 Economies of scale in RWH systems

Figure 4 on next page compares the cost of the RWH systems that have storage tanks (already presented in Figure 2) with the volume of the storage tanks. It shows that across the range of rainwater storage tanks, cost increases with volume, but economies of scale (i.e. cost per unit volume decreases with increasing storage volume) will also need to be considered. The outliers on this scatter plot are the rock dam catchment and the plastic tank.

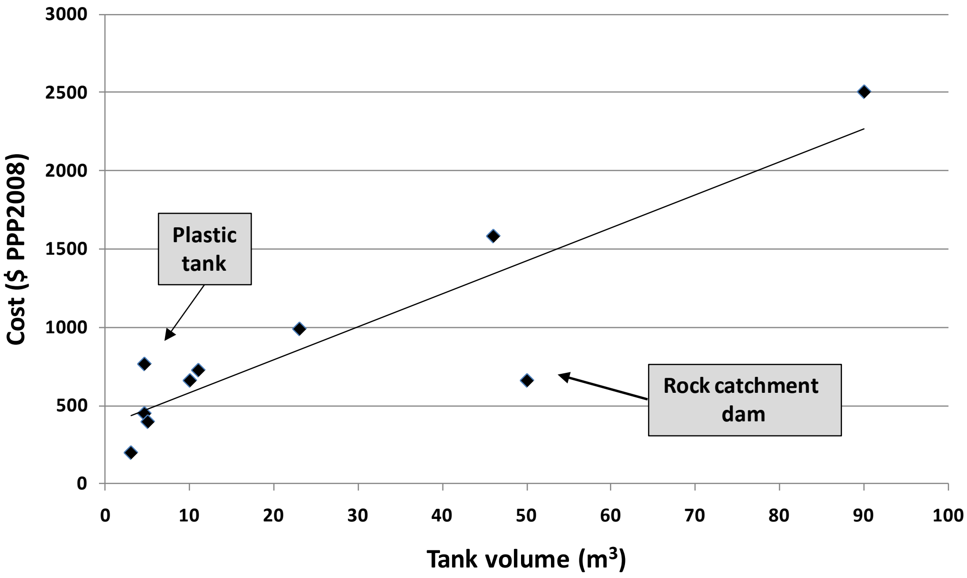

Figure 4 Comparison of RWH system CapEx (labour and materials) with storage tank volume, Kenya

Source: Gould and Nissen-Petersen, 1999.

3.3 Influence of lifespan and climate on costs of RWH

Table 5 highlights the important influence of RWH system lifespan and the probability of annual fill on the cost of water storage. In this table the typical cost range per m^3 is calculated for three lifespan scenarios. As mentioned earlier, the volume of water harvested and provided by a RWH storage tank is a function of annual rainfall, size and distribution of rainfall events, size of catchment area and the rate at which water is withdrawn from the tank. In an arid environment with erratic rainfall and a limited catchment area, the average annual supply may be equivalent to only one tank volume. The overall conclusion here is that the unit cost of catching and storing water increases with reduced lifespan and reduced rainfall. But in the case of reduced rainfall, the intrinsic value of harvested water may increase in a low-rainfall context

Table 5 Cost of storage under three RWH system lifespan scenarios

Annual catch/provision (tank fills/year)	Cost of water (US$/m3 PPP 2008)		
	10 years (Pessimistic)	20 years (Realistic)	30 years (Optimistic)
1 (Arid)	2.6 – 15.8	1.3 – 7.9	0.9 – 5.3
2 (Semi-arid)	1.3 – 7.9	0.7 – 4.0	0.4 – 2.6
5 (Semi-humid)	0.5 – 3.2	0.3 – 1.6	0.2 – 1.1
10 (Humid)	0.3 – 1.6	0.1 – 0.8	0.1 – 0.5

Source: Gould and Nissen-Petersen, 1999.

3.4 Regional differences in CapEx and OpEx of RWH systems

Figure 3 on page 23 illustrated that the CapEx (labour and materials) of RWH systems tends to be higher in Africa as compared to Asia and Latin America. Leaving aside the fact that these comparisons are not like for like and are based on a limited sample, Table 6 shows that CapEx and, in this case, OpEx of household RWH systems tends to be higher in Africa than in Asia or Latin America. Further, regional OpEx estimates are very low when compared to CapEx, regardless of whether CapEx is annualised. Notably, Table 6 also reveals that in some countries the per capita OpEx costs are rather low, and in Kenya for example, indicative figures reveal that per capita CapEx cost is (unrealistically) high.

