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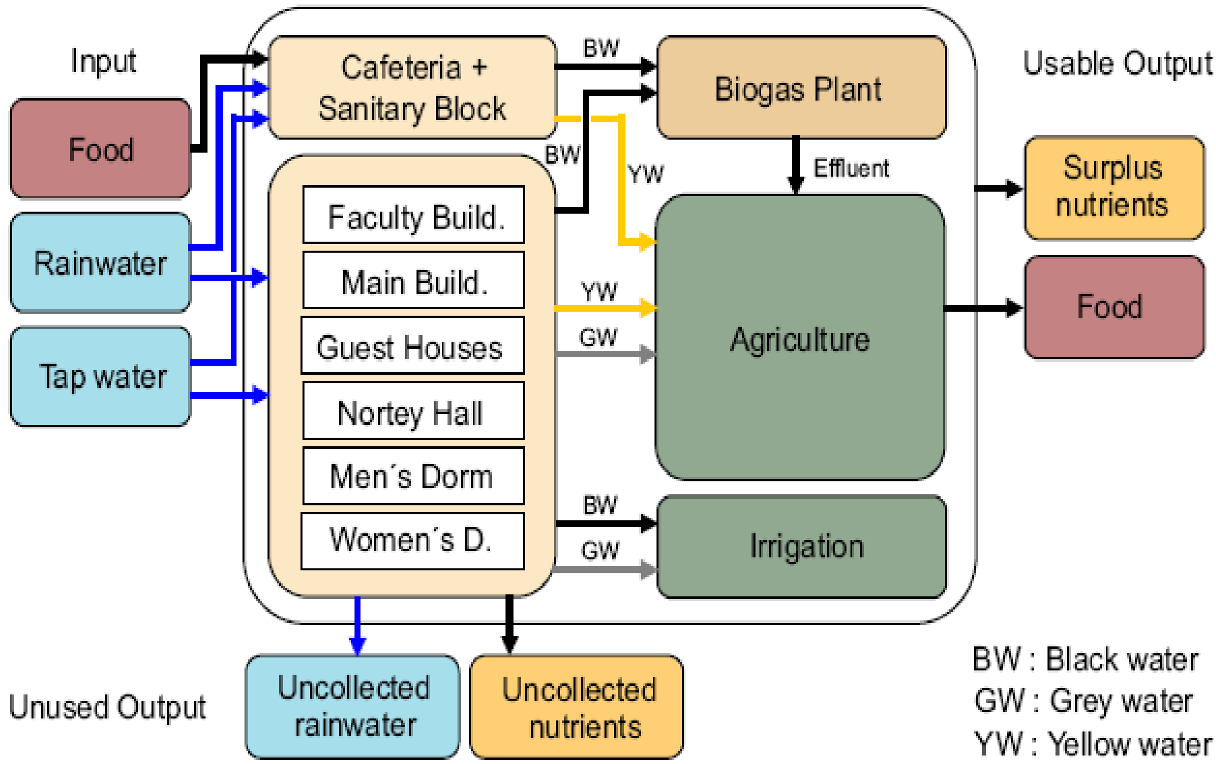
Ecological cycle management in Valley View University, Accra



Economic analysis of ecological cycle management: *A case study of ecological sanitation project in Accra, Ghana.*

Raymond Luwita

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Master of Science Thesis
by

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Abstract

With population growth and the recent unprecedented rate of urbanization in most cities of developing countries, there is growing attention towards ecological city approach to cope up with the ever increasing demand for water supply, sanitation facilities, and food security. A number of studies are done on many ecological water and sanitation projects, with the aim to ensure that they can be developed in a manner that will not compromise the ability of future generations to meet their own needs. Economic and environmental valuations of these projects are often under rated yet it provides an effective means of establishing economic sustainability as well as the sustenance of the environmental ecosystems. This constitutes the main objective of this research.

In order to accomplish the objectives of this research, a case study of ecological cycle management project was conducted in Valley View University in Accra, Ghana. This project (ecological sanitation management) is an integral part of the university master plan which has a goal to provide a framework for sustainable development as the university prepares for an increasing population from 950 in 2003 to 5,000 in ten years. It is therefore an ideal case for assessing the prospect of decentralized wastewater reclamation and reuse in the cities of developing countries. Two of the five water/ wastewater streams, each separated at source to enable different treatment and reuse options, are financially and economically analyzed in this study.

In our approach to conduct the economic and environmental valuation, we adapt cost-benefit analysis as a basic framework for evaluations. The project impacts are classified as internal and external effects, and opportunity cost. Contingency valuation method was adopted to assess the willingness to pay for the reclaimed water at city scale. The analysis comprises two different components; firstly is assessing the financial and economic feasibility of the project within the university, and the second one is assessing the project feasibility at the city scale. To broaden the scope of our discussions on the feasibility of the project at city scale, various literature on other development aspects related to water and sanitation infrastructures are reviewed in order to avoid making conclusions which are over simplistic.

With this broad perspective on the feasibility of policy objectives, the main findings of the study can be summarized as follows: 1) ecological cycle management is economically a feasible water and sanitation management strategy for cities of developing countries, 2) the external benefits of reuse projects are more significant than the internal benefits, hence the justification for government support, 3) it is not sufficient to make conclusion on the project success in real life situations as we have to consider the influence of institutional aspect as well; 3) policy objectives involve political maneuvers and, should be considered as norms and standards that are maintained and modified over time.

Keywords: Ecological city, on-site water reclamation and reuse, economic analysis, grey water, rainwater, Valley View University, cost-benefit analysis, city scale, internal effects, external effects.

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I am extremely grateful to Dr. Mathew Kurian for his professional guidance and systematic approach to research. Mathew gave invaluable comments that made me meditate more broadly and deeply on the subject of the study. Without his continuous support and guidance, this research wouldn't have been completed successfully.

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List of Acronyms and Abbreviations

AVWR	Annual volume of water reclaimed
CBA	Cost-benefit analysis
CVM	contingency valuation method
CWSA	Community water and sanitation agency
DALYs	Disability adjusted life years
GAMA	Greater Accra metropolitan area
GSS	Ghana Statistical Services
GWCL	Ghana Water Company limited
IRR	Internal rate of return
IWMI	International water management institute
MDG	Millennium development goal
MSPWR	Minimum price of water reclaimed
MWRW&H	Ministry of water resources, works, and housing
NGO	None governmental organization
NPV	Net present value
O&M	Operation and maintenance
OBA	Output based aid
OWS	Oyibi water scheme
RWH	Rainwater harvesting
SPWR	selling price of water reclaimed
SWITCH	Sustainable water management improves tomorrow's cities' health
VVU	Valley View University
WHO	World health organization
WPFWA	World Panel on Financing Water for All
WRC	Water resources commission
WWTP	Wastewater treatment plant

1 Introduction

Current trend shows that larger cities in developing countries are experiencing unprecedented urbanization trend within the last two decades than ever before. Coupled with population growth, the urban authorities are overwhelmed, and failing to cope up with the ever increasing demands for water supply, sanitation facilities, and food security (Bracken et al., 2009) (Qadir et al., 2008). Currently about 1 billion and 2.5 billion people worldwide (most of whom live in developing countries) are without access to safe water supply and improved sanitation facilities respectively (UNICEF/WHO, 2008).

Target # 10 of the millennium development goals (MDG) is "to half by 2015 the proportion of people without sustainable access to safe drinking water and basic sanitation facilities. Certainly, developing countries are far from meeting the MDG target # 10 unless drastic steps are taken to accelerate the progress sustainably. An integrated approach to urban development is being adapted within the concept of ecological city in order to achieve sustainable, livable and economically vibrant cities within the context of developing countries (van Dijk, 2009). To assess the feasibility of this concept, the need for an in-depth consideration of the social, institutional, technological, economical, and environmental aspects cannot be over emphasized.

1.1 Problem definition

Over the years, most water and sanitation interventions have been based on technocratic solutions associated with the construction of new engineering infrastructures, which have in the long run, proved to be unsustainable (Hutton & Bartram, 2008). These infrastructures involve long piping networks and big plants, which could be avoided, or suspended or smaller low cost options constructed, if economic and environmental aspects were given priority. The finances required for the investment, and operational costs of these projects make them infeasible options for cities of developing countries; and even in developed countries, most of these projects heavily rely on government subsidies for funding (Hutton & Bartram, 2008).

To meet the water and sanitation needs, and hence target # 10 of the MDG in cities of developing countries; requires an integrated approach to urban development with the aims to address all aspects of the water cycle, so that the water and sanitation management functions and urban design are incorporated to facilitate synergies for the ecological, social, and economical sustainability (van der Steen, 2008). This is the basic principle of ecological city - the concept on which the ecological cycle management at VVU in Accra, Ghana is founded. In its pursuit of economic and environmental valuations, this research reviews the significance of institutional aspects for the feasibility of on-site wastewater reclamation and reuse projects in real life situations.

1.2 Research objectives

The overall objective of this research is to carry out economic and environmental valuation of the on-site wastewater reclamation and reuse project in VVU in Accra, and assess the feasibility for scaling up this management and technology option to address water and sanitation challenges in the cities of developing countries. The following specific objectives have been formulated to address this main objective.

a) To determine whether the on-site wastewater reclamation and reuse project is financially and economically viable management and technology solution for Valley View University.
b) To assess whether this (on-site water reclamation and reuse) project in VVU is a feasible water management option for addressing the water challenges in cities of developing countries.

1.3 Structure of the thesis

The first chapter of the thesis gives an overview of the global developing challenges, with specifics to achieving MDG target # 10 in cities of developing countries. The research problems and objectives are also outlined in this chapter. Chapter 2 gives the basic information on the research area including location, and water and sanitation management challenges encountered within the area. Chapter 3 is the review of literature on the two main concepts of this research; the ecological city, and economic and environmental valuations. The methods for collecting and evaluating data on the benefits and costs for the on-site wastewater reuse are adequately described in chapter 4. The results and discussions are given in chapter 5, while chapter 6 gives the conclusion of the research. The scheme below gives a graphic illustration of the structure of the thesis.

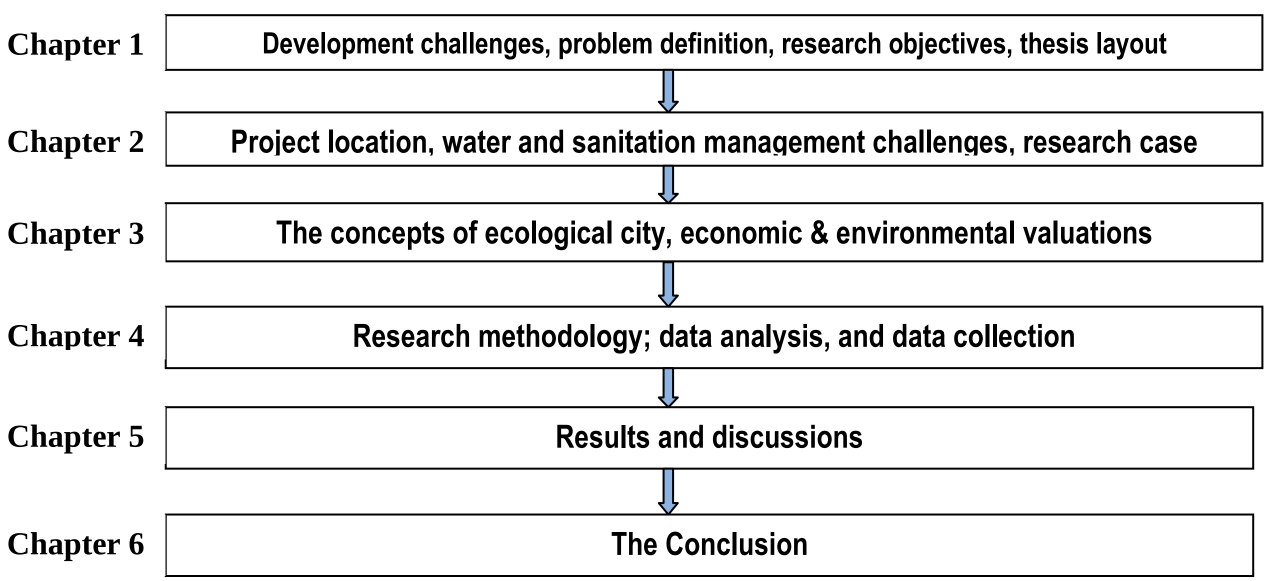


Figure 1.1: Schematic presentation of thesis structure

2 Background

2.1 Description of research area

Valley View University (VVU) campus is located about 30km north-east of Accra, the capital city of Ghana. Ghana is a country situated centrally in West Africa, and lies between latitudes 4º30' N and 11º10' N, and longitudes 1º12' E and 3º15' W (Fries et al., 2006). VVU is located in Tema Metropolitan Area, a municipality in the Greater Accra Metropolitan Area. The university campus is situated east of Akapim mountain ranges within Oyibi village, about 30km along eastern side of Accra – Dodowa road. The map and the ecological master plan in figures 2.1 and 2.3 respectively, show the location of Valley View University.

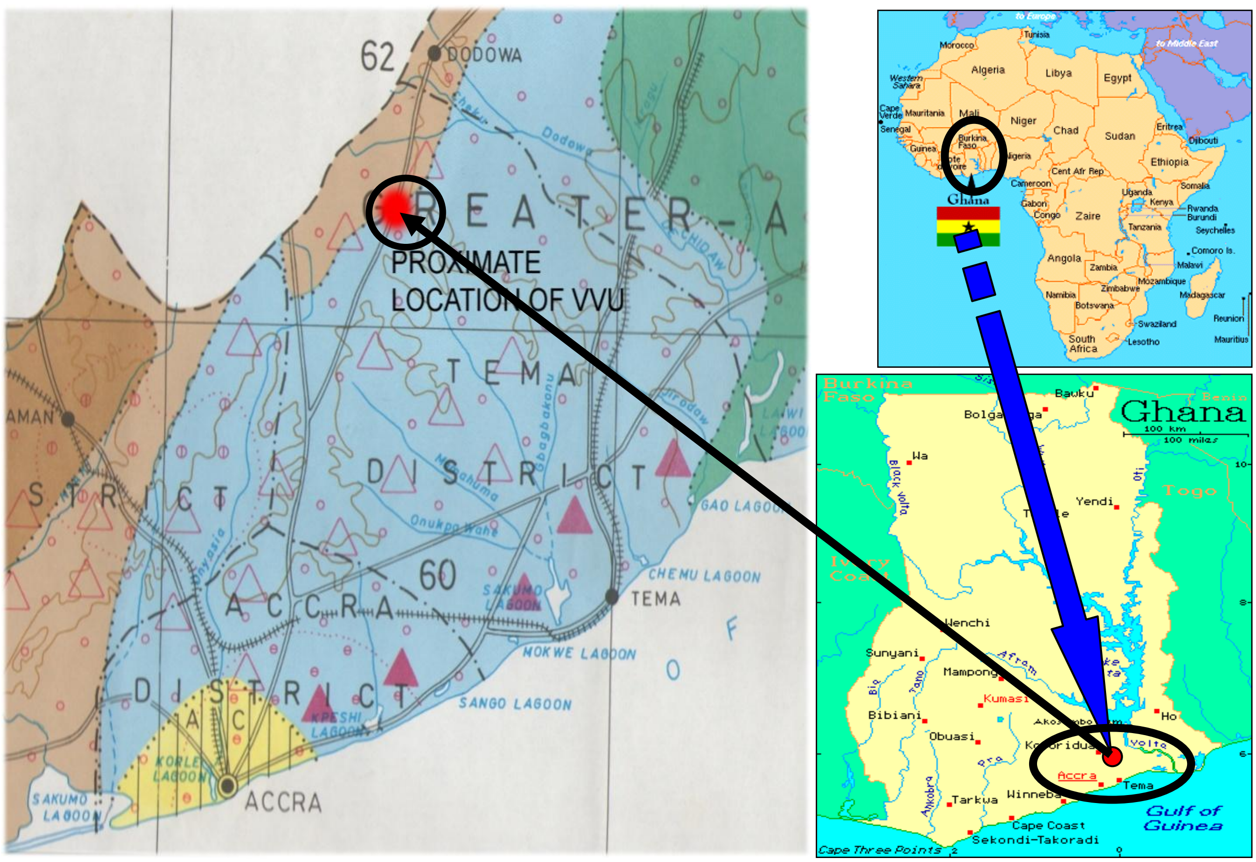


Figure 2.1: Location of ValleyView University in Accra, Ghana
Source: Google maps, (15/12/2009)

Although the weather station on Akwapim mountain range, at Aburi botanical gardens measures up to 1,200mm/year, differences in vegetation and available measurements indicate a much lower precipitation at VVU (Fries et al., 2006).

2.2 Rainfall characteristics

At Valley View University weather station, daily precipitation and temperature have been recorded since October 2003 and a comparison of the precipitation graphs with climate diagram of Accra shows that the total annual rainfall at VVU is the same as that of Accra (Fries et al., 2006). For estimating the average rainwater harvested in VVU, average monthly precipitation for Accra for the period from 1992 until 2004 was used, and this is illustrated in figure 2.10.

The figure below gives an overview of annual rainfall data and evapo-transpiration (ET_o) from 1970 to 2004. The graph shows that the annual rainfall is highly variable, with an average annual rainfall of 742 mm.

