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Impacts of variable energy prices on the financial sustainability of water facilities: case from Ghana

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Abstract: Water is conveyed to consumers through systems that generally rely heavily on energy. The dependence on energy is a major challenge to utility providers because of frequent variation in energy prices. This paper assesses the effect of energy price changes on the financial sustainability of water facilities. It further investigates the proportion of energy cost to total costs of water supply. The study is based on a field survey that targeted five small town water systems and 15 water systems existing under the urban water sector in the Greater Accra and Ashanti regions of Ghana. The results show that energy (diesel and electricity) expenditure forms substantial component of water supply cost. The proportions of energy to total supply costs for small town and urban water systems are 31% and 29%, respectively. The total operational costs per water supply stand at 1.19 US$/m^3 and 0.44 US$/m^3 for small town and urban water systems respectively. The energy costs per water supply for small town and urban water systems are 0.40 US$/m^3 and 0.13 US$/m^3, respectively. Results further show that diesel-driven water systems are more sensitive to energy price changes than those of electricity-driven systems; therefore making financial profit from diesel-driven systems is highly elastic to diesel price changes. The results thus indicate that urban water systems are more efficient than small town water systems in terms of both energy and operational costs.

Keywords: diesel prices; electricity prices; sustainability; water facilities; Ghana.

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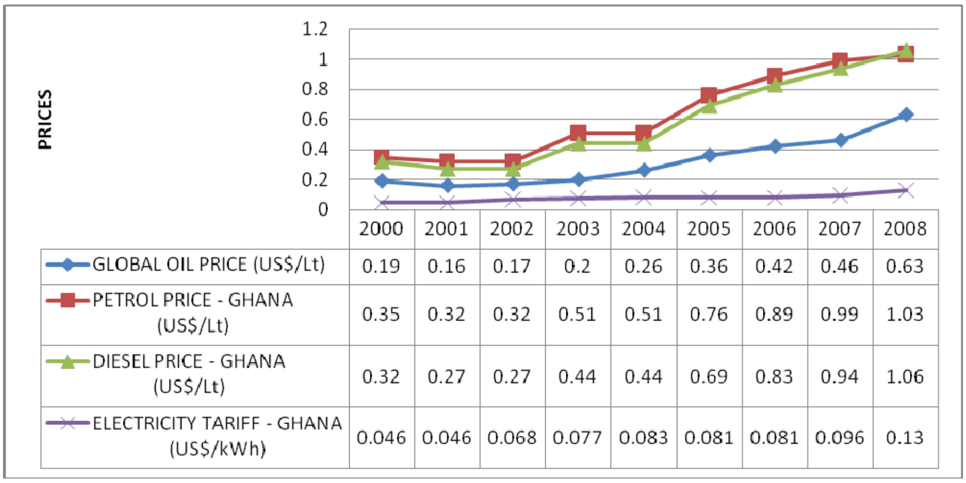
1 Introduction

Sustainable access to safe water is essential for human health and survival, and important for economic growth (SIWI, 2005). Raw water abstracted from water bodies usually undergoes some form of treatment before delivery to homes, institutions, industries, etc. The water systems which perform the treatment processes and conveyance run on energy (diesel or electricity). Frequent variation in global oil prices have been reflected in the domestic prices of fuel (diesel and petrol) and electricity which play an important role in any economy and particularly in the water sector. In July 2008, the world witnessed the highest crude oil price of about US$ 140/barrel (Forbes, 2008). It is of interest to note that generally oil and electricity prices trends in Ghana follow closely global oil price variations as indicated in Figures 1 and 2.