Table 6 Regional CapEx and OpEx cost per capita comparison of RWH systems

Reference	Location/region	CapEx (PPP US$ per capita 2008)	OpEx (PPP US$ per capita 2008)
GoU (2008)	Uganda	45.7	17.7
Hutton and Bartram (2008)	Africa	86.1	0.6
Hutton and Bartram (2008)	Asia	60.0	0.4
Hutton and Bartram (2008)	Latin America	63.2	0.4
WSP, PEMConsult and Frame Consultants (2005)	Kenya	335.3	4.8
Smits and Fonseca (2007)	Low income countries	45.2	-

Source: Fonseca, 2010.

In 2009, Enterprise Works/VITA (2009) undertook a desk study of RWH programmes across 20 locations that included developing countries and regions in Africa, Asia, and the South Pacific along with wealthier countries and regions with relatively developed markets for RWH systems. The study found that across the board cement-based storage technologies (jars and tanks) tended to be the cheapest. In a number of instances in Asia for example, water storage costs amounted to less than US$ 40 per m^3 of storage. Differences between costs in Asia and Africa were attributed to differences in the like for like costs of cement-based products. Whilst the aims and results of this study were interesting, the thrust and philosophy was directed at identifying low-cost RWH systems. The study was aimed at finding RWH storage solutions that could be marketed, sold and installed for less than US$ 40 per m^3, including enterprise profit. There is merit in this aim but, as shown in this report, systems with the lowest CapEx costs do not always have the lowest annualised CapEx or life-cycle unit costs, nor do they always have the best cost-benefit ratio when the services provided by the system are taken into account.

The RAIN data presented in Table 4 (see pages 20 - 21) does not show obvious regional differences. CapEx per m^3 of storage for RWH jars and tanks is in the range of U$ 68-204 PPP 2008 (with a mean of US$ 113), whilst CapEx per m^3 of storage for sand dams is in the range US$ 10-30 PPP 2008.

3.5 Life-cycle costs of water supply systems

Table 7 compares the annualised LCC components in four different water supply systems in Andhra Pradesh, India. Although this table does not include data on RWH systems, it illustrates the relative magnitudes of different life-cycle costs components and reveals that many households invest in their own services, at levels that could support the capital and recurrent costs of a RWH system.

The figures in Table 7 are based on data collected from over 30 villages by the WASHCost Project[12]. The figures show that village mean service levels based on volume of supply (in lpcd) are similar across all systems, but annualised village mean CapEx per household ranges from US$ 13 to US$ 57. Annual OpEx is significantly lower than annualised CapEx and the magnitude of OpEx is linked to the relative complexity and scale of the technology used (i.e. OpEx was lower for direct pumping schemes as compared to more complex multi-village piped water supply schemes).

An interesting finding arising from this study reveals that the village mean household capital expenditure (CapEx (HH)) is significantly higher than expected most notably, in areas where single-village schemes are implemented. Level of CapEx (HH) expenditure is also found to be a good indicator of whether or not the public supply system was providing an adequate service level. Some indicators used include: were households that willing and able to pay, were households responding to inadequate service levels by: constructing water storage tanks, buying pumps to extract water from the piped water supply network and paying for illegal connections to pipelines. It should be noted that the last two household responses mentioned as indicators have significant negative trade-offs because they disrupt the hydraulic integrity of the supply network and exacerbate “tail-end” water supply problems.

Table 7 Comparison of annualised cost per household, Andhra Pradesh

Technology	Life-cycle costs components (US$ per household PPP 2008)					Service level (lpcd)
	CapEx	CapEx(HH)	CapManEx	OpEx	CoC	
Direct pumping	57	-	-	1	13	60
Mini-piped water supply	13	24	3	6	12	56
Single-village scheme	13	57	0.4	5	12	58
Multi-village scheme	23	28	1	28	20	62

Source: WASHCost.

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[12] See *http://www.washcost.info*.

In addition to collecting and analysing data on CapEx (HH) at the village level, the WASHCost Project mapped this expenditure along with service levels (based on a water quantity). Figure 5 shows the considerable spatial variation in one-off CapEx (HH) in a typical village in Andhra Pradesh. Investment by many household was in storage tanks at a level that could easily have supported construction of a RWH system (i.e. around US$ 100). However no instances were recorded of households investing in the additional components needed to fill these tanks with harvested rainwater. Storage tanks were invariably filled with water from the public supply system. From the surveys carried out, it was not clear whether this choice was based on a preference for water provided by the public supply system or a lack of awareness of the potential benefits of RWH.