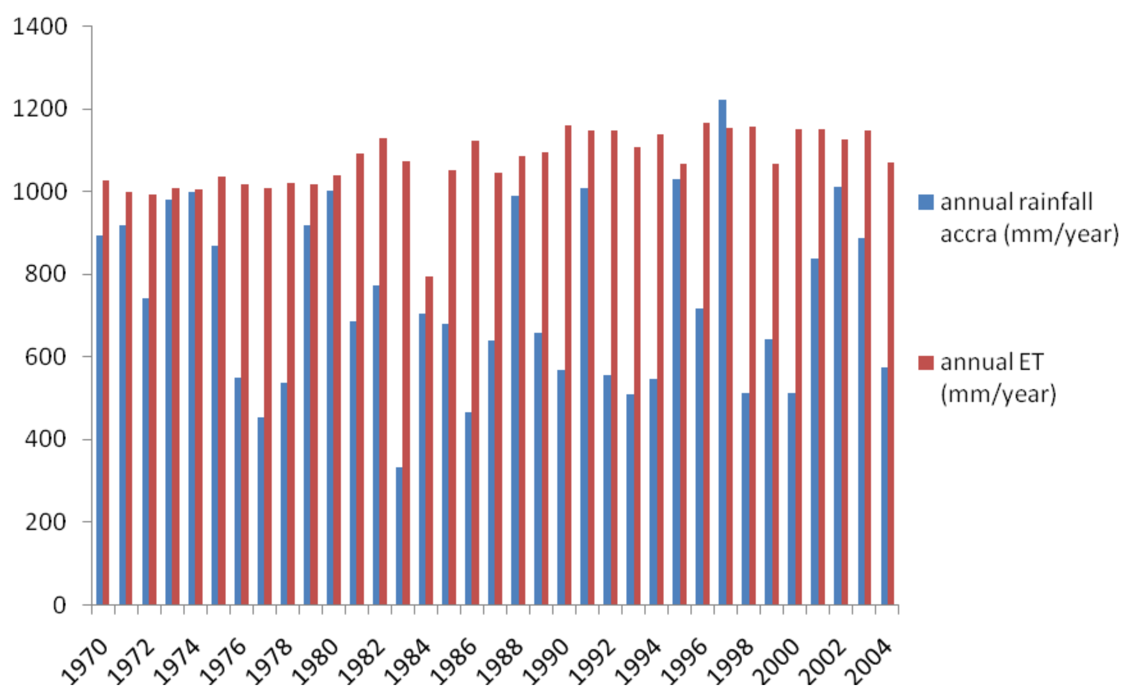


Figure 2.2: Annual rainfall and ET_o from 1970 - 2004
Source: SWITCH, (2009)

Analyzing the departure and cumulative departure from mean rainfall using the data given above indicates a trend of a declining cumulative departure from mean rainfall since 1985. Figure 2.3 below illustrates this scenario. However, these sets of data are not sufficient to make a conclusive statement about the current trend. For the computation of the amount of rainfall harvested in VVU, a more recent set of data from 1992 to 2004 are used.

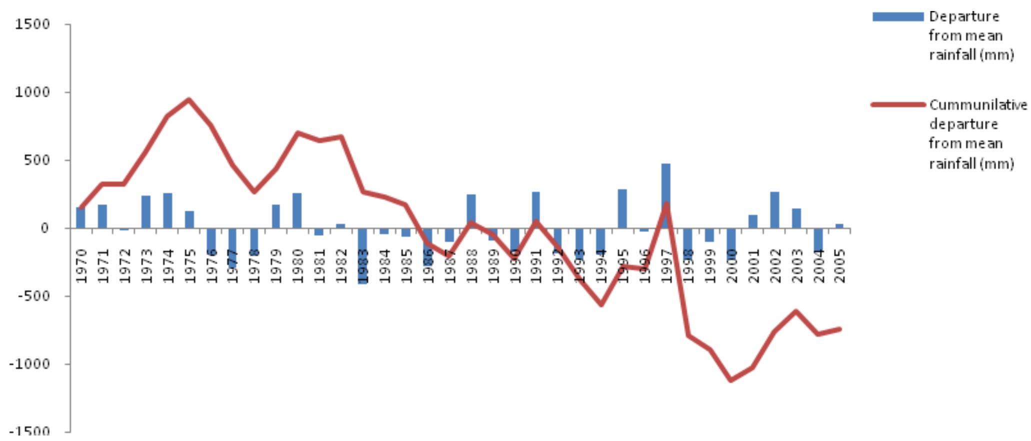


Figure 2.3: Cumulative departure from mean rainfall
Source: SWITCH, (2009)

2.3 Water supply and sanitation situations in Accra

2.3.1 Institutional set up in the water sector in Ghana

Water and sanitation services fall in different ministries in Ghana. Sanitation is under the ministry of Local Government, while water is under the Ministry of Water Resources, Works and Housing (MWRW&H). MWRW&H has a department called Water Directorate that is responsible for governance, inter-sectoral coordination of projects, and monitoring the achievements of national goals in the water sector. The Water Directorate has three important central institutions with different competencies in the provision of water supply and management of water resources, (CWSA, 2007):

- Water Resources Commission (WRC)
- Community Water and Sanitation Agency (CWSA)
- Ghana Water Company Limited (GWCL)

The Water Resources Commission (WRC) is responsible for regulating and managing Ghana's water resources and the coordination of related policies. Community Water and Sanitation Agency (CWSA) on the other hand is responsible for facilitating the provision of safe water and related sanitation services to rural communities and small towns and the implementation of the National Community Water and Sanitation Programme (CWSA, 2007).

Ghana water Company Limited (GWCL) has similar responsibilities like the CWSA but it is in charge of large towns and cities or medium towns that are not managed by CWSA. Currently GWCL has contracted out service delivery to Aqua Vitens Rand Limited under a management contract. This is in line with government policy of involving private sectors in service delivery, which means all utilities are encouraged to operate at cost recovery to attract private operators. The

management of water and sanitation services in the whole Greater Accra Metropolitan Areas (GAMA) is under the mandates of GWCL and the Municipal Local Government respectively. In all these sectors (water and sanitation), service delivery is handled by the private operators.

2.3.2 Water resources, infrastructure and demand in Accra

There are limited fresh water resources potential within Accra. The available basins within the city are either highly polluted or has very low potential making them unsuitable for urban water supply development. While the Volta dam which has adequate potential is located far away from the city at about 53km, making it very expensive to construct the transmission pipelines (Brobbey, 2010). As for ground water, the aquifer potential is low but highly variable ranging from 0.7-27.5 m^3/hour with a mean value of 2.7 m^3/hour. The transmissivities are very low due to the high clayey content; with the regolith having median transmissivity value of 0.23m^2/h and that of the fissured zones is 4.0 m^2/h (SWITCH, 2009).

Assuming physical losses to be reduced to 25%, the current infrastructures have a combined capacity to serve 2.1 million people at a per capita consumption of 150 l/p/d, or 3.2 million people with a per capita consumption of 100 l/p/d (SWITCH, 2009). However; actual per capita consumption always varies between the poor and the rich consumers. Taking the service criteria used for the design of urban water systems, 75 l/p/d for the poor and 150l/p/d for non poor; and assuming that 73% wealthy inhabitants have water demand of 150 l/p/d, and 23% poor inhabitants have 75 l/p/d; a detail water demand for Accra has been estimated and presented in table 2.1 below.

Table 2.1: Estimates of water demand for GAMA against production capacity

	2007	**2010**	**2020**	**2030**
Average system capacity (business as usual)	363,517	363,517	(363,517)	(363,517)
Popn of GAMA (using district rate 5.5%)	3,930,517	4,645,376	8,442,941	16,356,315
Water demand (m^3/day)	509,985	602,738	1,095,472	2,122,232
%age coverage (assuming loss of 25%)	71	60	(33)	(17)

Adapted from SWITCH, (2009)

The three main dams that supply GAMA are: Kpong dam on Volta River, Weija dam on Densu River, and Anun Boso. Table 2.2 below gives an illustration of their total production capacities.

Table 2.2: Infrastructural capacity

System name	**Plant capacity (m^3/day)**	**Prodn capacity (m^3/day)**	**%age plant output**
Total Kpong (New & old)	220,454	193,430	88
Total Weija (clark, Candy & Bamag)	203,680	169,987	83
Anun Boso	100	100	100
Total	424,234	363,517	86

Adapted from SWITCH, (2009)

Tables 2.1 & 2.2 above show that with all the infrastructures running at 86% capacity, and even with assumption that water loss is reduced to 25%, GWCL is able to meet only 60% of the demand. These estimates are by far lower than the real value of 50% since the current water loss is much higher than the 25% assumed.

2.3.3 Possible measures for addressing water supply problems

Given the fact that Accra is water resource constrained, the options of increasing production are slim. The available options like desalination and surface water from Volta dam may not be financially viable for now, thereby limiting feasible measures (within the short run) to water conservation, non-potable recycling, potable recycling, and rainwater harvesting. A study conducted in Australia indicates that the average saving from water conservation measures is about 25%, non-potable recycling 45%, and potable recycling 55% (Anderson, 1996). Taking into consideration the urban population growth rate of 4.4% and current water consumption per capita of 150l/d for the 73% rich and 75l/d for the 27% poor inhabitants; the impacts of these measures on urban water demand is significant as illustrated in table 2.4 below. Figure 2.3 gives the resources potential for GAMA which is used to analyze the increasing demand with time.

Table 2.3: Water resources capacity for GAMA

Source	Reservoir	Capacity	Remarks
Densu river catchment	Weija dam	0.1	
Volta river	Kpong dam	0.08	
Ground water	Aquifers	(2.7m3/hr) ~ 0.00024	
Rainwater	Land surface	2.15	Not included in the total
Total		**0.18024**	

Source: SWITCH, (2009)

Table 2.4: Impacts of the different possible measures on water demand in Accra

Measures	**Average water demand with time**			
	2007	**2010**	**2020**	**2030**
Business as usual (km^3/year)	0.186	0.220	0.400	0.775
Water conservation (km^3/year)	0.186	0.165	0.300	0.581
Non-potable recycling (km^3/year)	0.186	0.121	0.220	0.426
Potable recycling (km^3/year)	0.186	0.099	0.180	0.349

Source: adapted from Anderson, (1995)

Table 2.4 above shows that using only demand management measures (leakage control, retrofitting, and economic pricing) and non potable reuse, can delay expensive investments for the next 10 years, yet meeting the city water demand. Adapting rain water harvesting as additional source of water supply will postpone major investment even further.

2.4 Water and sanitation services in VVU

The main sources of water supply to the university are from Oyibi water scheme (OWS) and the university boreholes, in all they provide a total of 512 m^3/week to the over 3,500 people within the campus. Oyibi water scheme is a community water supply utility which was constructed with the financial support from Danida and government of Ghana in 2004/05. It is managed by the board members elected from within Oyibi community, who recruit personnel to run the day to day activities of the utility. According to the manager (whom I interviewed) the scheme is operating at cost recovery and has now accumulated sufficient money for expansion. However, the service level is still low since the supply is only above 36 hours a week.

Valley View University therefore subsidizes this supply by using its 14 m^3 water tanker lorry to collect water from GWCL operated centers in Accra or Tema; over 30 km from the campus. The costs includes: cost of water, fuel for the lorry, wages to the lorry driver and turn buoy, and servicing the lorry. An average of 3,200 USD is spent per month, which is quite expensive and unsustainable in the long run (Sarpong, 2009). As for sanitation services, there is no central WWTP or sewer line within accessible distance from the campus, the nearest being Tema WWTP which is over 25km from the university and the sewer line has not reached VVU yet. The only viable option for waste management as of now is the decentralized sanitation management through the use of septic tanks.

2.4.1 Ecological sanitation project in VVU

To respond to the development challenges of the institution, Valley View University developed an ecological master plan. The main objective of the master plan is to provide a framework for sustainable development as the university prepares for an increasing population from 950 in 2003, to 5,000 in ten years (Fries et al., 2006). In pursuing its objective, the master plan has to answer among others, the question of "how limited natural resources like land, soil, vegetation and water can be used economically in a campus that is developing and expanding; yet maintaining its status as a modern ecological university" (Fries et al., 2006).

With specifics to the concerns of water supply, sanitation, and nutrients cycle, the university adapted the principle of ecological cycle management in order to reduce potable water demand and promote sustainable waste management. The project is an integral part of the university ecological master plan established in 2003, and funded by the German Ministry of Research and Education until 2008 (Geller & Laryea, 2008). Figure 2.4 below shows the ecological master plan of Valley View University detailing the spatial planning of the campus.

Figure 2.4: Ecological master plan of VVU
Source: Fries et al., (2006)

2.4.2 Mass flow of food, and water in VVU

The idea of the master plan is to achieve its goals with sustainable development in the fields of urban planning, building, sanitation, agriculture, water and nutrient cycle management as illustrated in the diagram for the mass flow shown in figure 2.5 below.

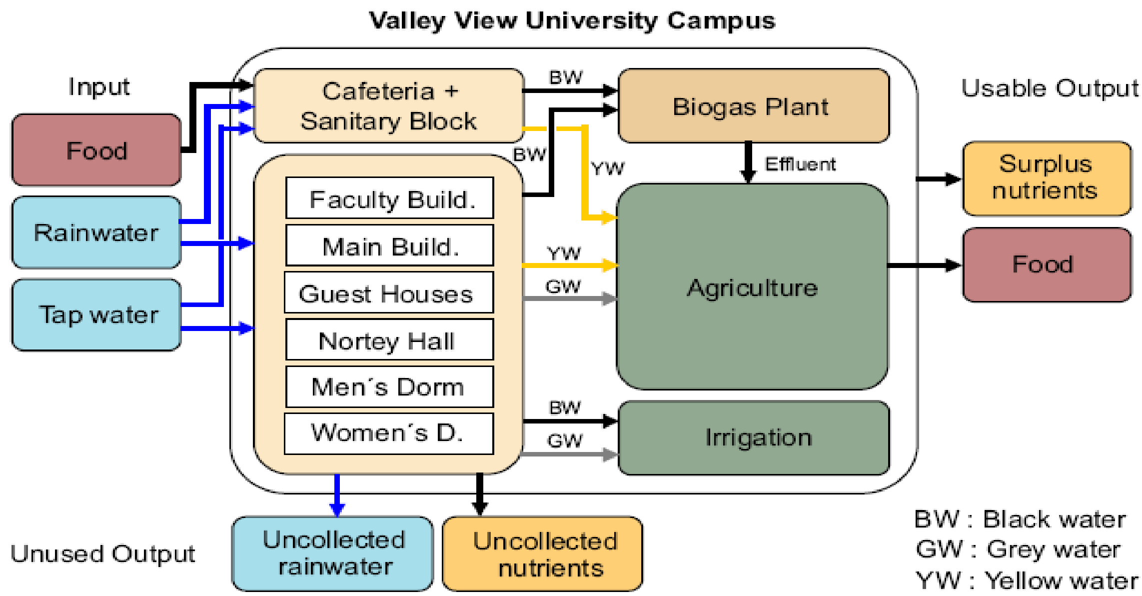


Figure 2.5: Mass flow in VVU

Source: Fries et al., (2006)

2.4.3 On-site wastewater reclamation and reuse

In Valley View University, wastes are separated at source, producing five different streams, each with a different treatment technique, hence offering various reuse options as illustrated in figure 2.6 overleaf. This approach uses the concept of 'ecological cycle management' which considers human excreta and domestic wastes as valuable resources that should be made available for reuse thereby offering triplet solution to urban problems of water supply, sanitation management, and food security (Geller & Laryea, 2008); (Muellegger & Langergraber, 2005); (Bracken et al., 2009); (Kurian et al., 2009).

Table 2.5: Objectives and benefits of ecological cycle management

Targets	Benefits/advantages
To protect and conserve fresh water for potable use, and promote rainwater & grey water utilization for other purposes	Reduced cost of treatment and supply of drinking water (reduced spending), and postpone construction of new infrastructures and reduces cost on waste management
To reduce waste water production	Reduced or completely avoid cost of transporting wastewater as most or all of it is reclaimed and reused on-site, and increased crop production since reclaimed water complements rain fed agriculture
To retain rainwater and improve bioactivity	
To close the nutrient loop by recycling water for increased production and sustainable development	Increased food production yet at a reduced cost as reclaimed nutrients supplement or completely replaces chemical fertilizers. Reduced cost of wastewater management

Adapted from Fries et al., (2006)

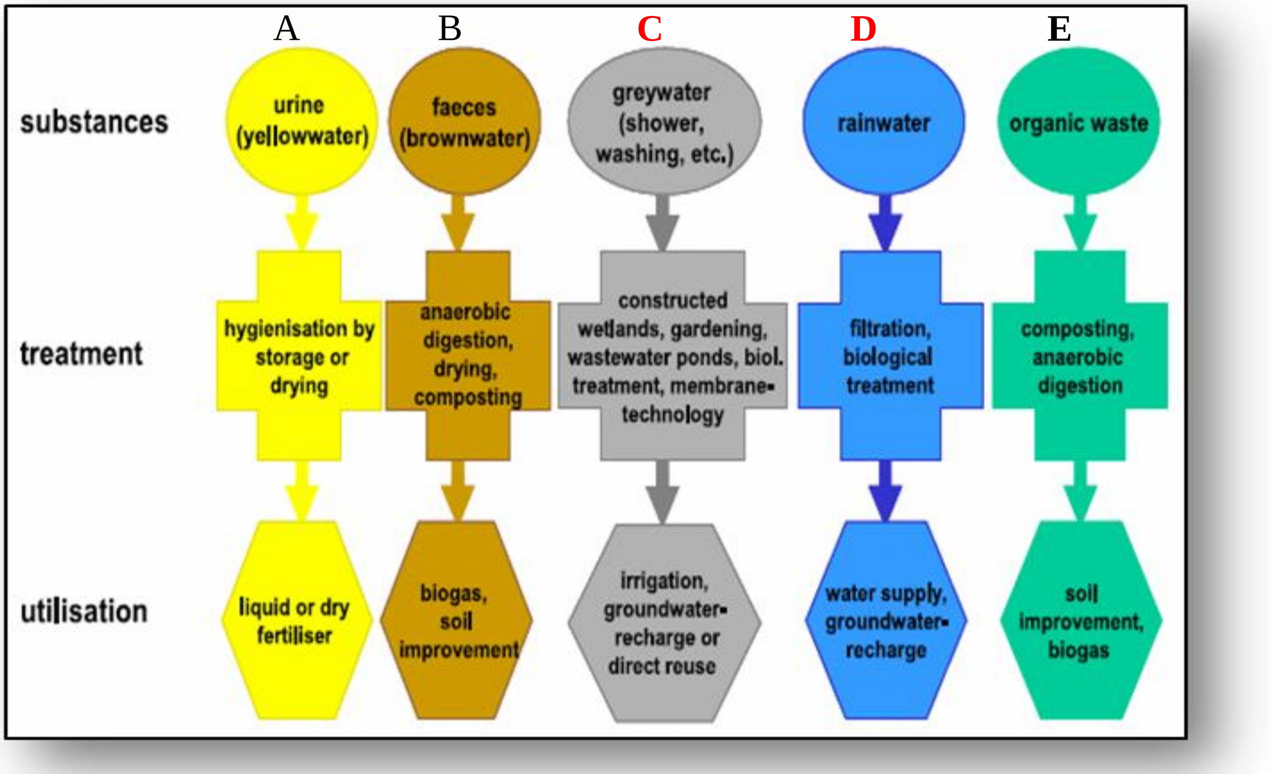


Figure 2.6: On-site waste reclamation and reuse

Source: GTZ, (2002)

2.5 Description of the different wastewater streams in VVU

This subsection gives an outline of the five different streams (A, B, C, D, E) that are implemented in Valley View University, and describes in more details streams C&D for which economic and environmental valuations are done (figure 2.6 above). The two streams were chosen for detailed analysis because they are now fully operational, and therefore their economic feasibility is of great interest for sustainable management in an institution like university. In addition, their "success story" also offers prospects that they could be adapted as alternative water and sanitation management strategy for addressing problems of adequate water supply in cities of developing countries.