Figure 1 Ghanaian energy prices against global crude oil prices (see online version for colours)



	2000	2001	2002	2003	2004	2005	2006	2007	2008
◆ GLOBAL OIL PRICE (US$/Lt)	0.19	0.16	0.17	0.2	0.26	0.36	0.42	0.46	0.63
■ PETROL PRICE - GHANA (US$/Lt)	0.35	0.32	0.32	0.51	0.51	0.76	0.89	0.99	1.03
▲ DIESEL PRICE - GHANA (US$/Lt)	0.32	0.27	0.27	0.44	0.44	0.69	0.83	0.94	1.06
× ELECTRICITY TARIFF - GHANA (US$/kWh)	0.046	0.046	0.068	0.077	0.083	0.081	0.081	0.096	0.13

Note: Based on raw data on global oil prices of US EIA, 2009 and Ghanaian energy prices

Recovering the cost of water service is a major obstacle in achieving sustainable drinking water supply in developing countries (Carter et al., 1999). In Ghana, it has been the persistent outcry of water service providers that the existing tariffs are not sufficient to recover the full supply cost of the services.

The performance of urban water supply in Ghana is poor with an estimated coverage of about 60%. Rural water supply in Ghana has coverage of 53% comprising boreholes, hand-dug wells, and small-piped systems (Nyarko et al., 2008).

Every stage of the water supply processes depends on some sort of energy. Abstraction, treatment, transmission and distribution of water for public water supply systems are complex and resource-intensive activities requiring significant amounts of energy (California Energy Commission, 2005). Studies show that pumping between treatment processes requires nearly three-quarters of the total electricity used for water treatment. The actual treatment processes – flocculation, sedimentation, filtration, and disinfection use the remaining of the total electricity (Goldstein and Smith, 2002).

The energy use for supply and conveyance of water varies widely depending on the local infrastructure and geography. Many gravity-fed systems require less energy, whereas long-haul systems require high energy investments to move water across or within a region and over mountain ranges (California Energy Commission, 2005). This corroborates large sums of money expended on energy in transporting water from the second largest water headworks in Ghana, the Kpong water works, to the country's capital, Accra. Again, the energy requirements for water distribution vary with the distribution of end users in relationship to the treatment plant. Additionally, aging infrastructure with old pipelines may have leaks and may create more friction, requiring more electricity for water distribution (Goldstein and Smith, 2002).

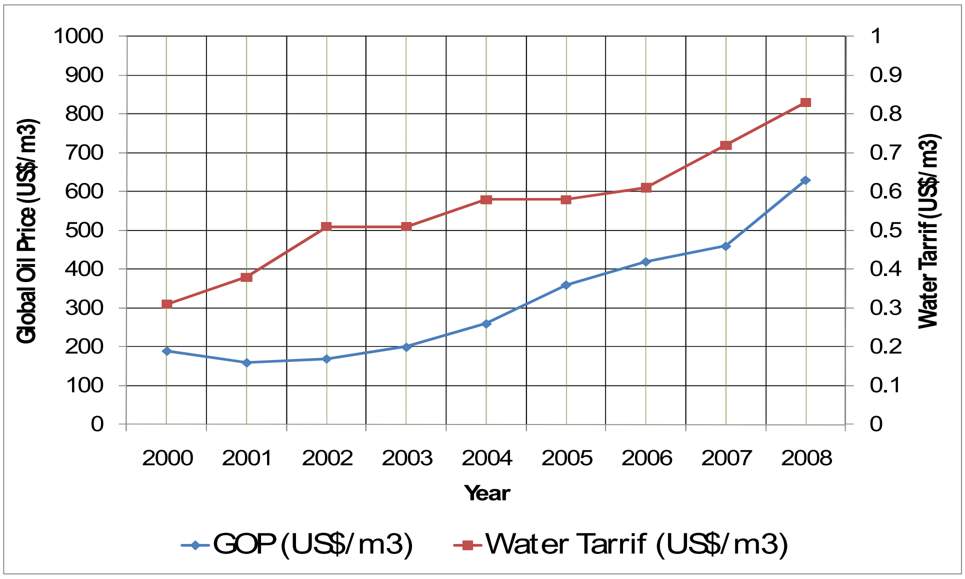
Financial sustainability of any water system is guaranteed if an element like money which plays a key role in defraying operational expenses is in place (Carter et al., 1999). Further, water service provision is seen to be sustainable if water is delivered at the same rate and quality all the time as designed and constructed. According to the operation and maintenance (O&M) guidelines for small towns water systems in Ghana (CWSA, 2004), a water system is said to be delivering water in a sustainable manner if:

1. the design quantity of water is produced over the design life of the system
2. water produced meets Ghana Standards Board Water Quality Standards
3. water is delivered in a cost effective manner
4. water is delivered in an uninterrupted manner (at least 95% of the time)
5. planned routine and periodic maintenance are carried out for all electro-mechanical equipment and civil works.

Tariffs serve as means of recovering moneys expended on the water systems in providing water to ensure long term sustainability (Nyarko et al., 2007). It is clear from Figure 2 that as global oil price increases, there is a corresponding increment in the water tariff. For the sake of sustainability, the increments in the water tariff must be commensurate with the global oil price changes else, the sustainability of the water systems will be in doubt.

It is worth mentioning that there is scanty and non reliable data on water systems that run on diesel energy in Ghana. The few water systems that run on diesel have either been converted to another source of energy or are not in operation and lack good data to make meaningful analysis. Due to this challenge, the conclusions from the study are based on five small town water systems of which two are powered by diesel motors and the urban water systems in the Greater Accra and Ashanti Regions of Ghana.

Figure 2 Average GWCL tariff against global oil price changes (see online version for colours)



Note: Based on raw data on global oil prices of US EIA, 2009 and Ghanaian water prices

2 The study area

Ghana is in West Africa with total population of about 24,791,073 inhabitants distributed over ten regions.

Two sectors are responsible for the supply of water to the Ghanaian populace. The Ghana Water Company Limited and the Community Water Supply Agency are responsible for the delivery of water to the urban and rural communities in Ghana, respectively. Urban water supply involves the provision of water services (mainly drinking water supply) through complex pipe systems serving large urban centres of population generally exceeding 50,000 and managed by the Ghana Water Company Limited. There are 86 urban water supply systems with a total installed capacity of 162,000,000 gallons per day (162 MGD). However, because of plant and equipment deterioration, fuel price increments and shortages and some other reasons, actual production levels are about 121,000,000 gallons per day (121 MGD). The Accra-Tema systems of Kpong and the Weija system make up 60% of total production (Adombire, 2007). The urban water coverage is about 60% with 50% of its total production lost through un-accounted-for water (Nyarko et al., 2008). In Ghana, the main water supply technologies adopted for the urban water supply systems include

1 conventional water supply system

2 packaged systems

3 mechanised borehole system

The four biggest urban water systems situated within both the Greater Accra and Ashanti regions are considered for this research because quarterly reports submitted by the operator show that 70% of the company's revenue is generated from these systems. There are a total of 15 urban water systems within Greater Accra and Ashanti regions with Weija, Kpong, Barikese and Kpong water systems forming the biggest systems under the urban water sector. The remaining systems are relatively smaller and are mainly dependent on ground water.

The community water supply sector is managed by the District Assemblies (DAs) and their operations are facilitated by Community Water and Sanitation Agency (CWSA). A small town is defined in the CWSA Act as "a community that is not rural but is a small urban community that has decided to manage its own water and sanitation systems". A further working definition used by CWSA is "a community of between 2,000 and 50,000 inhabitants, who are prepared to manage their water supply system", even though the Small Towns Act goes on to define rural community to be those with a population of less than 5,000. According to CWSA (2003, 2004, 2005), there are about 300 small towns' water systems which fall into three groups:

1. Old community systems built through resources via the Government of Ghana (GoG), external support agencies (ESA) and non-governmental organisations (NGOs)
2. new systems facilitated by CWSA, built through resources from GoG and ESA, with the communities contributing between 5% and 10%
3. the GWCL transferred systems (old and rehabilitated), previously owned by GWCL and transferred free of charge to DAs for community management under a memorandum of understanding (MOU).