Figure 5 also shows that there is considerable variability in service levels in the Bandasomavaram village in Andhra Pradesh. Similar levels of variability in household expenditure and service levels were observed in the other thirty villages that were surveyed. Focus group discussions indicated that many factors influence the ability of households to invest in water systems (e.g. income level, livelihood diversification, outside remittances etc.). However the main factor determining willingness of a household to invest in the provision of their own water services was whether or not the level of service provided by public supply was perceived to be adequate.

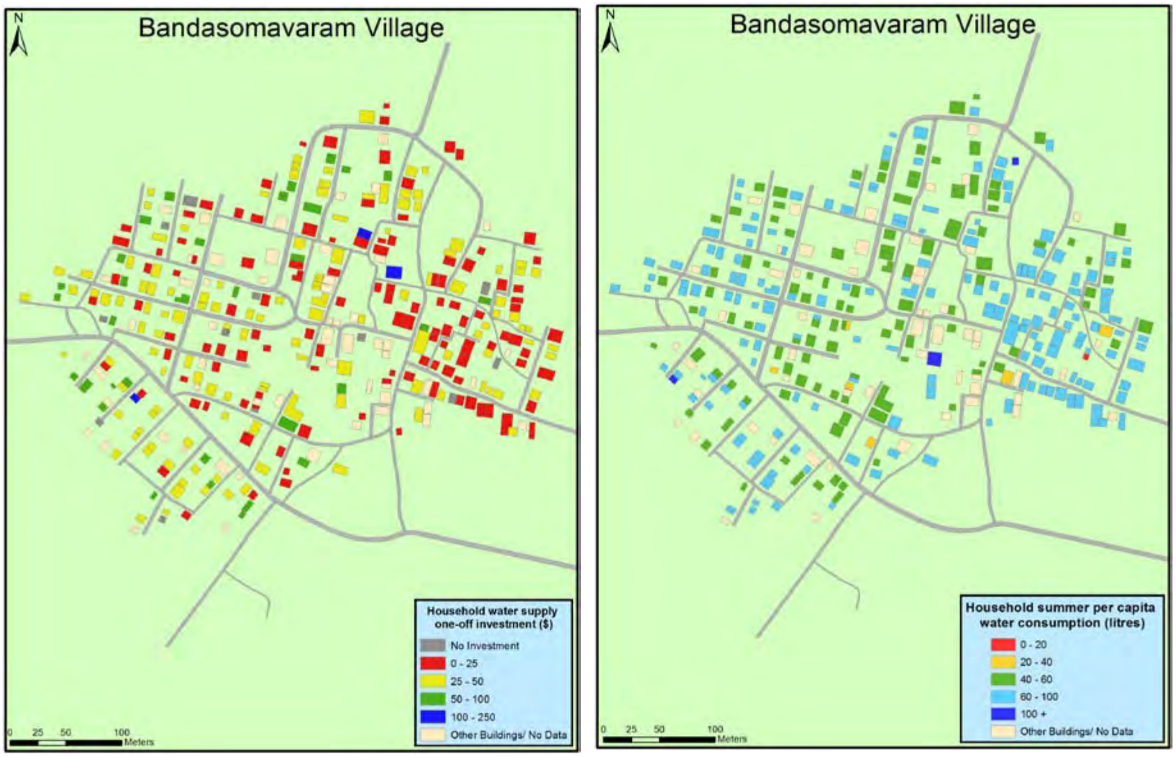

Figure 5 **Maps of household CapEx investment in water supply and household water service levels, Bandasomavaram village, Andhra Pradesh**

Source: WASHCost.

Table 8 illustrates the non-linear relationship between per capita costs and the different levels of services provided by different types of water supply technology. Although this table does not include RWH systems, the main point to note is the order of magnitude leap in costs between the most basic level of hand pump service and all subsequent "improved" services. In particular, the first step up the ladder from a rural hand pump to a public stand post delivers no additional water for a 12-fold increase in CapEx and a 3-fold increase in OpEx. This highlights the fact that, in many circumstances, investment in RWH can be a cost effective means of improving service levels.

Table 8 Incremental costs of providing domestic water supply in South Africa

Technological service level	Rural hand pump	Rural public stand post	Urban yard tank (low pressure)	Urban roof tank (medium pressure	Urban household connections (full pressure)
Typical consumption	20-35	20-35	35	80	165
CapEx (US$/HH PPP2008)	35	420	535	645	725
OpEx (US$/HH/yr PPP 2008	6	23	32	40	62

Source: Moriarty and Butterworth, 2003.