Stream A is urine, termed as yellow water; collected separately and sanitized to be used in the farm as liquid fertilizer. In Valley View University, the use of yellow water as fertilizer is currently being experimented under "the climate change project". All crops except vegetables are being tried using only yellow water without chemical fertilizers. According to the farm manager, Mr. Solomon Adai, the preliminary result is promising.

Stream B is faecal waste (faeces plus urine and water) – termed as brown water. It is decomposed to produce manures for soil improvement. When faecal waste is collected separately without urine, the resultant waste collected in a biogas plant is called black water. In a biogas plant, bacteria biodegrades waste through anaerobic process to produce methane gas. The process requires high concentration of organic matter and little water in a gas-tight digester in order to produce significant amount of methane gas. The biogas in VVU does not produce significant amount of gas due to the high water content of the waste.

Stream C is wastewater from showers, wash basins, kitchen etc. - it is termed grey water. In VVU this stream is an important source of water for irrigation and is described in more details in section 2.5.1 below. Stream D is rain water harvested from roofs of buildings and treated to provide additional source of water; it is commonly termed as blue water. This stream is also an important source of water for flushing toilets and irrigating the lawns, and is elaborately discussed in section 2.5.2.

Stream E is organic waste collected and decomposed to produce biogas and manures for soil improvement. It is not a fully operational stream in VVU. However, of interest under solid waste management within the campus, is the management of plastic waste. The university practices separation of solid wastes to ease management. It has an arrangement with a plastic waste recycling factory who collects the plastic waste at a cost of GH ¢1.20/kg, or GH ¢1.50/kg if the waste is taken to the factory by the university (Sarpong, 2009). This waste management initiative has ensured proper sanitation and clean environment in the university - a practice worth emulating.

2.5.1 Grey water reclamation and reuse (Stream C)

Water from kitchen, bathrooms, wash basins termed as grey water are collected separately and treated for reuse to augment the water supply from other sources. The degree of treatment depends on the source of grey water and the intended use. The first step of treatment is sedimentation in a coagulation tank with three chambers. Grey water from kitchen contains fats and organic matter which passes through a fat separator to remove fats before storage in a sedimentation tank for further treatment. Grey water reclamation and reuse offers a simultaneous approach to solving water and sanitation problem in that, apart from reducing cost on potable water supply; it also avoids excessive volume of black water to be transported for treatment and hence reducing costs for sewage management. In VVU the water reclaimed from grey water is reused for irrigation of crops, and watering green areas (Sarpong, 2009). As argued by Bracken et al. (2009), this management strategy simultaneously addresses the urban problems of water supply, sanitation management, and food security.

Figure 2.7: Grey water treated and used for planting trees (mangoes) in VVU
Own photo from the field, (2010)

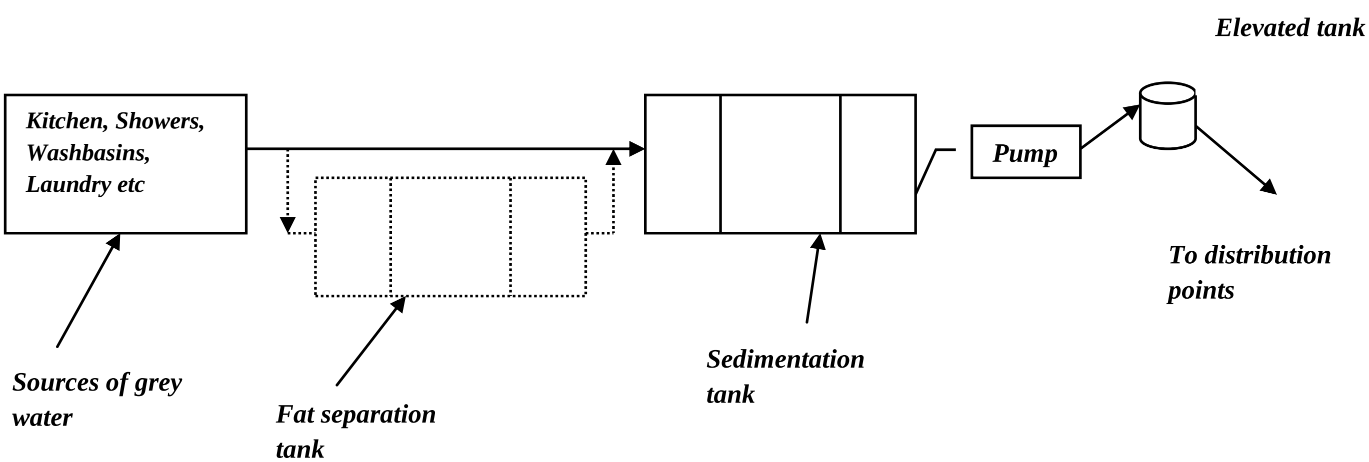


Figure 2.8: Scheme showing grey water reclamation
Own sketch, (2010)

The data on the amount of grey water reclamation and re-use available were estimated based on the design estimates and meter readings by Lauterbok (2009). About 90.2m³ of grey water accumulate per week at Women Dormitory, Cafeteria and Columbia hall but the exact amount used is not known. At the Guest Houses about 1,7m³/week of black & grey water is reclaimed and utilised for car washing and irrigating the lawns (Table 2.6).

Table 2.6: Quantity of grey water reclaimed disaggregated by buildings

Building	Guest houses	Women dorm	Columbia hall	Cafeteria	Total
Quantity collected (m^3/wk)	1.7	66.0	1.1	21.4	90.2
Grey water reclaimed (m^3/yr)	88.4	3,432	57.2	1,112.8	**4,690.4**

Since this water (grey water) is not intended to be used as potable water but for irrigation of plants, the drinking water requirements of Ghana Standards Board are not suitable for comparison. The guideline values from the U.S. Environmental protection agency (2004) was used instead. Under this guideline, irrigation of plants or other agricultural crops, except vegetables that are eaten raw, does not require drinking water quality standards, hence grey water in valley view university qualifies.

2.5.2 Rain water harvesting and use (stream D)

In VVU rainwater is harvested from the roofs of the following buildings; cafeteria, administration block, Columbia hall, female Dormitory, women center, guest houses, and staff houses. Each of these buildings has an underground tank where rain water is collected and stored for treatment (by filtration and sedimentation), and later pumped to elevated tanks to be distributed by gravity for flushing toilets in the buildings.

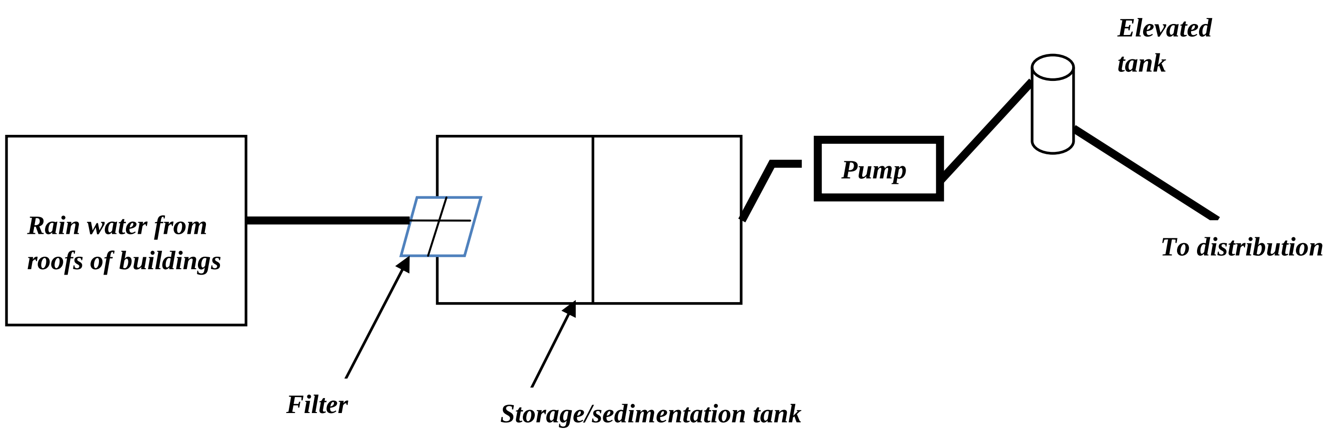


Figure 2.9: Schematic diagram for rain water harvesting system
Own sketch, (2010)

2.5.2.1 Determining the quantity of rainwater harvested

Three distinct periods are considered for computation of rainwater harvested. The dry period reflects the months with rainfall under 35mm (December, January, February and August), while the Semi-dry period are the months with rainfall between 69 and 79mm (March, April, July and November). The distinctive rainy season are those months with rainfall exceeding monthly average

of 100mm (May, June, September and October). A monthly average of 85mm has been used in the computation of rainwater harvesting.

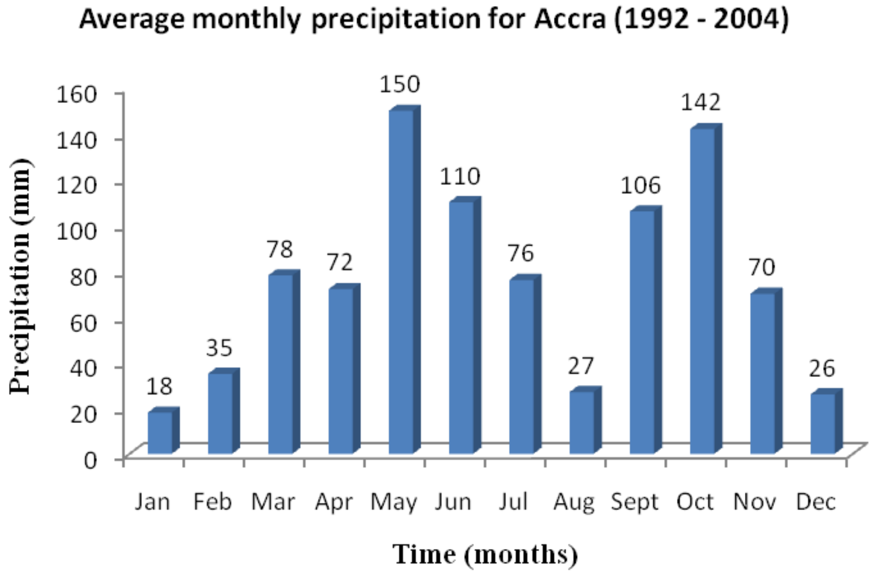


Figure 2.10: Average monthly precipitation for Accra (1992 - 2004)
Source: Sarpong, (2009)

As described earlier, precipitation values for the period from 1992 to 2004 were used for estimating the average rainwater harvested. The formula used for the computation of the amount of rainfall harvested is: Rainfall = (roof area x precipitation)/1000 x (runoff coefficient) (Krämer, 2007). Krämer, (2007) estimated the runoff coefficient to be 0,75, which implies that 25% of rain water is lost through evaporation on the roof, and in piping networks and tanks.

2.5.2.2 Water Flux in VVU

The water flux in the university indicates a potential of 6,118 m^3/yr of rainwater of which 4,256 m^3/yr is currently collected and utilized, while 1,862 m^3/yr is untapped due to non functional facilities (pumps, gutters, and leaking tanks), constituting about 30% of rain water lost. The harvested rain water is used for flushing toilets and irrigating the green areas within the university (Sarpong, 2009).

Table 2.7: Volume of rainwater reclaimed and utilised

	Guest houses	Women centre	Women dormitory	Columbia hall	Staff houses	Cafeteria	Total
Roof area (m^2)	340	400	655	1,495	2,464	1,320	**6,674.0**
Dry period (m^3/wk)	1.6	1.8	3.0	6.9	11.4	6.1	**30.8**
Semi-dry period (m^3/wk)	4.3	5.1	8.3	19.0	31.3	16.8	**84.8**
Rainy period (m^3/wk)	7.4	8.7	14.3	32.7	53.9	28.9	**145.9**
R/water reclaimed (m^3/yr)	217	255	418	953	1,571	842	4,256

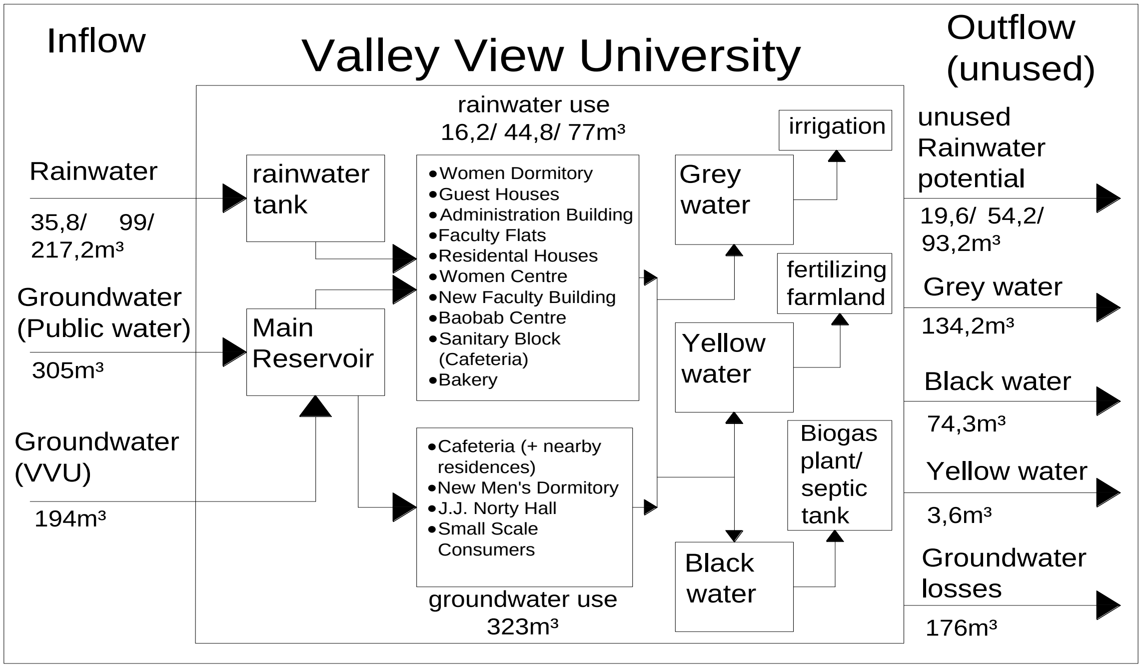


Figure 2.11: Water balance in VVU.
Adapted from Lauterbock, (2009)

Table 2.8: Summary of water flux in VVU

Type of water	Water collection potential (m^3/yr)	Water used (m^3/yr)	Water unused (m^3/yr)	%age of H2O lost (m^3/yr)
Ground water from OWS	16,536	-	-	-
Ground water from VVU	10,088	-	-	-
Total ground water	26,624	16,796	9,828	37%
Rain water harvested	**6,118**	**4,256**	**1,862**	**30%**
Total	32,742	21,052	11,690	36%
%age rain water	19	20	16	

2.6 Knowledge gaps on the impacts of on-site water reclamation in VVU

Despite the enormous investments, no study has been done to assess the economic and environmental sustainability of the ecological sanitation project in the Valley View University. A handful of studies have been carried out on this project (Krämer, 2007), and (Lauterbock, 2009); but none of them evaluated the economic and environmental impacts of the project. Besides, there is no initiative by the university to evaluate and communicate the effects of the project to other stakeholders (Lauterbok, 2009; p. 137). Since water and sanitation situation in Accra city is equally

alarming, the effects of such a project need to be assessed in order ascertain the possibility of scaling it up to a city level to address the water and sanitation problems.

Although the ecological sanitation project in VVU is apparently technologically feasible, the institutional environment within an organization like Valley View University is completely different from that faced in the community. The university is management by a set of rules and regulations which are administered through top-down chain of commands offering limited freedom of choice. No problems are therefore expected over the issue of acceptance of reclaimed water for reuse, as opposed to community settings. Besides, project financing in institution does not depend entirely on public budgetary process unlike community projects. This means that the financial and economical feasibility of the ecological cycle management project in a community setting may take a different dimension.

Given the circumstances outlined above, the need for a study to assess economic and environmental impacts of the ecological sanitation project in VVU; and to evaluate the possibility of scaling it up to a city scale cannot be over emphasized. To accomplish these tasks, this study has been designed to comprise two components; firstly to evaluate the internal and external infects of the project in VVU, and secondly to assess the possibility of scaling up this ecological project to a city scale. The first component focuses on the financial and economic valuation of the project within the university, while the second one deals with the project feasibility at city scale on verifying the social acceptance and willingness to pay for the reclaimed water. A review of institutional challenges is done to widen the scope of assessing the project feasibility at city scale. In both cases (feasibility in VVU and city scale), cost-benefit analysis is used as the basic framework for analysis.