The main water supply technologies adopted for small towns' water service delivery in Ghana includes (CWSA, 2003):

- groundwater or surface water piped system
- rain water harvesting.

It is worth noting that all the systems mentioned above directly or indirectly use energy as input in both abstraction and for distribution purposes. Generally, energy sources for both the small town and urban water systems include:

- grid electricity
- solar energy
- diesel generator

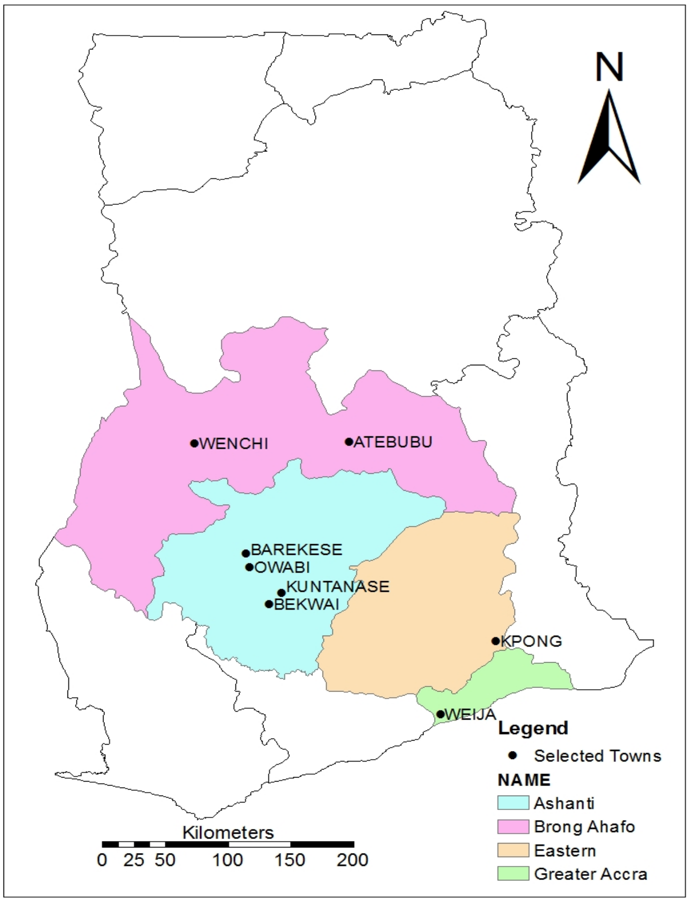
For the rain water harvesting, it is a technology that Community Water and Sanitation Agency (CWSA) employs in areas where a groundwater or surface water piped system is not feasible. It is normally used for separated or stand-alone colonies like market centres and small schools. It is important to note that depending on the quantity of rain harnessed and the location from the area to be served, energy may either be an input or not. The processes involve collection, storage, treatment and distribution. The main systems used for small towns are the groundwater or surface water piped system, and that is focus for the study.

For the small town water supply systems, Kuntunase, Wenchi, Bekwai, Atebubu and Aburi systems were sampled because of the reliable data associated with the systems due to good management practices of the operators. Barikese, Owabi, Kpong and Weija are the four urban water treatment systems chosen and are the biggest systems functioning currently under the urban water supply scheme. All the systems with the exception of Atebubu and Aburi water systems are powered by electricity.

3 Research methodology

This research study is based on purposive sampling, where water systems known to have reliable and high level of record keeping were considered. The data collection procedures comprised of field visits and surveys including interviews with technical operators of the systems, field investigation and review of annual, quarter and monitoring reports. Questionnaires were structured and administered during the interviews to address the characteristics of the systems including location, production rates, management plans and sources of energy.