3.6 Expenditure on post-construction support

Well-documented empirical information on the costs of post-construction support for households or communities using RWH systems is limited. The RAIN Foundation estimates that, over a number of years, post-construction makes up around 10% of the total expenditure of a RWH system (pers. comm.). Table 9 presents the operating and support costs that were needed to manage water supply systems in two district municipalities (DM) in eastern South Africa (Gibson, 2010).

Table 9 Comparison of Opex and ExDS versus service levels for two water supply systems, in South Africa

Area name	OpEx + ExpDS (US$ per year PPP2008)	Service level components	
		Water quality	Continuity of supply
Chris Hani DM	67.6	98%	96%
Alfred Nzo DM	29.1	83%	84%

Source: Gibson, 2010.

Gibson's (2010) study found that post-construction technical support costs were large in absolute terms and relative to other costs. Costs for technical support and transport represented 52% and 65% of the total operating costs for the two project areas respectively. It also concluded that: 1) public water supply schemes in rural areas need and benefit from effective technical and managerial support; 2) consideration should be given to the “repair-ability” of supply systems during system design; and 3) the main cost drivers of O&M and support to rural water supply schemes must take cognisance of the type and complexity of the infrastructure, the remoteness of schemes, and the number of schemes to be maintained (i.e. economies of scale of direct support costs). Although the study did not encompass RWH systems, it raises issues and makes recommendations relevant to the design and implementation of RWH programmes -- especially in areas with systems and/or programmes organised by community-based management. The study also gives an indication of the additional costs for providing support to communities in remote areas.

4 RWH: historical trends and drivers

In areas with a long tradition of RWH, the decline in the popularity of RWH can be attributed in part to the arrival of cheaper and more convenient water supply systems. In India and Sri Lanka, for example, interest in RWH dwindled as communities became increasingly reliant on groundwater-based public supply to meet their domestic needs, and private investments in boreholes to meet landowners' demand for irrigation water. In the late 1990s, an upsurge in RWH was prompted by massive publicly-funded watershed development and tank rehabilitation programmes. But, in both cases, the emphasis was on using RWH to increase water availability for agriculture rather than domestic supply. Around the same time, water supply departments also started investing in source protection or augmentation measures such as check dams and other recharge structures. Relatively less attention was given to promoting or supporting household level RWH. In the few instances that household level RWH was promoted, the emphasis has often been on groundwater recharge rather than catching, storing and/or utilising rainwater.

Similarly in India during the last 3-4 years, the massive Mahatma Gandhi National Rural Employment Guarantee scheme funded the labour component of groundwater recharge activities rather than RWH supply systems.

In cases where governments funded RWH, the quality of design and construction tended to be unsatisfactory. The EWV study (EWV, 2009) noted that in Tamil Nadu, many RWH systems were poorly installed and maintained because the impetus for purchase came from a government mandate, rather than user demand. The study also found that the skill of the RWH suppliers and technicians ranged widely and few component providers specialised in rainwater harvesting equipment or installation. Overall, these trends point out that, in many countries, expenditure on RWH has been increasing however, expenditure was primarily focussed on augmenting water supplies for agriculture rather than domestic supply.

4.1 User preferences

The EWV study (2009) found that the popularity of RWH in the countries and locations reviewed depended to a great degree on the availability of government-provided piped water. Because of its convenience, consumers with access to piped water were less inclined to install rainwater harvesting systems. One caveat, however, was the occurrence or expectation of a crisis. For locations faced with a water crisis, it was observed that governments were more inclined to promote or mandate RWH installations. Similarly, consumers were seen to have invested significantly towards technology. Additionally, a tradition of rainwater harvesting increased the likelihood of adoption of modern RWH systems or technologies.

In a survey of user preferences and perceptions, the EWV (2009) study noted that user opinions of rainwater and RWH were generally positive. In relatively more developed areas, many users were reported to have a liking for RWH systems as they were seen to be environmentally friendly options. Others considered RWH systems as "modern" befitting of today's trends. A few however, disliked the taste of harvested rainwater, upkeep activities that accompany its maintenance (such as sweeping roofs and courtyards in advance of a rain event), and the lack of adequate storage for reliable and year-round supply of harvested rainwater.

When comparing RWH to other systems of supply, the EWV survey concluded that in general, rainwater is not considered a favoured source of drinking water -- even when taste and quality were not considered factors behind preference. The convenience and aspirational nature of piped water make it the preferred option. In most places where piped water is available, piped water is preferred for its convenience (in-home), its costs (usually fairly cheap), and it is presumed to be safer than rainwater. Consumers without access to piped water, however, rank rainwater a little higher over other alternatives. While users did not necessarily consider RWH to be more reliable than gathering water from a stand pipe or stream because of the seasonality of supply, in almost all cases -- rainwater was considered to be a better supplementary or secondary source of supply, when compared to other alternatives.