2.7 Research questions

The questions for this research focus on whether the on-site wastewater reclamation and reuse project is both financially and economically viable water and sanitation solutions in university, and at city scale. The questions seek for an answer as to whether this water and sanitation management strategy can be adapted to address the overwhelming urban problems of insufficient water supply and sanitation facilities in the cities of developing countries. The following specific questions were formulated to guide the study achieves the set objectives:

a) Is the ecological sanitation project in VVU financially and economically viable water and sanitation management solution for the university?

b) Is the ecological sanitation project in VVU viable water and sanitation management option for cities of developing countries like Accra?

3 Literature review

This section analyses different literature on the two main concepts of this study: ecological city and economic and environmental valuation. Institutional challenges are seen as the overarching factor determining the success of any ecological city project. It is therefore reviewed here to give a wider perspective when assessing the feasibility of the ecological cycle management at city scale. A review of the possibilities and limitations of cost-benefit analysis in evaluating environmental factors is also given in this chapter, with emphasis to the key concepts used when applying cost-benefit analysis.

3.1 The Ecological city

The concept of ecological city is developed from the theory of sustainable development which became prominent after the report of the world commission on environment and development in 1987. The report defines sustainable development as “development that meets the needs of the present without compromising the ability of the future generations to meet their own needs” (Barnaby, 1987). However, there is no consensus on the specific definition of ecological city yet. Van Dijk, (2007) proposes an easy definition by considering the positive and the negative aspects of environmentally friendly cities, and defines an ecological city as; “one that is livable and saves energy, promotes integrated water and sanitation, better urban waste collection and processing, more greens and biodiversity, better public transportation and deals with climate change”; and **does not encourage** air, water and soil pollution, congestion, flooding, and lack of greens” (van Dijk, 2009; p. 1).

Ten dimensions for an eco-city were developed by Kenworthy, (2006, pp 67-86) and they provide a broader framework for analyzing what qualifies to be an ecological city. Ecologically managed closed loop urban water system is just a component and is stipulated in dimension number 4. But cities are consumers of natural capital like water, food, energy, and other resources and produce large quantities of waste which must be absorbed by the environment (Kenworthy, 2006). This means that if cities are to be sustainable, they must reduce their consumption of all resources, and decrease on their waste output.

Ecological cycle management projects are developed on the concept of decentralized wastewater management that encourages separation of wastes at the source and promotes recycling for the various reuse options (van der Steen, 2008). Moreover, sustainability of such projects depends on how we deal with the tradeoff between economic sustainability and environmental sustainability; and how urban managers coordinate the urban multi-actors at the various urban multi-sectors within the city. On-site water and wastewater reclamation and reuse project in Valley View University adapts this concept of ecological city.

The critical aspects to consider when evaluating the feasibility of scaling up any water and sanitation project include; technological aspect, institutional aspect, social aspect, environmental

aspect, and economic aspect. Geller & Laryea (2008) apparently, content that the technological aspect of the ecological cycle management project in VVU is successful ..."and can be replicated in other settings" (Geller & Laryea, 2008; p. 285). This study takes the case of this ecological project in VVU to analyze the financial and economic feasibility of the project within the university, and at city scale through economic and environmental valuation. However, there are also institutional challenges that may confound the success of scaling up this water and sanitation management approach to city scale, and is worthy to be analyzed in this study.

3.1.1 Institutional challenges of scaling up

It would be over simplistic to limit our criteria for assessing the feasibility of scaling up the ecological sanitation project in Valley View University to technology and economic aspects, because 'policy making involves a political process and therefore decision-makers do not often make economically rational decisions' (Kurian & McCarney, 2010). We recognize the significance of institutional reforms in this study and review them herein under infrastructural financing, budgetary process, and organization - roles and responsibilities.

3.1.1.1 Infrastructure financing

Sources of project financing for water and sanitation projects can be from the public sector (government, donors, or multilateral agencies), or private sector (domestic or international). However, experiences of the 1990s have indicated that most public financing failed to produce effective service delivery due to poor reliability, uncertain quality, or limited affordability of service (Kurian & McCarney, 2010). As a result, donors and multilateral agencies have preferred to channel their finances through the international or domestic private sectors.

Financing water infrastructure entails spending huge sunk cost to finance long-term physical assets, which can be financed through present cash flow, or reserves of the utility or by taking loans or equity that have to be reimbursed over time by users, or fiscal transfers. According to Mathew Kurian (in Kurian & McCarney, 2010; p. 143), such financing sources are only feasible if long-term reimbursement through tariffs, taxes or transfers are possible. Conversely, private sector participation in financing water and sanitation infrastructures has been frustrated by of lack of guarantees that public finances will be raised to reimburse their investment capital. The main limiting factors to private financing of the water infrastructures in developing countries are: sub-sovereign risk, land tenure arrangements, inadequate guarantee that users will pay due to political interference, and inappropriate legal and policy framework. Appropriate legal and policy framework is a fundamental factor because it ensures that investments are realized by specifying how resources can be recovered, setting service delivery standards that promote customers orientation, and providing clear guidelines for inter-governmental transfers and tariff structures that promote equity.

Because the limitations outlined above shift risks to the private sectors, which constitute the main source of infrastructure financing, they (private sectors) get discouraged to effectively participate in financing water and sanitation infrastructures. The prospects of scaling up on-site wastewater reclamation and reuse project can therefore remain in balance. Nevertheless, recent approaches to

fiscal transfers through output based aid (OBA) have registered some reasonable successes in some countries (eg. Morocco, Colombia and Vietnam), making it a promising approach to financing water and sanitation infrastructures, under this approach (OBA) disbursements are tied to performance, hence reducing risks of none reimbursements of investment capital.

3.1.1.2 Budgetary process

Wildavsky (1975: 5) defined budget as "attempts to allocate financial resources through a political process to address the differing human purposes". Budget lies at the heart of the policy implementation because without money, very little can be achieved and this makes budgeting an attractive aspect in the success of ecological cycle management at city scale. Since budgeting is a political process, it therefore entails conflicts and compromise in rationing the often limited resources among the differing and unlimited purposes.

Public budget comprises uncontrollable and controllable line items. Uncontrollable line items are those that are no longer subject to appropriations unless through change of substantive law, and often constitutes about 95%; while controllable budget line item is the one where appropriations exist in any annual budget, and conversely it constitutes only 5%. Warner Björkman (in Kurian & McCarney, 2010; p. 164), observes that although most developing countries have adapted decentralization policy, most sub-national and local governments are not mandated to raise revenues through taxes, limiting their financial capacity to deliver services. They all have to compete for the 5% under controllable line items, which with the limited resources and unlimited human purposes that characterize developing countries, is definitely insufficient.

At the city scale, the success of on-site wastewater reclamation and reuse project is subject to the budgetary process, which being a political process, is characterized by secrecy, lack of comprehensive review procedures, and inadequate decision making criteria. However, since local conditions vary too much to allow uniform prescriptions under a 'one size fits all' formula, the success of policy objectives will vary from country to country. Warner Björkman further argues that modes of budgeting are not just simple carbon copies of those used in developed systems but are based on criteria of budget performance with the discussion organized around major common problems rather than abstract comprehensive categories.

3.1.1.3 Organization - roles and responsibilities

The influence of political forces in the day to day functioning of water utilities appears to be the main reason that determine performance of the water and sanitation sector, as many authors have indicated in their analyses of the sector performance (Foster, 1996), (Nickson & Lambert, 2002), and (World Bank, 1994). Vivien Foster (1996) identifies two institutional defects that underlie the causes for poor performance as; 'poacher-game keeper problem' and 'politicization of management'. The poacher-game keeper problem refers to “the confusion or juxtaposition of regulatory and operational roles”; while the politicization of management relates to “the tendency to base decisions on political rather than technical or commercial criteria as a result of external influences from government” (Foster, 1996; p. 2). These two problems manifest themselves through a number of

transmission mechanisms like; ineffective oversight, soft budget constraints, and absence of efficiency incentives.

On a similar note, the World Development Report 1994, (World Bank, 1994) found that the most common problems in improving performance of infrastructure services were:

- Goals of the public sector infrastructure providers were "ambiguous and changing because governments are forced to balance many, often inconsistent, economic, social and political objectives".
- Managers do not control day-to-day operations or decisions on process, budgets, etc.
- Because the financial status of the utilities often depends on budgetary decisions unrelated to performance and on pricing decisions by politics, financial difficulties are common.
- Governments impose overstaffing on infrastructure agencies to create public sector jobs, passing the additional cost on to taxpayers or consumers.

With the confusions of regulatory and operational roles, water sectors in developing countries are always characterized by: low tariffs, poor quality of service, inadequate investments, poor accountability, and low efficiency; which are in turn factors that affect cost recovery and private sector participation.

3.2 Economic and environmental valuation

To ensure efficient implementation of policies in a manner that avoids negative effects on environment and human health; yet ensures financial sustainability, requires that their social and economic values are determined and incorporated into the decision making process (Hernández-Sancho et al., 2009); (Birol et al., 2006). However, the basic evaluation problem is how to aggregate these (environmental, social and economic) dissimilar entities. The economic approach applied by most economists to evaluate the project effects on human health and the environment centers around cost-benefit analysis (Hansjürgens, 2004). Cost-benefit analysis solves the problem of aggregating dissimilar entities by summing up of the willingness to pay for good things (benefits), and subtracting the summation of willingness to accept compensation for bad things - costs (Price, 2000).

3.2.1 Cost-benefit analysis

Cost-benefit analysis (CBA) provides a framework which helps to systematically and coherently identify the social, environmental and economic impacts of projects, making it a heuristic concept in that it can provide guidance for the analysis of health and environmental effects of projects (Hansjurgens, 2004, pp. 242). Price, (2000) cites this as the main strength of CBA, and argues that in a stroke CBA solves all the problems of aggregating dissimilar items by mapping them into a common scale of value (Price, 2000; pp 187). The challenges in applying cost-benefit analysis though, are manifold. The main challenges center around the issues of measuring scales for different types of values against each other; combining view points of different stakeholders, and including different scenario with future uncertainty (Hernández-Sancho et al., 2009); (Price, 2000);

and (Hansjürgens, 2004). Therefore in applying CBA, we have to adapt some key concepts that adequately mitigate these challenges.

3.2.1.1 Key concepts of cost-benefit analysis

Net present value (NPV) and discount rate

Cost-benefit analysis is an analytical tool based on the welfare theory, which is conducted by summing up the total costs and benefits of a project or policy over both spatial and temporal scale to guide decision making process at the present time (Spash & Hanley, 1995). Costs and benefits should therefore be in their current-day values and future costs and benefits have to be discounted using an appropriate rate (Hansjurgens, 2004 pp. 243). The project with the highest net present value is recommended in the case of multiple projects under consideration, while for only one alternative project, the net present value should be positive. Net present value is therefore the excess of benefits over costs (net benefits), while Internal rate of return (IRR) is that rate of discount which makes the present value of the entire streams – benefits and costs – exactly equal to zero (Mishan, 1988).

Shadow pricing and opportunity cost

However, CBA of a policy or project with environmental impacts is complicated because most environmental and water resources are public goods and therefore subject to market failure (Birol et al., 2006). This means that you cannot correctly value relevant variables through markets, in which case non market valuation procedure is required to assess the net worth of the project or policy. Under this scenario, the concept of shadow pricing is applied. CBA can therefore be used to appraise the project either prospectively or retrospectively (Perman et al., 1999).

For a water and wastewater reuse project, (which is the focus of this study), the analysis basically includes project impacts on the individual consumers, and the general public (Friedler & Hadari, 2006). The results of the analysis can be expressed in terms of the net present value (NPV) and the internal rate of return (IRR). In the evaluation of net benefits, consideration is made at national perspective in terms of opportunity costs. Opportunity cost of the current use of some good or input is its worth in some alternative use, or of the foregone interest (Kuosmanen & Kortelainen, 2007). Since valuation of most water and environmental related impacts suffers market failure, the concept of avoidance cost or shadow pricing is applied. Shadow pricing (or avoidance cost) of a WWTP is an estimation of an economic value of environmental benefits obtained from the treatment process (Hernández-Sancho et al., 2009). It neither represents the full economic value, nor the willingness to pay for the environmental enhancement as a result of wastewater treatment; but rather the minimum of the real value of the benefits. It is applied in estimating social benefits or losses that cannot either be priced or the price can be unsatisfactorily determined through the market.

Contingency valuation method

Another technique of data collection for cost-benefit analysis is through contingent valuation method (CVM). It is a concept that fits the fashionable democratic approach to decision making by seeking the views of the people on the price they are willing to pay for the impacts of the project (Price, 2000). CVM elicits people's response to the price of a hypothetical good or service through direct questions on individual's willingness to pay (Kurian M. & McCarney, 2010).

However, the outcomes of CVM are always misleading since willingness to pay is often skewed to ability to pay and hence may not reflect the right value of the reclaimed water. Kurian & McCarney, (2010) argues that the resilience and increasing focus on the application of contingency valuation method is due to the reasonable degree of success that the method registers. In this study, the process of contingency valuation survey was guided by the price of the current services, and the result is validated using revealed preference – a techniques based on data from past behaviors.

Disability adjusted life years (DALYs)

Like most environmental impacts, valuation of health impacts is complicated by the fact that prices for death and sickness are not easily determined by market. In most economic valuations, these challenges are addressed through value of statistical life, willingness to pay, and adjusted human capital, but this is only relevant when large volume of data is available. This study applies an indirect method using disability adjusted life years (DALYs), developed by WHO and the World Bank (Murray & Acharya, 1997). Disability adjusted life years are the sum of the present value of future lifetime lost through premature mortality, and the present value of future lifetime adjusted for the average severity of any mental or physical disability caused by a disease or injury (Rushby & Hanson, 2001).

Introduced in 1993, DALYs is used as a method for estimating global burden of diseases, and as an outcome measure for use in cost-benefit analysis. In this research, DALYs is used to compute the monetary value of health risks as a result of using reclaimed water. The health impact of the project is computed from the national DALY rate and the DALY amount of Ghana. The information used for the calculation (of DALY rate and the DALY amount) is based on the national data (of Ghana), and other data from WHO (2008) on the estimation of DALYs.

3.2.1.2 Challenges in applying CBA

Despite the possibilities outlined above, the limitations of economic cost-benefit analysis are also manifold. It is therefore important to take note of these shortcomings when applying cost-benefit analysis so that appropriate methodologies are designed, and suitable techniques are incorporated to handle the task at hand. Below are some of the limitations worth noting.

Evaluating future scarcity, and problem of uncertainty

Most of the human health and environmental risks that arise from projects and need to be costed are incurred both in the present and future. Evaluating both the costs and benefits (of these risks) is

certainly difficult due to uncertainty since there is always limited knowledge on scarcity that may arise in future (Hansjürgens, 2004). This makes quantitative CBA of regulatory measures only applicable on a limited scale. Economic cost-benefit analysis thus often adapts other methods involving qualitative information gathering, like contingency valuation method and data envelopment analysis, to mitigate these limitations. In this particular study, contingency valuation method is applied in assessing project feasibility at city scale.

Problem of substitutability and irreversibility

Cost-benefit analysis is based on the concept of neoclassical welfare economics which relies basically on the assumptions that project benefits and costs can be weighed up against each other (Hansjürgens, 2004). This implies that cost-benefit analysis cannot be applicable in a situation where an action alternative is not dispensable or is very essential and cannot be substituted. Another basic assumption of neoclassical economics is that of reversibility, meaning that the selection of an action alternative can in principle be reversed. This implies that CBA is impermissible unless decision on resource allocation can be reversed for any spatial or temporal change in scarcity. Nevertheless, when applying CBA in a situation where this reversibility is a major concern, the concept of opportunity cost is adapted to address this challenge, although ecological economists argue that in most cases application of the concept of opportunity cost in CBA does not address the issue of irreversibility sufficiently.

The problem of discounting and compensation

In applying cost-benefit analysis usually a suitable discount rate is estimated or capital market rate are used (Kuosmanen & Kortelainen, 2007). However, the nature of environmental costs and benefits are always of long-term, hence costs and benefits are spread over time. Identifying a suitable discounting rate is often a problem that results to impermissible perspective reduction. On the other hand, cost-benefit analysis is based on the principle that a project is successful when benefits outweighs costs, because then the losers can adequately be compensated. Some schools of thought view this principle as inhumane because they argue that human life and health are sacrosanct and cannot be subject to economic weighing (Hansjurgens, 2004 pp. 244). In this study, a social discount rate that incorporates the national interest rate has been adapted.

Therefore, much as cost-benefits analysis is still the most widely used instrument to reduce inefficiency and irrationality in environmental policies, its application should not be limited to quantitative data, but rather incorporate some qualitative information gathering methods. This study addresses these limitations of CBA by adapting some of the relevant concepts discussed section 3.2.1, and applying them in the methodology.

3.2.1.3 Sensitivity analysis

Since determination of prices of most of the environmental impacts are not precise, most projects end up having unreasonable prices on environmental impacts, and hence qualify. Further analysis is needed to determine their resilience to changes in key parameters that determine project financial feasibility. Varying the values of these key parameters like discount rate, selling price, and project

period; may guide decision makers in allocating the often scarce resources (Kuosmanen & Kortelainen, 2007).

4 Research Methodology

This research involves a case study on ecological sanitation project in Valley View University in Accra. The study has two components; economic analysis of the project in the university, and evaluation of the possibility of scaling up this project (ecological sanitation) to a city scale. In each case, cost-benefit analysis is used as the basic framework for analysis. Sensitivity analysis is done using different scenarios for assessing the project feasibility and resilience. Data collection exercise was coordinated from VVU campus using stakeholders' interviews, desk study, field observation and contingency valuation methods.

4.1 Methods for data analysis

From the public point of view, it would be interesting to evaluate the overall impacts of decentralized wastewater management and technology (Liang & van Dijk, 2009). These impacts can be classified as internal effects, external effects and opportunity costs. Where the internal effects are the costs and benefits that affect the individual users and the utility management directly, while the external effects are those (costs and benefits) associated with the economy, environment and the society. On the other hand, the opportunity costs are applied to represent the value of a good or input in its worth in some alternative use. All the costs and benefits of this project are therefore identified and classified as illustrated in Table 4.1 below. Cost-benefit analysis is then used as the basis for evaluation.