Figure 3 Map showing the study areas (see online version for colours)



The analytical period of the small town water and urban water systems are five years (2003–2007) and four years (2006–2009) respectively as complete datasets were available for the aforementioned periods. For the purpose of effective comparison, all the income and expenditure components were adjusted to a 2009 base year with the aid of inflation values according to the Ghana Statistical Services (GSS, 2008).

The cost-benefit ratio of water was calculated based on the actual operational expenditure/costs d (OPEX) and direct benefits (revenues) provided by the survey is given by equation (1).

$$\text{BC ratio} = Bt / Ct \tag{1}$$

where

Bt direct benefits or revenues (US$/year) or (US$/m^3)

Ct direct operational costs (US$/year) or (US$/m^3)

The operational costs are the sum of energy costs (diesel or electricity expenses), personnel costs (staff salaries and emoluments at head office, regional offices and district offices) and other operational costs and is given in equation (2).

$$Ct = E + L + O \tag{2}$$

where

E energy costs (US$/year) or (US$/m^3)

L personnel costs (US$/year) or (US$/m^3)

O other operational and maintenance costs (US$/year) or (US$/m^3)

Calculation of revenues was based on the billing information supplied by the service providers as represented in equation (3).

$$Bt = T.Q \tag{3}$$

where

T water tariff (US$/ m^3)

Q quantity of water (US$/ m^3)

Assessing the benefit-cost (BC) ratio was based on the percentage of total benefits (Bt) to total costs (Ct) as represented in equation (4).

$$\text{BC ratio} = T.Q / \{E + L + O\} \tag{4}$$

Benefit-cost ratio analysis was also made in response to a set of marginal increases and decrease (α_e = 5%, 10%, 20%, 30%, 50%, …., and 100%) to the current diesel and electricity expenditures; assuming that all other parameters do not change. The intention of this study is to highlight the profitability implications of changes in diesel and electricity prices (the energy elasticity of profit), as given by equation (5).

$$\text{BC ratio} = T.Q / (\alpha e.\ E + L + O) \tag{5}$$

where

α_e =coefficient of energy (energy increases or decreases)

Accordingly, water tariff or revenue increases or decreases to cope with each of the energy increase or decrease cases were suggested as given in equation (6) (Abu-Madi, 2010).

$$\text{BC ratio} = \alpha t.T.Q / (\alpha_e.E + L + O) \tag{6}$$

where

α_t coefficients of water tariff (water tariff increases and decreases)

The financial viability of the operations of water facilities is represented in terms of profit change ratio (ΔP) [equation (7)], which is the percentage of change in financial profit ($Pt - Po$) with respect to current profit; this is in response to a set of marginal increases and decreases (α_e) to the diesel and electricity expenditures. Profit as used in the study is purely surplus revenue before depreciation and tax (actual revenue minus operational expenditure).

$$\Delta P = \left(Pt - Po\right) / Po \tag{7}$$

where

Pt forecasted financial profit (US\$/year) or (US\$/m^3)

Po current financial profit (US\$/year) or (US\$/m^3)

$$Po = Bt - Ct \tag{8}$$

$$Po = T.Q - \left(E + L + O\right) \tag{9}$$

$$Pt = T.Q\ (\alpha_e.\ E + L + O) \tag{10}$$

$$T.Q = Revenue\ or\ Billing\ Information \tag{11}$$

The degree to which a change in energy price will cause a change in profit is called energy elasticity of profit (ε), as represented in equation (12); if the absolute energy elasticity of profit, ε is greater than 1, profit is considered to have high energy elasticity, and if ε is equal to zero or less than 1, profit is considered to be energy inelastic.

$$\varepsilon = \frac{\Delta p}{\alpha \varepsilon} = \frac{(Pt - Po) / Po}{(Et - Eo) / Eo} \tag{12}$$

The operational cost ratios from the water systems were also deduced and can be divided into energy cost ratio and total cost ratio. The energy cost ratio is the ratio of energy cost to total volume of water produced where as the total cost ratio is simply the ratio of total operational cost or expenditure to the volume of water produced.