4.2 Long-term role of RWH and water scarcity

Increasingly, water is a contested resource even in areas that are relatively well endowed with water resources. The common perception is that *water shortage* (i.e. an absolute shortage of water supply in a specified domain) is the main reason for this state of affairs. However, the reality is that *water scarcity* (i.e. an excess in water demand over available water supply in a specified domain) is by far the biggest challenge.

The drivers of water scarcity crisis are well known. Water use has been growing globally at more than twice the rate of population increase in the last century. Currently, it is observed that an increasing number of regions are reaching the limit at which reliable water services can be delivered. Essentially, demographic growth and economic development are putting unprecedented pressure on renewable, but finite, water resources especially in semi-arid to arid regions. It is clear also that the situation is being exacerbated as rapid urbanisation increases competition for water resources, and where urban areas are increasingly becoming an important source of water pollution. Moreover, there is increasing recognition that environmental services and ecosystem functions should not be treated any longer as the residuals of all water users. Finally, climate change and bio-energy demands have the potential to amplify the already complex relationship between world development and water demand.

Much of the current debate is driven by a perception that water resources are becoming increasingly scarce as a result of trends that are, to some extent, unavoidable (e.g. population growth and, as a result increased demand for water for food production and domestic, industrial and municipal uses). This prompts the use of emotive terms such as “water crisis”. The simple fact however remains that the more predictable challenges (i.e. potential crises) can be avoided or mitigated by revisiting, changing and improving upon the way in which water is being managed and governed (Moriarty, Butterworth and Batchelor, 2004). With improvements in water management and governance, there is no reason -- even in the driest parts of the world -- why water cannot be equitably, efficiently and sustainably distributed to meet people’s most basic human (and environmental) needs.

Whilst they are not a panacea, RWH systems also enable people at household and community levels to manage their own water, thereby reducing reliance on public supply systems especially when these are either unreliable or difficult to access. Arguably, household RWH systems provide a more resilient and cost-efficient means of improving household water security than constructing ever more complex and expensive public water supply systems. In India, for example, the 2010 National Rural Drinking Water Programme Guidelines (Government of India Department of Drinking Water Supply, 2010) give high priority towards improving water security through the development and implementation of District and Village Water Security Plans that facilitate improved and increased access to water supply systems by users. The guidelines rest on a logic that when a supply system fails – another system exists to supply the water demands and needs of users.

In some areas in India, RWH is now being promoted as a secondary supply system (e.g. Churu District in Rajasthan). However other state governments continue to promote the use of extremely expensive state-wide water supply grids. Strong arguments for national campaigns (in India and elsewhere) to promote household RWH as a means of improved household water security as one of two water supply systems include:

- In many cases, proposed water supply grids compete for surface and ground water that are already under pressure. In the long run, water supply girds may prove to be less reliable or sustainable than household RWH systems.
- Water supply grids are very expensive in terms of CapEx, OpEx and CapManEx given the non-linear relationship (see Section 3.5) between LCC and the complexity of supply systems or services provided.
- In terms of management, household RWH is often more resilient than public supply systems because they do not rely on a proper functioning government or community-based institutions.
- From the RWH perspective, it makes good sense to promote RWH systems as one of two supply systems given that many RWH systems do not have the same buffering potential as groundwater-based systems. Put another way, many RWH supply systems are more susceptible to prolonged drought as compared to groundwater-based system.

Of course, in many countries, providing access to one safe source remains an immediate challenge. In many places in Latin America, governments do not actively promote or provide RWH systems. Where these exist, households themselves have seen through the construction of RWH systems using their own funds or with the help of NGOs working in isolated communities. Government engineers opt for conventional piped supply systems and RWH is rarely considered, even as a secondary source. In the Colombian Pacific coast for instance -- recorded to have one of the highest rainfalls in the world -- many villages and towns are provided with expensive piped water systems (as opposed to RWH systems), many of which had quickly fallen into disuse and disrepair. In response to this, households themselves have taken the responsibility to install their own RWH tanks. Based on the experience of communities in Latin America, it therefore becomes clear that many government engineers and officials continue to be unfamiliar with RWH and/or the potential benefits of using RWH systems.