Table 4.1: Classification of costs and benefits

Classifications	Benefits/ costs	Subdivision of costs/benefits
Internal effects	Benefits	Economic (income from the sales of reclaimed water)
	Costs	Investments costs (construction & equipments, labour)
		O&M costs (power, routine maintenance, employee)
		Financial costs (interest on investment)
External effects	Benefits (positive externalities)	Economic (cost of connecting to WWTP & WS mains avoided)
		Social benefits (cost of customer education avoided)
		Environmental (water resource fee avoided)
	Costs (negative externalities)	Social costs (cost of DALYs due to water and sanitation diseases)
Opportunity costs	Cost	Value of alternative use of land

Adapted from Hernändez et al., (2006)

4.1.1 Cost-benefit analysis (CBA)

In calculating the total net benefits, we shall include all the internal benefit, external benefits, and the opportunity costs of the project (Hernández et al., 2006). Presenting it mathematically;

$$B_{TN} = B_I + B_E - OC \quad \text{.......} (1)$$

Where;

B_{TN} is total net benefits (total income –total cost) of the project

B_I is the internal benefits (internal income – internal costs) of the project, and

Internal income = (selling price of water reclaimed) x (volume of water reclaimed)

Internal costs = (investment cost + O&M costs + financial costs + taxes)

B_E is the external benefits (positive externalities – negative externalities) of the project, and

OC is the total opportunity costs of some items in the projects.

4.1.2 Internal effects

The internal benefit (net effect) is the resultant of the internal costs and benefits on the project, and it assesses the financial viability of the project. It is the factor that motivates system management when it is positive since it implies investment and operational costs are met from within, while a negative value would imply the project does not meet cost recovery.

Table 4.2: Internal cost and benefits

	Benefits/ costs	**Subdivision of benefits/ costs**
Internal effects	Benefits	Economic (income from sales of water reclaimed)
	Costs	Investments costs (construction & equipments, labour)
		O&M costs (power, routine maintenance, employee)
		Financial costs (interest on investment)

Presenting mathematically:

$$B_I = \sum_{t=0}^{t=n}[(AVWR_n \; X \; SPWR_n) - (IC_n + O\&MC_n + T_n + FC_n)] \quad \text{.......} (2)$$

Where; B_I is internal benefits (net effect), IC_n = investment cost, $O\&MC_n$ = operating and maintenance costs, $T_{\boldsymbol{n}}$ = taxes, $FC_{\boldsymbol{n}}$ = financial costs, $AVWR_n$ = annual volume of water reclaimed, and $SPWR_{\boldsymbol{n}}$ = selling price of water reclaimed; while $\boldsymbol{n}$ the project period in years.

The financial cost (FC_n) for the whole project period (in this equation) is discounted using social discount rate (r) of Ghana, which is 6% as given in table 4.6.

This study comprises two different components; firstly is the analysis of the project feasibility within the university. As outlined in chapter 2 section 2.4, the university is implementing on-site water reclamation and reuse project as an integral part of the overall ecological master plan. The project (on-site water reclamation and reuse) is aimed at providing water to meet the other objectives of the master plan. In this case, the valuation takes the form of 'with on-site water reclamation and reuse project', and 'without on-site water reclamation and reuse project'. The selling price for potable water from public water supply utility is therefore applicable in this scenario since the university would have to get water from any alternative source if there were no on-site water reclamation and reuse project. The $SPWR_n$ (selling price of water reclaimed) in equation (2) above is therefore equal to the price per unit volume of potable water from public utility (1.18 USD/m^3). This criterion is applicable to both rainwater and grey water reclamation for use in the university. When computing equation (2) using this criterion, a positive value of B_I implies that the internal income outweighs the internal cost in which case there will be an internal net benefit and the project is considered to be financially feasible. While a negative value of B_I indicates an internal net loss and the project will be considered financially infeasible (Liang & van Dijk, 2009), (Hernández et al., 2006).

The second component is the analysis of the project feasibility at the city scale in the event of scaling up. Under this circumstance, the cost per unit volume of reclaimed water is subjected to the users' willingness to pay survey. Since the community indicated their willingness to use harvested rainwater, the price used in the evaluation of rainwater harvesting is therefore the one which the majority of the community indicated their willingness to pay. In this case, $SPWR_n$ in equation in equation (2) is 0.71 USD/m^3 (the price the majority of the households have indicated their willingness to pay). This price per unit volume of reclaimed water in used in equation (2) together with the other data given in table 4.6, and a positive value of BI implies the project is financially viable while a negative would mean it is not financially viable.

However, for the case of reclaimed grey water which the community leaders expressed their reservations to use, (may be after sensitization of the community), there is no cost per unit volume of water reclaimed. In order to obtain this price, the cost per unit volume of water reclaimed will be made equal to the minimum selling price for which cost recovery is achievable (Hernández et al., 2006). Under this circumstance, the internal net value (B_I) criterion is used to obtain this price. The minimum selling price of water reclaimed is that price which makes the internal net benefit B_I in equation (2) equals to zero.

$$B_I = \sum_{t=0}^{t=n}[(AVWR_n \; X \; SPWR_n) - (IC_n + O\&MC_n + T_n + FC_n)] \quad = \quad 0$$

Where $SPWR_n = MSPWR_n$; for the project period n = 20 years;

MSPWR = (IC + O&MC + T + FC)*20/ (AVWR)*20... (3)

If the minimum selling price obtained in equation (3) is less than the price of potable water from the public water utility, then the project is considered financially feasible, whereas a greater value of the minimum selling price would imply the project is financially infeasible (Hernández et al., 2006).

It is the second component of the study (analysis of the project feasibility at city scale) that is subjected to sensitivity analysis to verify the robustness of the project under different real life situations by varying the values of key parameters. The parameters whose values are varied include discount rate, selling price of reclaimed water, and investment return period. Equation 2 is used to evaluate the project feasibility when the selling price and investment return period are varied, whereas equation 3 is used to assess the project when the discount rate is varied.

4.1.3 External impacts

Table 4.3: External cost and benefits

External effects	Benefits (positive externalities)	Economic (cost of connecting to WWTP & WS mains avoided)
		Social benefits (cost of customer education avoided)
		environmental (cost of water resource fee avoided)
	Costs (negative externalities)	Social costs (cost of DALYs due to water and sanitation diseases)
Opportunity cost	Cost	Value of alternative use of land

External costs and benefits are regarded as any consequences which can be positive or negative, intentional or random; that is derived from the project and its value can be calculated. For external influence which has no explicit market value, economic valuation method (shadow pricing) is used basing on hypothetical scenario observed in related markets (Hernández et al., 2006). The difference between the positive and negative externalities gives the external benefits. Presenting mathematically;

$$B_E = \sum_{t=0}^{t=n}(PE_n - NE_n) \quad \text{.......} \quad (4)$$

Where;

B_E is the external benefits (net externalities); PE_n is the positive externalities (cost of connecting to GWCL water supply main & WWTP, water resource fee, and customer education avoided); while NE_n is the negative externalities (cost of DALYs due to sickness & death as a result of water and sanitation related diseases); and *n* is the project lifespan in years.

The positive externalities (PE) of the on-site wastewater reclamation and reuse in VVU comprised of the avoidance costs of the following:

1. Cost of connecting to the nearest GWCL water supply mains (since the OWS to which the university is connected is inadequate). The distance used in this evaluation is 15km, and the unit cost per meter is 27 USD/m (details of sources given in table 4.6 below),
2. Cost of connecting to the nearest water treatment plant (WWTP). The nearest WWTP is in Tema which is about 25km from the university, and the unit cost of construction is 200 USD/m, there is still no sewer connection from this WWTP to the university.
3. Cost of water resource fee avoided, the cost per 1,000m^3 (0.65 USD/1,000m^3) being paid by Aqua Vitens Rand is used in the evaluation, and
4. Cost of customer education avoided by the university as a result of the project, the rate per customer used by AVRL is applied in the evaluation. Table 4.6 gives details of these rates and their sources.

On the other hand, negative externality is the cost of DALYs due to diseases that can be contracted from using reclaimed water. One DALY corresponds to one lost year of healthy life, and the burden of diseases to the gap between current health status and an ideal situation where everyone lives until old age, free of diseases and with no disabilities (WHO, 2007). In this study, DALYs is used as a means to convert to monetary value, the health risk from national level to the scale of an institution as VVU, and the Ayensu River housing estate. The value of DALYs used in this study is adapted from the one based on the output approach which derives its justification from the use of the human capital approach in valuation of mortality in developing countries (Markandya, 2004). This approach takes the per capita GDP as the lower bound. Table 4.4 below gives the details of how the DALYs for this study is computed.

Table 4.4: Calculation of DALYs for VVU

Population of Africa	967,000,000	People
DALYs attributed to WASH in Africa	6,916,000	DALYs/year
Average cost of DALYs in Africa	6bn	USD/year
Population of Ghana	23,000,000	people
DALYs attributed to WASH in Ghana	164,496	DALYs/year
Population of Accra	3,695,399	"
DALYs attributed to WASH in Accra	26,429	DALYs/year
Population of VVU	3,500	"
Area of VVU subject to irrigation (1/3 of VVU area affected)	0.067	km^2
DALY number (26,429*0.016%*4/12) popn of Accra x proportion of project area and city size	1.41	DALYs/year
DALY rate	868	US $/DALY
Valuation of health impact (DALY rate x DALYs number)	1,223	US $/year

Adapted from Markandya, (2004) & WHO, (2004)

The difference between the positive and negative externalities gives the external benefits B_E. A positive value of B_E, on computing the equation (3), means the project is economically viable, while negative external benefit implies that the project is economically infeasible (Liang & van Dijk, 2009), (Hernández et al., 2006), and (Friedler & Hadari, 2006).

4.1.4 Economic feasibility of the project

The overall project economic feasibility in this study is determined by computing the total net benefit B_{TN} given by equation (1). Therefore, substituting equations (2) and (3) into equation (1), the total net benefits B_{TN} can be computed using equation;

$$B_{TN} = \sum_{t=0}^{t=n} [(AVWR_n * SPRW_n) + (PE_n - NE_n) - (IC_n + O\&MC_n + FC_n + OC_n)] \text{ .... } (5)$$

Where: $AVWR_n$ is the annual volume of water reclaimed, and $SPWR_n$ is the selling price of water reclaimed. OC_n is the opportunity cost incurred during the project period *n*.

A positive value of B_{TN} implies that the project is economically feasible, while a negative value means the project is not feasible.

Underlying assumptions:

1. This study assumes that there will be no capital investment during the project period. The capital cost remains the initial investment which has simple interest charged on it using the national social discount rate. The only cost that shall be incurred annually throughout the project period is the financial cost and O&M cost, which is also assumed to be constant during the period.

2. The government policy of no taxes on water and sanitation projects to the community is assumed to apply to wastewater reclamation and reuse projects as well.

3. The social discount rate is assumed to remain constant throughout the project period.

4. The interest on investment is computed using simple interest rate; $P_n = P_0*(1+rn)$.

5. The selling price for water is assumed to remain constant throughout the project period.

6. Connection to GWCL mains will provide adequate water supply to the institutions.

Table 4.5: Description of general data

Data description	**Figure**	**Source**
Population of Africa (2008)	967,000,000	Internet
Population of Ghana (2008)	23,000,000	Department of statistics, Ghana
Population of Accra (2008)	3,695,399	Archive information from SWITCH

Data description	**Figure**	**Source**
Population of VVU (2009)	3,500	VP, general administration, VVU
Population of Ayensu River estate	900	Estate manager,
Average size of household in Ghana	5 people	Ghana Statistical services
Social discount rate of Ghana	6%	Ghana Statistical services
Gross domestic product (GDP)	16,124	Ghana Statistical services
GDP growth rate per annum	4.98%	Ghana Statistical services
GDP per capita	1,572	Ghana Statistical services
GDP growth rate per capita per annum	2.2%	Ghana Statistical services
Project lifespan	20 years	Director physical plants
Cost of customer education	23.56 USD/person	Aqua Vitens Rands ltd
Water resource fee	0.65 USD/ 1000m^3	Aqua Vitens Rands ltd
Cost of constructing of sewer lines	200 USD/m	Aqua Vitens Rands ltd
Cost of constructing water supply pipes	27 USD/m	Aqua Vitens Rands ltd
Vol. of grey water reclaimed	4,690 m^3/year	Valley View University
Potential for rainwater harvesting in vvu	6,118 m^3/year	(Lauterbök, 2009)
Vol. of rainwater harvested	4,256m^3/yr	Valley View University
Cost of emptying septic tanks	130USD/10,000m^3	Valley View University
Minimum distance to WWTP	25 km	Valley View University
Nearest GWCL WS mains	15 km	Valley View University

4.2 Methods for data collection

The methods employed for data collection are: stakeholder interviews, desk study, filed observation, and contingency valuation method.

4.2.1 Stakeholders interviews

The stakeholders in the water and sanitation sector in Accra were identified with the assistance of International Water Management Institute (IWMI). Self administered questionnaires were used to get information from key informants. The same visit to the offices of stakeholders from the formal sectors also provided opportunities to ask for secondary literature from their archives. While within

the university, the sources of data were mainly from technical design plans and bills of quantities for the ecological project, interviews with the Director Physical Plants and other key staff involved in the management of the project. Operational budgets and expenditures, and associated benefits both within and outside the compass were among the areas where data were collected.

4.2.2 Desk study

The secondary literature collected from the stakeholders plus the project documents from the university were reviewed to validate the information collected from the key informants (Yin, 2003). Other sources of literature for desk study were got from the internet and documents of other studies on the same project from the university library. The main focus for desk study was to provide information on service delivery levels, DALYs, social discount rate, per capita demand, common water and sanitation diseases, and other water and sanitation management challenges. Table 4.6 provides details of general information collected.

Table 4.6: Description of data collection exercise

Type of data	**Methods used**	**Data source**
Information on market prices	Self administered questionnaires	GWCL (Aqua Vitens)
		Oyibi Water Scheme (OWS)
Information on cost of investment and O&M of project	Questionnaires, Project documents	Department of Physical Plants, VVU
Information on demographic data and other social dev't indicators	questionnaires, internet	Ministry of Finance, dept of Statistics, websites
Information on water resources potential	Questionnaires, literature review	Ministry of water – water resource department, secondary literature
Information on quantity of rain water reclaimed and used	Questionnaires, literature review	Department of Physical Plants, VVU Project documents, and secondary literature
Information on quantity of grey water reclaimed and used	Questionnaires, literature review	Ecosan manager, farm manager, Project documents, secondary literature, VVU
Information on acceptance and willingness to pay for rain water	CVM, FGD	Ayensu River housing estates

4.2.3 Field observation

Direct observation and recordings of the physical infrastructures of the project was done. A visit to the university farm together with the farm manager enabled me to appreciate the significance of the reclaimed water for reuse. This was used to provide multiple sources of evidence in order to construct validity of the findings (Eisenhardt, 1989).

4.2.4 Contingency valuation method

In order to assess the prospect of scaling up the ecological sanitation project (in VVU) to a city scale, a contingency valuation method was used to determine the social acceptance and willingness to pay for the reclaimed water for reuse.

4.2.4.1 Identification of respondents

Given the fact that on-site water reclamation and reuse projects require nucleated settlement pattern like flats/storey buildings, housing estates (Friedler & Hadari, 2006), the nearby housing estates provided a good opportunity. These were Oyibi and Ayensu River estates. However, due to limited funding and time, a survey was done only in Ayensu River estate. The survey targeted all the 180 households in the estate.

4.2.4.2 Focus group discussions

A group discussion was held with the manager of the water utility supplying the estate, the estate chairperson, and opinion leaders in the area to explain the objectives of the intended survey and get their views on the on-site water reclamation and reuse (Whittington, 1998). Five people were involved in the discussion; utility manager, 2 representatives of the community in each estate, and 2 opinion leaders – the opinion leaders were identified in consultation with the first 3 leaders.

During the discussion, the following issues came up:

- The leaders expressed reservations on the use of reclaimed grey water. They argued that they have not heard of it being used anywhere and would not wish to be the pioneers since it may have adverse health risks.

- The utility manager advised that the survey on grey water reuse should not be administered to her customers since they may later think that water from OWS contains grey water. On the issue of affordability, the utility manager said she believes the rate of GH¢ 1.65 (1.18 USD/m^3) per meter cube of water is affordable to her customers because she has not had any problem in bill collection, (in a separate interview, she said the utility realises payment of over 95% of the bills).

- The community leaders welcome the idea of harvesting rainwater for domestic use and they commented that rainwater is good for washing, it is a free gift from God, and may even be purer than the water they are using now.

- The utility management observed that rainwater harvesting for domestic use is a good initiative but wonders how the supply can be made consistent throughout the year.

After all the discussion, assessment on the acceptance and willingness to pay for grey water was dropped. The questionnaires designed did not focus much on affordability since the cost of rainwater is expected to be lower than that of potable water, which was assumed to be affordable.

4.2.4.3 Social acceptance and willingness to pay survey

A questionnaire was developed on the acceptance and willingness to pay for rainwater harvested for flushing toilets. Four university students on holidays were identified and trained as enumerators to administer the questionnaires on contingency valuation survey in Ayensu River estate. All the four enumerators are university students on holidays who reside in the neighbourhood of VVU campus and the estate. The questionnaires were pretested before conducting the survey. The questions for the interviews were about social acceptance and willingness to pay for the rainwater harvested. Affordability was not an issue because the utility manager says she does not have any problem with bill collection and there are no complaints about the price of water. Since the price of reclaimed water is assumed to be lower or equal to the price of potable water, (though they serve the same purpose i.e. in flushing toilets), the customers were expected to afford the price of reclaimed water as well.

To avoid confusion on the willingness to pay for the "hypothetical good", the price per cubic meter of water from Oyibi Water Scheme (same as for GWCL) was used as a guide (Whittington, 1998). The price per cubic meter of water from OWS is GH¢ 1.65; and a price range from GH¢ 1.65 to GH¢ 0.50 was used in the questionnaires. A sample of the questionnaires used is attached in the Annex 4.