4 Results and discussions

4.1 Proportions of OPEX

The results show that energy costs represent 31%, 26%, 26%, 34% and 39% of the total production costs for Wenchi, Kuntunanse, Bekwai, Atebubu and Aburi water systems respectively (Table 1). The diesel-driven water systems recorded higher proportion of energy values and this can be attributed to the diesel motors which incur higher costs than electricity-driven systems. The proportions of personnel and O&M to total production costs for small town water systems range between 27% and 42% and 29% and 47% (Table 1).

Table 1 Proportions of OPEX from small town water systems

	Income and OPEX (US$/Yr)				
	Electricity-driven			*Diesel-driven*	
	Wenchi	*Kuntunase*	*Bekwai*	*Atebubu*	*Aburi*
Proportions of OPEX (%)					
Energy cost	31	26	26	34	39
Personnel cost	36	42	27	37	32
Other O&M cost	33	32	47	29	29

The study shows that energy costs represent 29%, 35%, 29% and 28% of the total operational costs for Weija, Kpong, Barikese and Owabi treatment headworks respectively. The difference in the proportions of energy may be attributed to the different pumping distances and the local geography of the water systems. The proportion of personnel and O&M to total operational costs for urban water systems ranges between 29% and 33% and 36% and 42% (Table 2).

Table 2 Proportions of OPEX from urban water systems (headworks)

	Weija	*Kpong*	*Barikese*	*Owabi*
Proportions of OPEX (%)				
Energy cost	29	35	29	28
Personnel cost	33	29	31	30
O&M cost	38	36	40	42

4.2 Operational cost ratios from the water systems

Wenchi, Kuntunase, Bekwai, Atebubu and Aburi small town water systems recorded energy cost per cubic metre of 0.21 US$/m^3, 0.16 US$/m^3, 0.18 US$/m^3, 0.56 US$/m^3 and 0.90 US$/m^3 respectively (Table 3). The total cost per cubic metre of water produced for Wenchi, Kuntunase, Bekwai, Atebubu and Aburi water systems recorded are 0.67 US$/m^3, 0.61 US$/m^3, 0.69 US$/m^3, 1.66 US$/m^3 and 2.30 US$/m^3, respectively. It is evident that the diesel driven systems (Atebubu and Aburi) incur higher unit production cost than electricity driven systems (Table 3).

Table 3 Operational cost ratios from small town water systems

	Electricity-driven system			*Diesel-driven system*	
	Wenchi	*Kuntunase*	*Bekwai*	*Atebubu*	*Aburi*
Operational ratios (US\$/m^3					
Total cost per m^3 of water produced	0.67	0.61	0.69	1.66	2.30
Energy cost per m^3 of water produced	0.21	0.16	0.18	0.56	0.90

Weija, Kpong, Barikese and Owabi Treatment headworks recorded 0.06 US\$/m^3, 0.11 US\$/m^3, 0.11 US\$/m^3 and 0.13 US\$/m^3 as energy cost per cubic metre of water produced respectively (Table 4).

The energy cost per cubic metre of water supply and consequently the total operational cost per cubic metre of water supply for the urban water headworks are relatively lower than the values recorded for small town water systems. This can be ascribed to the large sums of money expended on energy in pumping the raw water for treatment as most of the sources of water for the small town water systems are ground water based which on average require three times more energy than needed for surface water treatment (Goldstein and Smith, 2002; California Energy Commission, 2005). Since energy cost per cubic metre of water produced for the water systems form a substantial component of the total cost per cubic metre produced, it is imperative to assess the sustainability of the water systems vis a vis variable energy prices.