Clearly, RWH will continue to provide an attractive and cost-effective means of water supply in areas that have ground or surface water quality problems (e.g. as a result of pollution or natural contaminants such as fluoride or arsenic). Similarly, RWH systems can continue to play a cost-effective role in the development of multiple use water services (MUS) that ensure access to sufficient water for small-scale productive uses (e.g. livestock, horticulture, backyard gardening and other small-scale enterprises).

The general conclusion is that water scarcity is an increasingly serious problem even in areas that are relatively well endowed with water resources. Household RWH could and should be promoted as a mainstream option for improving water security, financed by a combination of public and private expenditure. This said, attention has to be given to the findings of user preference studies. At one level, to find practical solutions to real issues (e.g. problems with taste) and at another, to make modern RWH aspirational in many developing countries in the same way that it has become aspirational (and trendy) to use RWH in many developed countries. Finally, RWH is rarely integrated into water management strategies as these usually focus exclusively on surface water and groundwater (FAO, 2006). Countries need to integrate rainwater harvesting more fully into their integrated water resource management strategies and to promote its use to alleviate poverty and water scarcity.

4.3 Unlocking potential household investment in RWH

Much public sector funding is spent on hardware subsidies. It is estimated that for government and NGO-supported rural water supply schemes across Sub-Saharan Africa, between 90 and 100% of the hardware costs are externally financed (i.e. not paid for by the community) (RWSN, 2009). Given that each scheme requires significant funding, the ability of government and NGOs to reach more communities is constrained. This does not acknowledge or capitalise on other sources of funding, especially money from communities and households themselves. Nor does this create an ideal environment in which local artisans can flourish and affordable RWH and other technologies are developed or adapted to meet local demand and preferences.

The Rural Water Supply Network and others suggest that the best way to utilise public funds may not always be to subsidise hardware. Instead, much greater recognition should be given to: 1) the financial contribution that many households and communities could make to improve their own water supplies; and 2) improving the knowledge at skills of local institutions, service providers and artisans so that they actively encourage households and communities to improve their own water supplies.

4.4 RWH and global trends

Many of the threats to sustainable and equitable water service delivery are outside the control of the water sector. These include: climate change, peak oil[13], economic downturns, population increase and civil unrest. Some of these threats are immediate and predictable (e.g. population increase) whilst others are uncertain in terms of severity, precise nature and timing (e.g. climate change). There are also threats that are completely unknowable and highly improbable but that could have major impacts[14].

Climate change: Clearly RWH can and should play an important role in climate adaptation programmes and or programmes aimed at improving the resilience of water services to a wide range of threats. As important, household RWH systems (e.g. roof water harvesting) are an obvious option for funding under "no or low regrets" expenditure programmes. Similarly RWH aimed at improving recharge will be, in most cases, a better option than, as discussed, constructing national water grids[15]. In many contexts, there is a strong argument for directing "no or low regrets" and, in some cases, employment guarantee expenditure towards construction of household and community storage that can be filled by RWH systems. In some cases, this could involve a dual storage system, with public water supply water storage for potable uses and RWH storage for household and MUS uses.

Peak Oil: RWH systems can be designed to rely entirely on gravity. As such, RWH could play an increasingly important role as energy costs increase and as pumped water supply systems become more expensive.

Economic downturn: RWH systems are good options when public finance is in short supply. This is due in part to the capacity for partial funding by individual households or communities, and because RWH systems may be constructed incrementally (e.g. a household can start with a small-capacity system that is enlarged over time).

Population increase: The Comprehensive Assessment (CA) of Water Management in Agriculture (2007) posed the question: "*Is there enough land, water and human capacity to produce food for a growing population over the next 50 years – or will we "run out" of water?*". The CA answered this question with the following: "*It is possible to produce the food – but it is probable that today's food production and environmental trends, if continued, will lead to crises in many parts of the world. Only if we act to improve water use in agriculture will we meet the acute freshwater challenges facing humankind over the coming 50 years*". Or put another way, "business as usual" is not an option. Real changes are needed in the way in which water is governed and used if transient or long-term crises are to be averted. Clearly RWH systems can be used as part of a strategy for:

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[13] *Peak oil* is the point in time when the maximum rate of global petroleum production is reached, after which the rate of production enters will go into terminal decline.

[14] See Taleb (2007) for an interesting discussion on events that are unknowable, highly improbable but have the potential to derail the best thought-out strategies and plans.

[15] See van Steenburgen and Tuinhof (2010) for a more detailed argument for this approach.