4.2.4.4 The findings of the willingness to pay survey

A total of 127 households completed the questionnaires, of which over 94% (120 respondents) said they are willing to use rainwater for flushing their toilets; while about 6% (7 respondents) said they do not agree to use rainwater for flushing their toilets. The details of the result are presented in table 4.7 below.

Table 4.7: Response to contingency valuation survey

Total No. of households	180	100
Number of H/H who participated	127	70.6
Number of respondents who said "Yes"	120	66.7
Number of respondent who said "No"	7	3.8

Of the respondents who said "No", 3 of them argued that rainwater is unreliable and there is risk of having no water to flush toilets in some seasons of the year, and 2 said they have not hard it being used anywhere and they do not want to be species for experiment, while the other two gave no reasons. In a democratic society, it can be concluded that the majority of the residents of Ayensu River estate have accepted to use rainwater and are willing to pay 0.71 USD/m^3 (GH C 1.00/m^3).

5 Results and discussions

In this chapter, the results of the different evaluations are discussed under sections 5.1, 5.2 and 5.3. Section 5.1 and 5.2 evaluate the financial and economic feasibility of grey water reclamation and rainwater harvesting respectively within the university, while section 5.3 evaluates the feasibility of on-site water reclamation and reuse project at the city scale. In every section, the internal and external effects, plus the total net benefits of the project are critically analyzed. Sensitivity analysis is done only in section 5.3 (evaluation of the feasibility of the project at city scale), where the project is tested for its resilience to future uncertainties in real-life situations in the event of scaling up. Finally, section 5.4 gives a general analysis of the benefits and costs of on-site water reuse projects to the different stakeholders. It further highlights the institutional challenges may confound the success of any water and sanitation project.

5.1 Grey water reclamation and reuse project in VVU

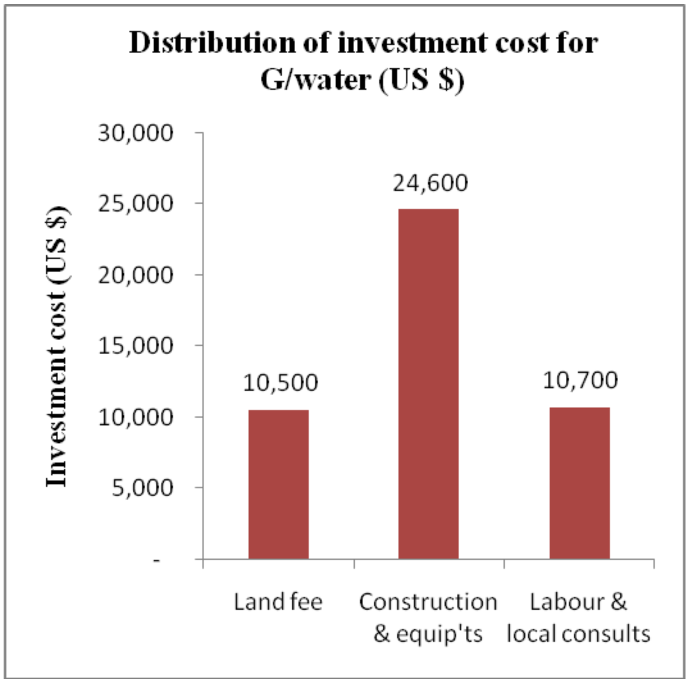
Since grey water reclamation and reuse project is an integral part of the university ecological master plan, the analysis takes the scenarios of 'with grey water reclamation project' and 'without grey water reclamation project', which means the market price for potable water is used in the evaluation. Financial analysis was used to evaluate the internal effects while external effects were assessed using economic and environmental valuations. The overall economic feasibility of the project is assessed using the total net benefit obtained by summing the values of the internal and external effects.

5.1.1 Internal effects of grey water project in VVU

Analysis of internal effects of the project applies the framework given in table 4.1, and equation (2) described in section 4.1.2. It focuses on the financial viability of the project. Figure 5.1 (a) below shows that most of the investment cost is attributed to construction and equipments followed by labour and consultancy, while the cost of land is the least expensive. On the other hand, the cost breakdown for operation and maintenance illustrated in figure 5.1 (b) indicates that routine maintenance takes the largest share. This is because it involves disinfecting the tanks plus checking and correcting the leaks in the piping connections (preventive maintenance). Power is the lowest because the system does not require much pumping. Water is collected by gravity to the treatment tanks and treatment is effected through flocculation and sedimentation which do not require power. The only stage where power is required is pumping reclaimed water from the sedimentation tanks to the elevated reservoirs from where it flows by gravity to reuse points. Table 5.1 below gives the unit cost of investment and O&M per m^3 of grey water reclaimed.

Table 5.1: Cost of producing and maintaining unit volume of grey water

Quantity (m^3)	Investment cost (USD)	Operational cost (USD)	Opportunity cost (USD)
4,690 m^3/year	35,300	922	10,500
$1m^3$	7.53	0.20	2.24



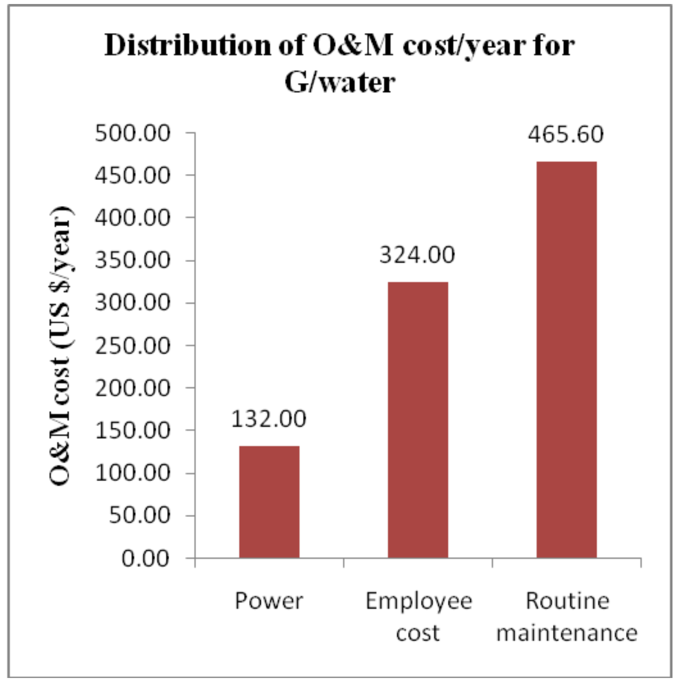


Fig. 5.1 (a): Cost for Investment for G/water **(b): Cost for O&M for G/water**

[Source of figures: Kwandahor, (2010)]

From equation (2) in section 4.1.2;

$$B_I = \sum_{t=0}^{t=n}[(AVWR_n \; X \; SPRW_n) - (IC_n + O\&MC_n + T_n + FC_n)]$$

Therefore: B_I = (4,690x20x1.18) – (35,300 + 18,432 + 0 + 42,360) = 14,592

The result of financial analysis above gives a positive net benefit implying that on-site grey water reclamation and reuse project is financially viable in the university. Further analysis reveals that if all the grey water reclaimed is put to use, the university saves about 730 USD per year in its quest to achieve the ecological master plan. With a production capacity of 4,690 m^3 per year (Table 2.5, chapter 2), it implies that 1 m^3 of grey water reclaimed for reuse incurred 7.53 USD on the initial investment, and the university spends 0.20 USD as operational cost to sustain production of $1m^3$ of grey water every year.

5.1.2 External effects of grey water project in VVU

From table 4.3 in section 4.1.3, positive externalities PE_n comprise cost of connecting to WWTP and public WS mains avoided, plus cost of customer education and water resource fee avoided. While NE_n has the cost of DALYs as a result of disease burden imposed on the inhabitants by the project. Table 4.4 in chapter 4 gives the methodology to compute the cost of DALYs, for the project in Valley View University.

Table 5.2: Costs of external effects for grey water in VVU

Positive externalities (PE_n)	**Quantity**	**Rate**	**Cost (USD)**	**%age**
Sewer line	25km	200	5,000,000	70.879
Piping for water supply	15km	27	405,000	5.741
Water resource fee	$4690m^3$	0.65 USD/1000m^3	60.97	0.001
Customer education	3,500	23.56 USD/person	1,649,200	23.379
Total			7,054,260.97	
Negative externalities	1.41	868 USD/DALY	24,460	
Net externalities			7,029,800.97	

The externalities is computed using equation (4) in section 4.1.3

$$B_E = \sum_{t=0}^{t=n}(PE_n - NE_n) \qquad = 7{,}029{,}801$$

The net externality is positive, implying that the project is socially, environmentally and economically sustainable.

The result shows that the cost of sewer construction avoided constitutes over 70% of the total positive externalities, connecting to water supply mains accounts for about 6%. Because of the on-site water reuse project, there is no spending on customer education and this, according to Aqua Vitens program saves up to 82,460 USD every year and is over 20% of the cost avoided. The cost that can be incurred due to health hazards attributed to by the project is only 1,223 DALYs/year (disability adjusted life years) which is less than 0.4% of the positive externalities of the project. While the total positive external impact is over 288 times greater than the negative externalities.

5.1.3 Total net effects of grey water project in VVU

This section analyses the total net effects of the project including both internal and external benefits. The evaluation procedure uses equation (1) in section 4.1.2 to determine the total net benefit B_{TN};

$$B_{TN} = B_I + B_E - OC$$

= 14,592 + 7,029,801 - 10,500 = 7,033,893 USD

The positive total net benefit implies the project is economically feasible. It is important to realize that this analysis takes the most extreme cost-sharing model in which all the costs are borne on the users, while the public (government) benefits from the all positive externalities without incurring any cost. However, in this case of VVU the investment capital does not need to be reimbursed (Sarpong, 2009); therefore the key parameters for financial feasibility are the internal income and the operation and maintenance costs. As shown in table 5.3 below, the operational net effect inclusive of financial cost (42,360 USD) gives a positive balance of about 50,000 USD (gross profit). Since the investment capital is not to be reimbursed, we can ignore the financial cost and the resultant effect will be a positive balance of over 92,200 USD; implying that the university is saving over 4,600 USD every year on grey water reclamation and reuse.

Table 5.3: Project impact analysis by benefit-cost items for grey water

Cost items	**Impact analysis**			**Remarks**
	Benefits	**Costs**	**Effects**	
Operational (income Vs O&M and fin. costs)	110,684	- 60,792	49,892	+ve gross profit
Economic (invest. avoided Vs invest. spent)	5,405,000	-45,800	5,359,200	+ve economic effects
Environ'tal (positive Vs negative impacts)	61	0	61	+ve environ'tal effects
Social (positive Vs negative effects)	1,649,200	-24,460	1,624,740	+ve social effects
Total net effects (B_{TN})	7,164,945	-131,052	7,033,893	+ve total net effects

5.2 Rainwater harvesting in VVU

The analysis of rainwater in the university is similar to that of grey water discussed above. The financial analysis takes the scenarios of 'with rainwater harvesting' and 'without rainwater harvesting', which means the market price for potable water is used in the evaluation. Financial analysis was used to evaluate the internal effects while external effects were assessed using economic and environmental valuations. And the overall economic feasibility of the project is assessed using the total net benefit obtained by summing the values of the internal and external effects.

5.2.1 Internal effects for rainwater harvesting in VVU

The project cost breakdown is given in figure 5.2 below. Similar to grey water reclamation, most of the investment cost is attributed to construction cost followed by labour and consultancy, while the cost of land is the least expensive. For the O&M cost, routine maintenance takes the largest share while power is the least costly because the system does not involve much pumping. Using the quantities of rainwater harvested given in table 2.8 in chapter 2; and the project cost details given in

figure 5.2 (a) & (b) below, the unit rates for investment and O&M are computed in table 5.4 hereunder.

Table 5.4 Cost of investment and O&M per unit volume of rainwater

Investment cost per unit volume of rain water			**O&M cost per unit volume of R/water**	
Quantity	Invest.cost (USD)	Opport'y cost (USD)	Quantity	O&M cost (USD)
6,118 m^3/year	60,200	8,000	4,256 m^3/year	92.60
1m^3	9.84	1.31	1 m^3	0.26

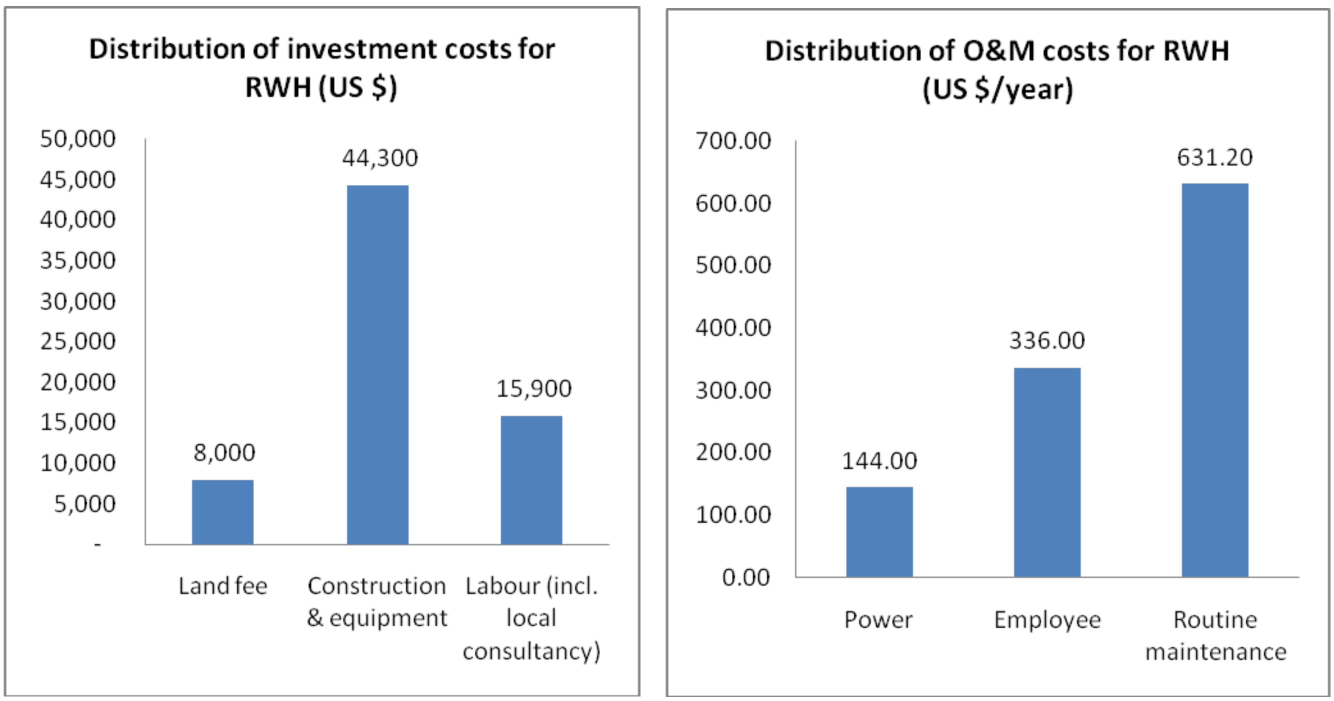


Figure 5.2: (a) cost for investment for RWH **(b) cost for O&M for RWH**

Source of figures: Kwandahor, (2010)

As illustrated in table 5.4 above, the university spent 9.84 USD as initial investment for every m^3 of rainwater being harvested, while 0.26 USD is assumed to be spent in maintaining 1m^3 of rainwater harvested every year. The cost for operation and maintenance is hypothetical in both grey water reclamation and rain water harvesting, because there are no proper records of expenditures for this project in the university, and the costs used in all cases are the designed estimates which would still be the same even if the whole potential was being utilized (Sarpong, 2009).

From equation (2) in section 4.1.2, the internal benefit B_I (the net effects) is computed thus;

$$B_I = \sum_{t=0}^{t=n} [(AVWR_n \, X \, SPRW_n) - (IC_n + O\&MC_n + T_n + FC_n)]$$

B_I = (4,256 x 1.18 x 20) – (60,200 + 22,224 + 72,240) = - 54,222 USD

The net internal effect is negative implying that the project is not financially viable and the university is spending over 2,700 USD/year more, compared to getting water from the public water supply company. If there were no water loss; B_I = (6,118 x 1.18 x 20) - (22,224 + 132,440) = -10,279 USD. In this case the university would have been spending only about 500 USD/year more compared to getting water from public water supply company. The non viability of rainwater harvesting could be attributed to the high investment and operational costs. The cost of filter used in the evaluation is high because it was imported from abroad (Kwandahor, 2010). Using locally made materials would reduce the cost of investment and the project could be financially feasible (Hatibu et al., 2006).

However, it is important to note that none of the two public water utilities (GWCL and OWS) have adequate capacity to meet the water demand of its customers; OWS supplies only 36 hours a week while GWCL WS main does not reach VVU, and even then the utility meets only about 50% of the demand of its customers. For the university to meet its ecological master plan, rainwater harvesting becomes a valuable project that should not be neglected.

Similarly, the investment model applied puts all the costs on the users without any input from the public; besides it is assumed that the university will reimburse the investment capital with an interest rate of 6%. Conversely, the university is not expected to be reimbursed the capital which means in reality the investment and financial cost should be excluded when assessing the project internal effects to the university. The analysis of the total net benefits considers this scenario and the result may be different as we shall see.

5.2.2 External effects of rainwater harvesting in VVU

The cost items for externalities for on-site rainwater harvesting are similar to that of grey water reclamation except that in this case there is no avoidance cost for connecting the university to the main WWTP since storm water does not necessarily need to be discharged to WWTP. On-site rainwater harvesting avoids the cost for connecting to GWCL water supply mains, customer education, and water resource fee. All the values for negative externalities for rainwater harvesting are negligible. The noise level of the pump is low and there are no complaints from the inhabitants and the neighbours. Besides, as the main objective of rain water harvesting is for flushing toilets, it offers limited exposures to cause disease infections implying that the health risk is also negligible.