Table 4 Operational Cost Ratios from Urban Water Headworks

	Weija	*Kpong*	*Barikese*	*Owabi*
Operational ratios (US\$/m^3)				
Total cost per m^3 of water produced	0.22	0.30	0.37	0.48
Energy cost per m^3 of water produced	0.06	0.11	0.11	0.13

4.3 Impact of changing energy costs on profit from water facilities

The results show that decreasing the current electricity prices by 10% whilst keeping current tariffs and other OPEX components constant will increase the profit from 0.29 US\$/m^3, 0.19 US\$/m^3 and 0.36 US\$/m^3 to 0.31 US\$/m^3, 0.20 US\$/m^3 and 0.38 US\$/m^3 for Wenchi, Kuntunanse and Bekwai water systems respectively (Table 5). At the same electricity price change, the BC ratios also shift from 1.42, 1.30 and 1.50 to 1.48, 1.33 and 1.56 for Wenchi, Kuntunanse and Bekwai water systems respectively (Table 5).

Decreasing the current diesel price by 30% and keeping tariffs at current level will increase the profit from 0.13 US\$/m^3 and –0.51 US\$/m^3 to 0.30 US\$/m^3 and –0.23 US\$/m^3 for Atebubu and Aburi water systems respectively. At the same energy change, BC ratios shift from 1.08 and 0.78 to 1.2 and 0.89 for Atebubu and Aburi water systems, respectively (Table 5). BC ratios recorded for the diesel driven systems at this energy change suggest that only Atebubu water system can be sustained.

On the other hand, increasing the current electricity prices by 50% will decrease the marginal profit from 0.29 US\$/m^3, 0.19 US\$/m^3 and 0.36 US\$/m^3 to 0.18 US\$/m^3, 0.10 US\$/m^3 and 0.27 US\$/m^3 for Wenchi, Kuntunanse and Bekwai water systems, respectively (Table 5). At the same electricity price change, the BC ratios also shift from 1.42, 1.30 and 1.50 to 1.23, 1.14 and 1.34 for Wenchi, Kuntunase and Bekwai water systems, respectively (Table 5). In this case, all the electricity-driven systems can withstand increasing the electricity prices by 50%.

Increasing the current diesel price by 50% also decreased the surplus revenue and BC ratio from 0.13 US\$/m^3 and –0.51 US\$/m^3 to –0.15 US\$/m^3 and –0.96 US\$/m^3 (Table 5) for Atebubu and Aburi water systems showing that the diesel-driven systems cannot withstand the 50% increment in the current diesel price. The BC ratios also shift from 1.08 and 0.78 to 0.93 and 0.66 for Atebubu and Aburi water systems (Table 5).

Again, increasing the current electricity prices by 200% will decrease the marginal profit from 0.29 US\$/m^3, 0.19 US\$/m^3 and 0.36 US\$/m^3 to –0.15 US\$/m^3, –0.15 US\$/m^3 and –0.03 US\$/m^3 for Wenchi, Kuntunase and Bekwai water systems accordingly (Table 5). At the same electricity price change, the BC ratios also shifted from 1.42, 1.30 and 1.50 to 0.88, 0.85 and 0.99 for Wenchi, Kuntunase and Bekwai water systems respectively (Table 5). In this case, all the electricity-driven systems cannot withstand increasing the electricity prices by 200%. The situation is not different for the diesel-driven system at 100% increment in current diesel price.

Table 5 Forecasted financial profit and BC ratio from small town water systems at incremental electricity and diesel price changes (2009)

	Electricity-driven systems			*Diesel-driven systems*	
(US\$/m^3)	*Wenchi*	*Kuntunase*	*Bekwai*	*Atebubu*	*Aburi*
			$\alpha E = 1$		
BC ratio	1.42	1.3	1.5	1.08	0.78
Forecasted Profit – Pt (US\$/m^3)	0.29	0.19	0.36	0.13	–0.51
	$\alpha E = –10\%$			$\alpha E = -30\%$	
BC ratio	1.48	1.33	1.56	1.2	0.89
Forecasted Profit – Pt (US\$/m^3)	0.31	0.2	0.38	0.3	–0.23
	$\alpha E = 50\%$			$\alpha E = 20\%$	
BC ratio	1.23	1.14	1.34	1.01	0.73
Forecasted Profit – Pt (US\$/m^3)	0.18	0.1	0.27	0.02	–0.69
	$\alpha E = 100\%$			$\alpha E = 50\%$	
BC ratio	1.09	1.02	1.2	0.93	0.66
Forecasted Profit – Pt (US\$/m^3)	0.07	0.02	0.17	–0.15	–0.96
	$\alpha E = 200\%$			$\alpha E = 100\%$	
BC ratio	0.88	0.85	0.99	0.81	0.57
Forecasted Profit – Pt (US\$/m^3)	–0.15	–0.15	–0.03	–0.43	–1.42