- Reducing overall demand on public water supply systems that struggle to cope with rapidly increasing demand and inter-sectoral competition for water resources.
- Ensuring that return flows from non-depleting recoverable water uses (e.g. domestic water use) are used productively for fodder production or horticulture[16], for example.

Civil unrest: Public water supply systems rely on timely public expenditure and a proper functioning government and/or community-based institutions. As such, they are more susceptible to civil unrest than household RWH systems.

4.5 Externalities and safeguards of RWH

As discussed earlier a RWH system comprises the following hardware: a catchment surface of an adequate size (e.g. a roof), a storage reservoir and space to locate a reservoir, a reticulation system (e.g. gutters, pipes and fittings) and a means of extracting water from the reservoir and conveying it to where it will be used (e.g. a rope and bucket). Less obvious, successful RWH systems require software that include: cash or a source of finance; knowledge, capacity and/or skills for designing, constructing, operating and repairing a system; access, entitlements or tenure over a catchment area; a user group of some kind in the case of communal RWH systems and, the time and/or inclination to construct and operate a RWH system. Financing software requirements can be a major constraint for the poor or marginalised. It is important therefore, that any RWH programme either takes a pro-poor strategy that aims to overcome software constraints or, if this is not feasible, steps are taken to ensure that excluded groups have alternative water supply systems.

RWH system design should be based on rainfall probability analysis[17] and not on mean annual rainfall. The design should also estimate current or future demands for water on the system. If analysis foresees periods of drought years for example, safeguards should be put in place (e.g. an alternative, back-up or emergency supply system) to ensure that the most basic needs and met during these critical times. Intensive RWH systems, especially when coupled with increased groundwater extraction for irrigation, impact upon downstream water availability (Batchelor, Rama Mohan Rao and Manohar Rao, 2005). Safeguards should be put in place to ensure that intensification of upstream water use does not impact on the primary needs of downstream users and/or the functioning of important aquatic eco-systems. One of the conditions of sustainable water management is to clearly recognise and differentiate amongst what may be perceived as negative externalities. To illustrate, while runoff out of the considered wasteful watershed may be from a local point of view, it may serve as a key resource for surface withdrawals or recharge of groundwater for downstream users (e.g. people, aquatic ecosystems).

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[16] See Perry (2007) for an interesting discussion on depleting and non-depleting water uses.

[17] See Critchley and Siegart (1991) for a practical guide on rainfall probability analysis.

More positively, the promotion of RWH systems as a secondary source of water may reduce the negative trade-offs in some regions (e.g. southern India) caused by household expenditure aimed at compensating for the inadequate public water supply. As mentioned earlier, some households invest in illegal connections or small electric pumps that divert water from pipelines to their homes. Both illegal connections and small electric pumps may result in reduced water pressure and flow in pipelines, impacting negatively upon access to water by users found further down the system.

Safeguards should be put in place to ensure that RWH systems provide potable water that meets national drinking water standards. Rainwater is relatively free from impurities but the quality of rainwater may deteriorate during harvesting, storage and household use (WHO, 2011). Wind-blown dirt, leaves, faecal droppings from birds and animals, insects and contaminated litter on the catchment areas can all be sources of contamination. Poor hygiene, storage, and abstracting water from tanks or at point of use can also represent a health concern. However risks from these hazards may be minimised with good design and practice.

Conclusions

Determining life-cycle costs or aggregate costs to ensure the delivery of adequate, equitable and sustainable services to a population in a specified area is not easy. Numerous factors influence costs and the costs of a water supply system can vary considerably from place to place, and over time. This is further complicated by the fact that the life-cycle costs of an adequate, equitable and sustainable service are not completely dependent on the hardware component of a supply system. Software costs related to design, capacity building, institutional development, establishment of micro-credit systems and so on are equally important, but often rendered invisible or not relevant enough. With little attention paid to software costs, cost data reviewed -- even in this study -- is severely limited to hardware and engineering costs. Notwithstanding these caveats, it is possible to offer generalisations regarding the costs of services delivery. These are (not in order of importance):

- CapEx of RWH systems is relatively high when compared to systems that do not require storage tanks, but are relatively low when compared with, for example, groundwater-based piped water supply. However the most expensive supply systems in terms of CapEx, are not necessarily the most expensive when consideration is given to: 1) the number of users and uses of the system; 2) unit CapEx per capita, per m3 of storage and/or per m3 of water supplied; and, 3) annualised CapEx that takes into account the expected lifespan of the system.

- Typically, CapEx per m3 of storage for RWH systems using jars and tanks falls within the range of US$ 40-200 PPP2008, whilst CapEx per m3 of storage for sand dams is more likely to be in the range US$ 10-30 PPP2008.