The net externality is given by equation (4) in section 4.1.3; while table 5.5 below gives the details of cost items. $B_E = \sum_{t=0}^{t=n} (PE_n - NE_n)$; solving this equation using values in table 5.3 gives B_E = 2,054,255 USD; the positive value of B_E implies that the project is economical, and environmentally and socially sustainable.

Table 5.5: Cost of external effects for rainwater harvesting in VVU

Positive externalities	**Cost (USD)**	**%age of total PE**
Connecting to GWCL WS mains	405,000	19.715
Water resource fee	55	0.003
Customer education	1,649,200	80.282
Total	2,054,255	
Negative externalities	0	Negligible, limited exposure routes for diseases
Net external effects (benefit)	2,054,255	

The result shows that the cost for water resource fee avoided is almost negligible because the rate imposed by government as natural resource fee is low. This may be taken as government reluctance in enforcing regulations that protect depletion of natural resources (Abdulla & Al-Shareef, 2009). Because of the on-site rainwater harvesting project, there is no need for customer education program and this, according to Vitens customer education program, saves up to 82,460 USD every year; which is over 80% of the total cost avoided. While avoidance cost for connecting to GWCL water supply main accounts for about 20%. The cost that can be incurred due to health risks attributed to by the project computed in terms of the cost of DALYs/year (disability adjusted life years), is negligible due to limited disease exposure routes. This is because the project offers limited contacts with harvested rain water especially when it is only used for flushing toilets.

5.2.3 Total net effects of rainwater harvesting in VVU

This section analyses the total effects of the project; both internal and external. The valuation uses equation (1) in section 4.1.2 to determine the total net benefit B_{TN} by summing up the values of B_I and B_E computed above, thus;

$$B_{TN} = B_I + B_E - OC$$

$$= -54{,}222 + 2{,}054{,}255 - 8{,}000 \qquad = 1{,}992{,}033 \text{ USD}$$

Table 5.6: Project impact analysis by benefit-cost items for rainwater

Benefit/cost items	**Impact analysis**			**Remarks**
	Benefits	**Costs**	**Effects**	
Operational (income Vs O&M and fin. costs)	100,442	- 94,464	5,978	+ve gross profit
Economic (invest. avoided Vs invest. spent)	405,000	-68,200	336,800	+ve economic effects
Environ'tal (positive Vs negative impacts)	55	0	55	+ve environ'tal effects
Social (positive Vs negative effects)	1,649,200	0	1,649,200	+ve social effects
Total net effects (B_{TN})	2,154,697	-162,664	1,992,033	+ve total net effects

Despite the negative internal effects in section 5.2.1, the high value of positive externalities compensates the internal loss. This implies rainwater harvesting project is environmentally friendly and promotes sustainable social development. Besides, the investment capital does not need to be reimbursed (Sarpong, 2009); and therefore the key parameters that determine financial feasibility in this case are the internal income and the operation and maintenance costs. As shown in table 5.6, the operational net effect inclusive of financial cost is positive (gross profit of about 6,000 USD). Since the investment capital shall not be reimbursed, adding back the financial cost would leave a positive balance of over 78,000 USD. Ideally the university is saving over 3,900 USD/year on rainwater harvesting alone.

5.3 'On-site water reclamation and reuse project' at city scale

The results obtained from the analysis of on-site water reclamation and reuse project in VVU gives high positive externalities which can be an incentive for government/ donor investment to promote such a socially and environmentally friendly project (Friedler & Hadari, 2006). Given the fact that Accra is water resource constrained, and hence the public water utility may not have adequate capacity to meet the customers' water demand in a near future, feasibility of on-site water reclamation and reuse at city scale can be an option to bridge the current water supply gaps in the city (Helmreich & Horn, 2009); (Abdulla & Al-Shareef, 2009); and (Friedler & Hadari, 2006).

This section evaluates the feasibility of scaling up this project (ecological cycle management) in Valley View University to a city level. The analysis is aimed at assessing the prospects of adapting this resource management strategy to compliment the conventional sources in cities of developing countries. The evaluation adapts the criteria of minimum selling price of water reclaimed (MSPWR) for grey water reclamation, and the willingness to pay survey for rainwater harvesting, as described in chapter 4, section 4.1.4.

5.3.1 Internal effects of grey water reclamation at city scale

Since the community did not indicate their willingness to pay for grey water reclamation during the contingency valuation survey, the criterion of the minimum selling price of water reclaimed (MSPWR) described in section 4.1.2 is applied in determining the project feasibility (Hernández et al., 2006). The minimum selling price of water reclaimed is that price which makes the internal net benefit B_I in equation (2) equals to zero. Equation (3) in section 4.1.2 is used.

$$B_I = \sum_{t=0}^{t=n}[(AVWR_n \; X \; SPWR_n) - (IC_n + O\&MC_n + T_n + FC_n)] \quad = \quad 0$$

Where $SPWR_n = MSPWR_n$; for the project period n = 20 years;

MSPWR = (IC + O&MC + T + FC)*20/ (AVWR)*20

MSPWR = (35,300 + 18,432 + 42360)/ (4690 x 20); MSPWR = 1.02 USD/m^3.

The MSPWR is lower than the unit cost of potable water from public water company, implying that grey water reclamation is financially feasible at city scale. In addition to being cheaper, grey water is a reliable source of water throughout the year. Sally Redy (in Kurian & McCarney, 2010), argues that on-site grey water reclamation project reduces both potable water demand, and the quantity of wastewater to be transported for treatment hence reducing costs on both potable water and wastewater management.

5.3.2 External effects of grey water reclamation at city scale

The evaluation of the external effects of grey water reclamation project at city scale is very similar to that discussed at the university level, and uses the same valuation criterion. The only difference in data is that Ayensu River estate is about 3km further from both the WWTP and GWCL WS main, giving more economic benefits compared to the university scenario. Another notable difference is on customer education which is much lower for Ayensu River estate compared to the university. This is basically due to scale effect, which is a critical factor when considering decentralized water and wastewater reclamation projects because it also affects the operation and maintenance capacity of a utility. Highly decentralized schemes often results to high per capita operational cost on the consumers, which negatively affects project sustainability.

Table 5.7: Cost of external effects for grey water in Ayensu River estate

Positive externalities (PE_n)	**Quantity**	**Rate**	**Cost (USD)**	**%age**
Sewer line	28km	200	5,600,000	91.694
Piping for water supply	18km	27	486,000	7.958
Water resource fee	4690m^3	0.65 USD/1000m^3	61	0.001
Customer education	900	23.56 USD/person	21,204	0.347
Total			6,107,265	
Negative externalities	0	868 USD/DALY	0	
Net external effects (benefit)			6,107,265	

$B_E = \sum_{t=0}^{t=n}(PE_n - NE_n)$ = 6,107,265 USD. A positive external benefit implies the project is economical, and environmentally and socially sustainable.

Since the project is financially feasible, and the external effects has high positive value compared to opportunity cost, it implies from equation (1) that the total net benefit is also positive; the project is therefore economically feasible. Table 5.8 below gives detail analysis of the project total net benefits.

Table 5.8: Project impact analysis by benefit-cost items for grey water

Cost items	Impact analysis			Remarks
	Benefits	Costs	Effects	
Operational (income Vs O&M and fin. costs)	95,676	- 60,792	34,884	+ve gross profit
Economic (invest. avoided Vs invest. spent)	6,086,000	-45,800	6,040,200	+ve economic effects
Environ'tal (positive Vs negative impacts)	61	0	61	+ve environ'tal effects
Social (positive Vs negative effects)	21,204	0	21,204	+ve social effects
Total net effects (B_{TN})	6,202,941	-106,592	6,096,349	+ve total net effects

5.3.3 Total net effects of rainwater harvesting at city level

Table 5.9 below gives the result of willingness to pay survey conducted for rainwater harvesting in Ayensu River estate. Using a democratic approach to decision making, it can be concluded that the residents of Ayensu River estate have accepted to use rainwater and are willing to pay 0.71 USD/m^3 (GH C 1.00/m^3).

Table 5.9: Customers' willingness to pay as disaggregated by H/H size

Household size	Price of rainwater (GH ¢ /m^3)						Total (H/H)	H/H size as % of total H/H
	1.18 **(1)**	0.86 **(2)**	0.71 **(3)**	0.57 **(4)**	0.46 **(5)**	0.36 **(6)**		
1 ≤ 3 inhabitants	0	4	8	1	0	0	13	10.8
3 ≤ 5 inhabitants	0	3	30	17	16	22	89	74.2
Above 5 inhabitants	0	1	2	2	3	10	18	15
Total respondents	0	8	40	20	21	30	120	100

Figure 5.5 below on percentage willingness to pay shows that over 30% of the households of size less than 3 inhabitants are willing to pay US $ 0.86/m^3, while about 62% of the households of same size (less than 3 people) are willing to pay US $ 0.71/m^3, and less than 8% goes for US $ 0.57m^3. On the other hand, only 3% of the household size with number of inhabitants between 3 to 5 is willing to pay US $ 0.86/m^3, while about 34% (majority) of the same household size (3 ≤ 5) is willing to pay US $ 0.71/m^3. The trend is interesting when it comes to the household size with above 5 inhabitants; only one household (i.e. 6%) indicated its willingness to pay US $ 0.86/m^3 while the majority (over 56%) are willing to pay US $ 0.36/m^3, and just 11% are willing to pay at the rate of 0.71 USD/m^3 (the rate chosen by the majority).

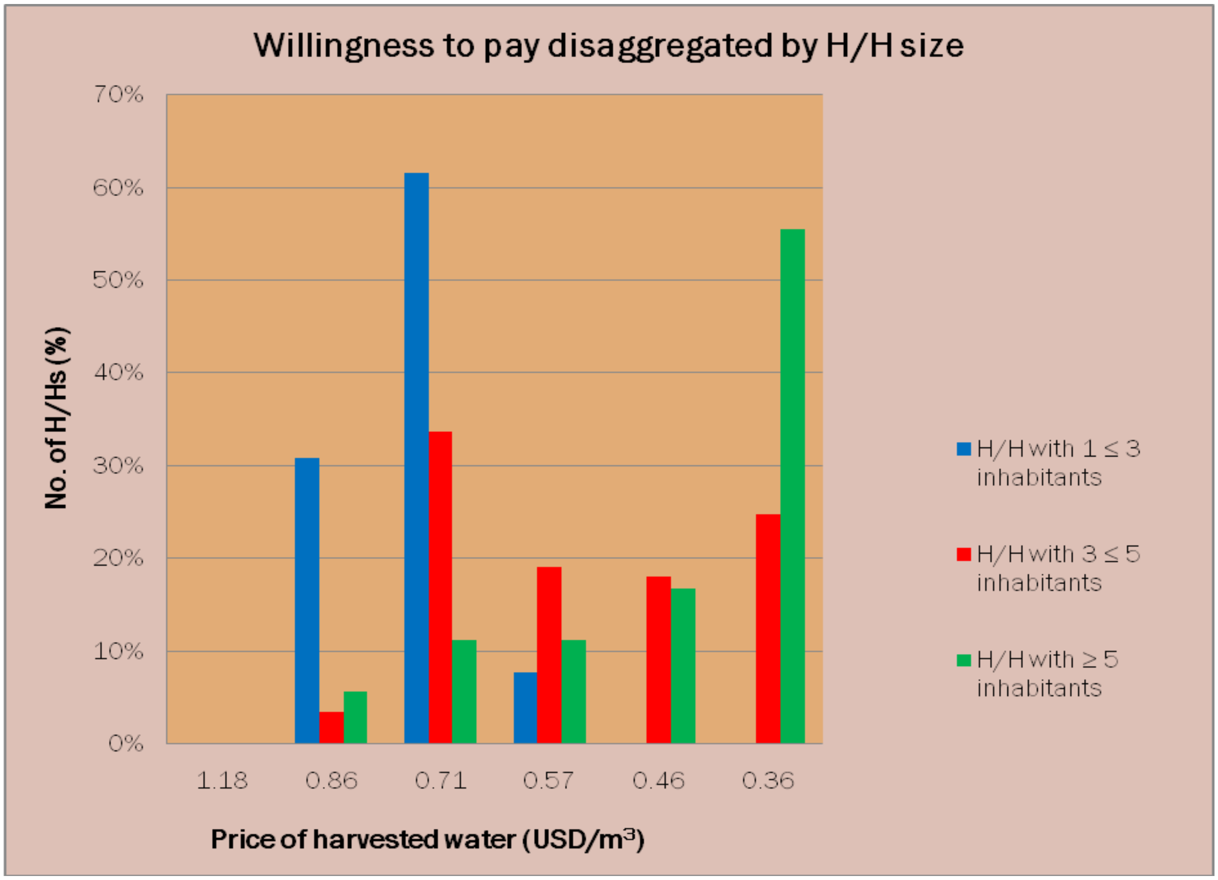


Figure 5.3: Percentage willingness to pay as disaggregated by H/H size

Analyzing the scenario where the majority (62%) of households with fewer inhabitants (1 ≤ 3 inhabitants) are willing to pay US \$ 0.71/m^3, while most of the households (56%) with more inhabitants (above 5 inhabitants) are willing to pay lower price (US \$ 0.36) for the same quantity of water, is an indication that lager families are being affected by the current price for water. This scenario disapproves the contention of the manager of OWS that the over 95% bill collection rate is an indication that the consumers are comfortable with the current rate of 1.18 USD/m^3. Based on the findings of this survey, one would argue that the high rate of payment of bills could be due to the limited amount of water used by customers (supply reliability of only 36 hours a week). For increased monthly water consumption to a reasonable average of 100 l/c/p/d with improved reliability, the findings of the survey would probably be reflected in payment of bills, and the bill collection rate may dramatically drop.

5.3.4 Internal effects of rain water harvesting at city scale

For the evaluation of the feasibility of rain water harvesting project at city scale we adapt the selling price proposed by the majority of households in Ayensu River estate as the selling price (SPWR) in equation (2). In this evaluation, it is assumed that at city scale the utility will improve the management and all the rainwater harvesting facilities will be operational. The annual volume of

water reclaimed (AVWR) in equation (2) would be 6,118 m^3/year, as illustrated in chapter 2 table 2.8.

From equation (2) in section 4.1.2;

B_I = (6,118 x 0.71 x 20) – (22,224 + 132, 440) = - 67,788 US

The internal benefit B_I is negative if rain water is sold at the price most people are willing to pay implying that the project will be financially infeasible.

The result of financial analysis shows that there is a negative internal effect (net loss) for rainwater harvesting in real life situation at city scale. This result implies that selling rainwater at the price accepted by the majority of the households would not yield cost recovery and the management would be unable to meet the project financial requirements unless with some form of subsidy. The reasons for this may be due to high investment and O&M costs for rain water harvesting. As given in table 5.4 (a), the investment cost per unit volume of about 10 USD is quite high and the operational cost of 0.26 USD/m^3 (i.e 260 USD/1000m^3) is equally very high. Meeting these financial obligations may require a larger scale.

The annual income from sales of reclaimed water in this case (4256 * 0.71) is 4,343.78 USD/year; while the operational expenses excluding the initial investment capital and financial cost (631.20 + 336.00 + 144.00) is 1,111.20 USD/year. The net surplus of income over operational cost is the sole means of running a water utility and hence a good indicator in determining the financial feasibility of on-site water reclamation project in the event of government subsidy. In this project the internal income per annum is about 4 times higher than the operational cost meaning the management will be able to meet the recurrent expenses from within.

5.3.5 External effects of rainwater harvesting project at city scale

The analytical framework adapted for computing external effect is described in table 4.3 section 4.1.3, the external effect B_E is computed by solving equation (4); $B_E = \sum_{t=0}^{t=n}(PE_n - NE_n)$. Table 5.10 below gives the details of cost items. The cost of DALYs in this case is negligible due to limited exposure to the reclaimed rainwater especially since the use is limited to flushing toilets only.

Table 5.10: Costs of external effects for rainwater in Ayensu River estate

Positive externalities	Quantity	Rate	Benefits (USD)	%age
Connecting to GWCL WS main (economic effects)	18,000 m	27	486,000	95.804
customer education (social effects)	900	23.56USD/person	21,204	4.180
Water resource saving (environmental effects)	6,118 m^3/yr	0.65USD/1000m^3	80	0.016
Total			507,284	
Negative externalities				

Positive externalities	Quantity	Rate	Benefits (USD)	%age
Cost of DALYs due to exposure to health risks, noise from the generator for pumping water	0	868 USD/ DALYs	0	0
Total net benefits			507,284	

B_E = (507,284) - (0) = 507,284 USD

The external benefit is positive implying that the project is environmentally friendly and promotes sustainable social development.

The table above illustrates that the main components of the positive externalities are the avoidance cost of connecting to GWCL water supply mains which contribute over 95% of the total externalities, while water resource saving is almost negligible with less than 0.016% of positive externalities. On the other hand, negative externality should have comprised of the cost of DALYs as a result of the health risks which the project is expected to impose on the users, and noise produced by the generator for pumping water to the elevated tank. However, as for the cost of DALYs there is limited exposure to harvested rainwater to facilitate contracting diseases, and hence the cost of DALYs can be neglected. While for the case of noise pollution, empirical finding from the rainwater harvesting project in VVU indicates that noise pollution from the generator is negligible as well. This means that the total negative external effect for this study is zero.

5.3.6 Total net effects of rainwater harvesting at city scale

The feasibility of rainwater harvesting at city scale is determined by computing the total net benefits B_{TN} given by equation (1) described in section 4.1.1. The cost items for the project net effect is quite similar to that at university level, and table 5.11 below gives the details.