- OpEx of RWH systems is relatively low when compared to boreholes and piped schemes. OpEx is also low when compared to CapEx. However when annualised CapEx is considered, OpEx is typically within the range 0-20% of annualised CapEx.

- CapEx of RWH systems in Africa is approximately double than that in Asia and Latin America.

- When the systems are designed and used according to a design specification aimed at meeting a household's primary needs, a typical borehole and hand pump system has lower CapEx per capita (around US$ 30-50 per capita PPP2008) than a typical RWH system (around US$ 50-100 per capita PPP2008). This point however is most likely to be incorrect, if there are a limited number of users of a borehole and/or a hand pump system.

- RAIN estimates that total post-construction support costs amount to around 10% of total costs. Intuitively this seems appropriate but clearly this percentage will increase for work in remote areas as a result of travel costs and increased staff inputs connected to time spent for travelling.

- Village-level averages of service levels, costs and expenditure mask many household-level realities (e.g. the low levels of service received by many poor households and/or households living towards the tail-end of water supply networks, or the high levels of variability in household expenditure on maintaining or improving service levels).

Cost comparisons, whether or not they are based on life-cycle costs or annualised, tend to focus on the costs water supply infrastructure. The result being that limited attention is given to the ultimate purpose of a water supply system -- that is, to provide a range of services. Based on the findings presented in this report, a number of interesting generalisations can be made regarding the influence of life-cycle costs on water services provided by water supply systems:

- Household level data from the WASHCost Project in India shows that households in rural villages are willing and able to make significant capital and recurring investments in their water services. In most cases, the primary aim is to compensate for the inadequate or unreliable services provided by the public water supply. Most common one-off investments in India are in storage tanks, pipes and fittings, illegal connections to the public supply system and small electric pumps that are used to extract water from the public supply system.

- In South Africa, Gibson (2010) reveals the potential benefits of allocating expenditure towards direct technical support, in terms of the levels of service provided by public supply systems. The study illustrates that, in terms of direct support costs, RWH systems that are privately owned and relatively easy to operate have significant cost advantage over more complex public systems. However this will not be the case when sand or check dams are used as a source of public supply.

- Also in South Africa, Moriarty and Butterworth (2003) show that higher levels of service tend to cost disproportionately more than lower levels of service.

Finally, a recent economic evaluation of water buffering concluded with a recommendation that a database should be established for consolidating cost information related to 3R measures (i.e. Rainfall, Retention and Reuse), and for making this information readily available (Tuinhof, van den Ham and Lasage, 2011). This study strongly supports this recommendation and suggests for broadening the scope of this database to encompass all life-cycle costs components (especially post-construction costs) and, as important, the information needed to annualise CapEx (hardware and software) in order to help calculate unit costs per capita and per m3 of water harvested and supplied/used.

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Collaborative partners

IRC International Water and Sanitation Centre (IRC) is an independent think-tank and knowledge centre for the international development sector focusing on Water supply, Sanitation, and Hygiene behaviour (WASH), and Integrated Water Resource Management (IWRM). IRC's staff facilitates a range of innovative research and learning support services with the aim of generating and sharing WASH related knowledge and information, and making them more accessible to, and better used by the sector.

IRC teams up with an international network of partners active in the public, private and non-governmental WASH development arena. With partners, IRC's work facilitates the achievement of sustainable WASH services in rural and peri-urban areas in developing countries.

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IRC International Water and Sanitation Centre

RAIN is an international network with the aim to increase access to water for vulnerable sections of society in developing countries - women and children in particular - by collecting and storing rainwater.

Started in December 2003, RAIN focuses on field implementation of small-scale rainwater harvesting projects, capacity building of local organisations and knowledge exchange on rainwater harvesting on a global scale.

RAIN aims to increase the access to water through developing capacity for the collection of rainwater, with a focus on regions where other means of water supply are not viable or available. RAIN projects use low-cost and simple technologies and are adapted to local conditions.

For more information, contact:
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RAIN Rainwater Harvesting Implementation Network

WASHCost is a five-year action research project investigating the costs of providing water, sanitation and hygiene services to rural and peri-urban communities in Ghana, Burkina Faso, Mozambique and India (Andhra Pradesh).

The objectives of collecting and disaggregating cost data over the full life-cycle of WASH services are to be able to analyse costs per infrastructure and by service level, and to better understand the cost drivers and through this understanding to enable more cost effective and equitable service delivery.

WASHCost is focused on exploring and sharing an understanding of the true costs of sustainable services.

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