Table 5.11: Project impact analysis by benefit-cost items

Cost items	Impact analysis			Remarks
	Benefits	Costs	Net effects	
Operational (income Vs O&M and fin. costs)	86,876	-94,464	-7,588	-ve gross loss
Economic (invest. avoided Vs invest. spent)	486,000	-68,200	417,800	+ve economic effects
Environ'tal (positive Vs negative impacts)	80	0	80	+ve environ'tal effects
Social (positive Vs negative effects)	21,204	0	21,204	+ve social effects
Total net effects (B_{TN})	594,160	-162,664	431,496	+ve total net effects

B_{TN} = B_I + B_E - OC

= (- 67,788) + (507,284) - (8,000) = 431,496 USD

Despite the negative internal effect (net loss) of rainwater harvesting, evaluation of the total net benefits B_{TN} shows that the project is economically viable. The high economic and social benefits are interesting from the public perspective and can attract government and/or donor support. There will be an annual saving of over 21,500 USD arising from positive externalities. Similarly, environmental impact analysis reveals that although the rate of water resource fee is low, the project does not have any significant negative environmental impacts, since the noise produced by the pump is low and therefore can be neglected. As for social effects, comparative analysis shows that the social benefits of the project is over 21,200 USD while the social cost is negligible since there is limited exposure to the rainwater harvested making it insignificant to cause diseases. Since Accra is water resource constrained, and GWCL does not have adequate financial capacity to meet the demand of its customers in a near future (Brobbey, 2010), rainwater harvesting project can complement the current supply as the government accumulates money for future construction of a bigger production plant say, from Volta dam. However, it is important to note that the internal cost (operational and financial cost) outweighs the internal income, implying that the project cannot operate without subsidy unless the interest on investment is waved off.

5.3.7 Sensitivity analysis for on-site water reclamation at city scale

Under this section, values of key parameters like the selling price for water reclaimed (SPWR), discount rate (IRR), and investment recovery period are varied in order to assess the resilience of the project financial viability under different future scenarios.

Varying key parameters for grey water reclamation at city scale

The evaluation of grey water reclamation at city scale was done on the basis of the minimum selling price of water reclaimed (MSPWR) because there was no selling price as the community did not indicate their willingness to pay for grey water during the contingency valuation survey. However, given that the public water utility does not have sufficient water supply, it can be assumed that after sensitization they (community) will be willing to pay for grey at 0.71 USD/m^3 (the price identified by the willingness to pay survey for rainwater). Under this scenario, the project will recover cost only if the government/ or donor reduces the discount rate to 1.8%. This means 1.8% is the internal rate of return (IRR) at selling price of 0.71 USD/m^3, for an investment recovery period of 20 years. This is not attractive to the creditors given the low interest rate and the long investment recovery period.

Alternatively, at a selling price of 1 USD/m^3, and the investment recovery period remains at the project lifespan, the IRR will be 5.7% which is still insignificant since the motivating factor to the investors and utility management would be short investment recovery period and low interest rate. However, if the IRR is reduced to 3% with the selling price still at 1 USD/m^3, the result will be very interesting in that besides the project recovering cost just in 13 years, the utility will be getting an annual net profit of over 1,300 USD/year. A discount rate of 3% for a public project with very high positive externalities may be realistic.

Varying key parameters for rainwater harvesting at city scale

According to the contingency valuation survey, the users indicated their willingness to pay 0.71 USD/m^3 of rainwater. Under this scenario; with 6% discount rate, and 20 years of project lifespan, the project was found to have a negative internal effect (net loss) of 67,788USD , meaning that it is financially infeasible. The price of reclaimed water identified by the willingness to pay survey will only recover cost within the project period if the IRR is reduced to 0.4%, which is insignificant to motivate any creditor. The minimum selling price (MSPRW) that would ensure cost recovery within the project period at the national discount rate is 1.26 USD/m^3, well above the price of potable water and almost twice the price the community is willing to pay. This is equally unattractive to the community and it is unrealistic to sell rainwater at a price higher the cost of potable water.

However, when the IRR is reduced to 3% at a selling price of 1 USD/m^3, the project will be able to recover cost within about 12 years. This is encouraging to both parties in that the community will be paying for reclaimed water at a price less than that of potable water yet with increased reliability of water supply. As for the utility, there will be cost recovery with a saving of over 2,000 USD every year for the whole project period, while the government will be able to postpone major investments (which is not feasible in the short run) yet getting interest on investment at a rate significant to convince creditors.

5.4 Impacts of ecological cycle management project at city scale

5.4.1 Cost and benefits to the individual consumer

The analysis discussed in section 5.3 above reveals that the individual consumer shall benefit from on-site water and wastewater reuse projects through increased water supply reliability, use of less potable water hence reduced cost, and reduced cost on sewerage bills (in case of grey water). While the cost of on-site water reclamation project to the consumers is the burden to meet the financial requirements for operational and investment costs for running and installing the projects respectively. However, as discussed above, on-site water reuse project are not able to recover costs at the selling price the consumers have indicated their willingness to pay. Furthermore, the contingency valuation survey result in Ayensu River estate indicates that larger households are already being affected by the current price of potable water (1.18 USD/m^3) and the majority of them are willing to pay as low as 0.36 USD/m^3. Attempts to raise tariff to achieve cost recovery may lead to what Myllylä & Kuvaja (2005) describes as 'commercial eco-city scenario'; a situation where water and wastewater reuse projects will be based on the users' ability to pay hence the risks to deny the poor the much needed services.

5.4.2 Cost and benefits to the utility

When the selling price is sufficient to attain cost recovery, the utility enjoys the reuse practice of the individual consumers. With reduced demand of potable water, future expansion can be postponed,

or smaller capacity and cheaper plants can be constructed. In this case, the utility can gain capacity to expand services to the poor even without subsidy. However, on-site water reclamation and reuse system usually adapts decentralized management and technology options. It is often difficult to achieve cost recovery with extremely low scale, since ideally the management incurs some minimum fixed overhead cost for effective operation. Reduced consumer demand leads to low payment and consequently low income to the utility, and this may result to lower income compared to investment and operational costs. Under this scenario, the project will be financially infeasible, despite the enormous external benefits which may make the project economically very attractive.

5.4.3 Cost and benefits to the government (public)

The above investment model is the most extreme cost-sharing model and rare in developing countries since the public does not share any costs with the individual consumer while it does share all the benefits except the reduced water and sewerage bills (Friedler & Hadari, 2006). Our financial evaluation to assess the project internal effects on the consumer is based on this model. On the other hand, the benefits and costs to the public are assessed through the evaluation of external effects, and a subsidy policy respectively.

From the result of the evaluations, it appears that the economic benefits that on-site water and wastewater reuse projects offer on a regional or national scale may be much more significant than the internal benefit to the individual consumer (refer to values of B_I and B_E in section 5.3). This scenario is true especially in developing countries with semi-arid climate where both natural and economic water scarcity are experienced (Abdulla & Al-Shareef, 2009). Thus, local and/or national authorities may want to encourage individuals to practice on-site water and wastewater reclamation and reuse. This can be done using different alternative policy measures such as; subsidies per m^3 of wastewater reused, establishing a fund from which individuals or private entrepreneurs can borrow money needed for the investment costs at interest rates lower than the market rates, and reduced property taxes for on-site wastewater reuse buildings. The sensitivity analysis discussed in section 5.3.4 reveals the effect of government subsidies in terms of reduced interest rates on investment capital for on-site water reclamation and reuse projects. This assumed government intervention impacts positively by reducing selling price for water reclaimed, and investment recovery period which in turn will motivate the consumers and the private sectors to participate in ecological cycle management projects.

5.4.4 Feasibility for scaling up on-site water reuse project

The economical analysis of ecological cycle management projects at city scale tends to indicate that with minimal financial support, projects would be a viable water and sanitation management strategy for the cities of developing countries, especially those in semi-arid regions. However, it would be a grave oversight to base our recommendations for policy decisions entirely on technological and economic aspects, without considering the overarching institutional aspects. Adapting policy objectives often involves a political process, and political decisions are always

irrational. It is therefore apparent that decision-making will not depend on the technical options that offer the highest cost-benefit ratio (M. Kurian, in Kurian & McCarney, 2010; p. 18).

Moreover, trends in recent years have indicated that most infrastructural financing comes from the private sectors. The often obscure institutional arrangements in developing countries tend to shift financial risks to the private sectors, deterring them from effective participation in the water sector. Notable among such institutional defects are: sub-sovereign risks, inappropriate legal and policy framework, and political interference. Besides, at city scale, the funding for water and sanitation infrastructures are dependent on the central government budgetary process which is, itself a political process, usually characterized by uncertainty and insufficiency in developing countries. Another institutional challenge to the feasibility of ecological cycle management project in real life situation is the juxtaposition of regulatory and operational roles by the politicians; in what Foster (1996) refers to as 'poacher-game keeper problem'. This scenario does not warrant the management of water utility the autonomy to manage the day-to-day activities, and in addition prohibits the effective monitoring and efficiency of system performance. It consequently transmits to ineffective oversight, soft budget constraints and absence of efficiency incentives; which are the main causes of financial insufficiency of water utilities (World Bank, 1994), (Foster, 1996).

Nevertheless, Lindblom's theory of incremental approach to policy reform could offer a workable alternative option of muddling through with our policy objectives into the political system to ensure appropriate strategies for financing water infrastructures. This means that we consider policy objectives as norms and standards that are maintained and modified over time, rather than problems that should be solved once and for all. Besides, output based aid (OBA) approaches recently devised by World Panel on Financing Water for All (WPFWA), provides a leeway to sustainable funding in the water sector. To ensure effective performance and guarantee private sector participation, OBA approach aims at tying disbursement of public funds to specific services or other outputs delivered by private firms or NGOs (Kurian M. & McCarney, 2010). The approach (OBA) can be used to target subsidy thereby guarantying services to the poor yet ensuring cost-recovery tariffs with time. When properly managed, OBAs has proved to be effective means of disbursing public funds (eg. Chile, Morocco, Colombia and Vietnam), making it a promising approach to financing water and sanitation infrastructures; since it restores private sector confidence, and promote their participation while ensuring that services reach the low income earners at affordable costs.

6 Conclusions

The concept of ecological cycle management is apparently an attractive water and sanitation management strategy for the cities of tomorrow, and has hit the wave in the current discourse. Many authors seem to have a common consensus that the current unprecedented urbanization trend plus population growth will compound urban water and sanitation problems, and ecological cycle management strategy would be an ideal approach that can simultaneously solve the city problems of water supply, sanitation management and food security (Bracken et al., 2009), (Qadir et al., 2008), (Muellegger & Langergraber, 2005).

The ecological cycle management project of Valley View University offers a good starting point. The technological evaluation by Geller (2008), plus the economic analysis in this thesis have indicated that this water management strategy could be a feasible option at city scale. However, the discussion of institutional challenges in this thesis reveals that it would be over simplistic to think that technological and economic aspects are sufficient to guide decision-making on policy objectives; because policy decisions are political in nature. The contention by Mathew Kurian (in Kurian & McCarney, 2010; p. 19) which emphasizes incremental reform, a method described by Lindblom (1959) as "by the branch approach", is worth considering in our drive to realize the success of most policy objectives in water and sanitation sector.

Finally, it is important to put the end users, with emphasis to the poor, at the center of our policy objectives in order to avoid turning ecological city in to a commercial city, a situation where the poor will be unable to access services as a result of high cost derived from the often expensive technological solutions. The result of the willingness to pay survey in Ayensu River estate in Oyibi, Accra (described in this thesis), has indicated the possibility of this scenario. Most importantly is our realization that the world is diverse and local conditions vary so much that uniform prescriptions of the "one size fits all formula" are unrealistic. It is therefore advisable to tailor ecological city programs to local situations using the 'best fit' and 'best-practice' approach.

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Annexes

Annex 1: Collection of data from water utilities (OWS & GWCL)

	Data on safe water supply	Response
1	Area population	
a)	What is the population within the service area?	
b)	What is the number of households?	
c)	What is the population growth rate (of the service area)?	
2	Production capacity, consumption and coverage	
a)	What is the volume of water produced per day?	
b)	What is the average consumption per capita (l/p/d)?	
c)	What is average reliability of supply per week?	
d)	Are the entire households within the area connected?	
e)	What are other alternative sources?	
f)	If no what is the current coverage?	
g)	Are there potentials for service expansion within the next 20 years?	
3	Source of water supply	
a)	Fresh water body (river, lake)	
b)	Ground water	
c)	Sea water	
d)	Rain water	
e)	Others (specify)	
4	System financing	
a)	What are the sources of funding to the scheme?	
b)	Does the sale for the supply meet cost recovery?	
c)	Does cost cover O&M, system expansion, and replacement?	
d)	What is the tariff rate per m^3 of water supplied?	
e)	How often is tariff adjustment, what are consumers responses to tariff	

	Data on safe water supply	Response
	increase?	
f)	Does the scheme receive any subsidy? From who and how much?	
g)	What is the tariff structure?	
h)	Is the natural resource fee catered for in the structure? If so, How much?	
i)	What is the average bill per house hold per month?	
5	Consumption criteria	
a)	What is the daily water use (in percentages)? (Accra: washing utensils & clothing 15%, bathing 45%, cooking food 37%drinking 3%)	
b)	Is there any plan for reclaiming some wastewater for reuse? If so which one is it? (say; grey water, black water, yellow water)	
c)	Is there any plan to promote rain water harvesting?	
d)	What is the consumers' likely response in 5 a) & b) above?	
e)	If wastewater is reclaimed for reuse, how much would you charge for the reclaimed water	
6	Data on sewerage systems	
a)	What is the technology used for waste management (septic tanks, sewerage system, pit latrine, ecosan)?	
b)	How far is the WWTP from the main estates, or town centre?	
c)	What is the cost per meter run for construction of sewer line?	
d)	What is the rate for sewage services? (%age of water used, How much?)	

Commends:

……
……
……
……

Annex 2: Expert query (department of statistical service, GWCL)

What is the national population figure (population of Ghana)?
What is the average life expectancy?
What is the average income per capita?
What is the national gross domestic product?
What is the per capita GDP?
What is the national discount rate (social discount rate on investment capital)?
What are the national mortality and morbidity rates?
What are the taxes (if any) on water and sanitation projects?
What is the water resource price per m^3?

Water and sanitation utilities
What is the cost per m^3 of potable water (cost of reclaimed water if available)?
What is the average cost per m^3 of treating potable water?
What is the cost (per head per month) of sewerage services, (whether connected to sewer, or served by cesspool emptier)?
What is the cost per meter run for construction of sewer line?
What is the cost per meter run for constructing a water supply main?

Valley View University
What is the distance to the nearest waste water testament plant?
What is the cost of land per meter square (or per hectares); for areas like VVU (within the suburb of the municipality); in case of alternative use?

Annex 3: Summary of cost breakdown (By Emanuel Kwandahor)

Below is the installation and running costs of various aspects of the Ecosan setup at VVU. Equipment cost include underground tanks, elevated tanks, pipelines and inspection chambers, eaves gutters, and pumps as applicable. The pipelines from the Women's Hall Grey Water Tank to the farms as well as elevated tanks on the farms have not been included because these belong to a separate project. Land fee for Women Dorm is nil because the underground and elevated tanks are all within the land occupied by the main building and do not occupy additional land.

1. **Rain water harvesting**

S/No	Description of cost items	Cost (US $)				Total
		Cafeteria	Columbia h'se	Women dorm	Guest h'se	
1	**Investment costs**					
1.1	Land fee	3,500	3,500	0	1,000	8,000
1.2	Equipments (reservoirs, pumps, filters)	9,500	11,200	15,500	8,100	44,300
1.3	Labour (including local consultancy)	3,500	4,200	5,200	3,000	15,900

S/No	Description of cost items	Cost (US $)				Total
		Cafeteria	Columbia h'se	Women dorm	Guest h'se	
	Total	**16,500**	**18,900**	**20,700**	**12,100**	**68,200**
2	**Operation and Maintenance costs**					
2.1	Power per month	3.0	2.0	5.0	2.0	12.0
2.2	Personnel per month	7.0	7.0	7.0	7.0	28.0
2.3	Routine maintenance per month	13.8	13.8	15.0	10.0	52.6
	Total per month	**23.8**	**22.8**	**27.0**	**19.0**	**92.6**

2. **Grey water reclamation**

S/No	Description of cost items	Cost (US $)			Total
		Cafeteria	Women dorm	Guest h'se	
1	**Investment costs**				
1.1	Land fee	3,500	3,500	3,500	10,500
1.2	Equipments (reservoirs, pumps, filters etc.)	8,200	9,700	6,700	24,600
1.3	Labour (including local consultancy)	3,500	4,200	3,000	10,700
	Total	**15,200**	**17,400**	**10,700**	**43,300**
2	**Operation and Maintenance costs**				
2.1	Power	3.0	5.0	3.0	11.0
2.2	Personnel	7.0	15.0	5.0	27.0
2.3	Routine maintenance	13.8	15.0	10.0	38.8
	Total	**23.8**	**35.0**	**18.0**	**76.8**

Annex 4: Assessing social acceptance and willingness to pay

Contingency valuation survey (Ayensu River Housing Estates)

Introduction:

1. About 40% of domestic daily water consumption goes to flushing toilets, which does not require the expensively treated potable water.
2. Rainwater can be harvested in large quantity, stored in underground tanks, and pumped to elevated reservoirs to be used for flushing toilets through a separate piping network.
3. This concept is currently being demonstrated in Valley View University and is contributing up to about 25% of the university water requirements.
4. The aim of this study is to evaluate whether this concept (in VVU) can be adapted as a water supply strategy for domestic uses in cities (eg. Accra).

A. General Household information

Question	Response	Remarks
Name of household head		
Household size (no. of people in the family)		
Average monthly water bill (current water bill)		

Question 1: Would you accept to use rain water for flushing your toilets?

Answer: (**Yes** or **No**) ………………….

If No in Question 1 above give comments/reasons..

....

Question 2: If yes in question 1 above, how much would you be willing to pay for 1 m^3 (235 gallons) of rainwater used? (**Hint:** 1 m^3 (235 gallons) of potable water from Oyibi water scheme cost GH**¢** 1.65)

(All figures in GH**¢,** mark the amount you would be willing to pay).

Answer: (a) 1.20; (b) 1.00; (c) 0.80; (d) 0.65; (e) 0.50;

Note: This research is done for the partial fulfillment for the Master of Science degree at the UNESCO-IHE Institute for Water Education, Delft – The Netherlands

Note: Information given for this research shall be used strictly for study purpose only.

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