For the urban water systems, the results show that decreasing the current electricity prices by 10% will increase the marginal profit surplus revenue from 0.13 US$/m³, 0.17 US$/m³ and 0.19 US$/m³ to 0.14 US$/m³, 0.18 US$/m³ and 0.21 US$/m³ for ATMA, Kumasi City and Ashanti rural water systems, respectively (Table 6). At the same electricity price change, the BC ratios also shift from 1.55, 1.44 and 1.29 to 1.60, 1.47 and 1.32 for ATMA, Kumasi City and Ashanti rural water systems respectively (Table 6).

On the other hand, increasing the current electricity prices by 50% will decrease the marginal profit from 0.13 US$/m³, 0.17 US$/m³ and 0.19 US$/m³ to 0.09 US$/m³, 0.12 US$/m³ and 0.10 US$/m³ for ATMA, Kumasi City and Ashanti rural water systems respectively (Table 6). At the same electricity price change, the BC ratios also shift from 1.55, 1.44 and 1.29 to 1.33, 1.27 and 1.12 for ATMA, Kumasi City and Ashanti rural water systems accordingly (Table 6). At this incremental factor, all the urban water systems can withstand the OPEX.

Again, increasing the current electricity prices by 200% decreases the marginal profit from 0.13 US$/m³, 0.17 US$/m³ and 0.19 US$/m³to –0.04 US$/m³, –0.04 US$/m³ and –0.18 US$/m³ for ATMA, Kumasi City and Ashanti rural water systems respectively (Table 6). At this incremental factor, all the urban water systems cannot withstand the OPEX.

Results of this study shows that the operational cost per cubic metre of water production of the small town water systems remains higher than that of the urban water systems but the small town systems are able to recover much in terms of income per cubic metre of water production to defray operational expenses due to their higher water tariff structure.

Table 6 Forecasted financial profits and BC ratio from urban water systems at incremental electricity changes (2009)

(US\$/m³)	*ATMA*	*Kumasi City*	*Ashanti rural*
	$\alpha E = 1$		
BC ratio	1.55	1.44	1.29
Forecasted Profit – Pt (US$/m³)	0.13	0.17	0.19
	αE = -10%		
BC ratio	1.60	1.47	1.32
Forecasted Profit – Pt (US$/m³)	0.14	0.18	0.21
	αE = 20%		
BC ratio	1.45	1.37	1.21
Forecasted Profit – Pt (US$/m³)	0.11	0.15	0.16
	αE =50%		
BC ratio	1.33	1.27	1.12
Forecasted Profit – Pt (US$/m³)	0.09	0.12	0.10
	αE = 100%		
BC ratio	1.17	1.15	1.00
Forecasted Profit – Pt (US$/m³)	0.05	0.07	0.01
	αE = 200%		
BC ratio	0.94	0.96	0.82
Forecasted Profit – Pt (US$/m³)	–0.04	–0.04	–0.18

4.4 *Tariff or revenue increases or decrease*

The coefficients of revenues suggest the appropriate increases or decreases that will cope with the corresponding energy price increases and decreases. BC_{ratios} that correspond with energy coefficient of one ($\alpha E = 1$) were used as reference for suggesting the coefficients of revenues. In cases of deficit revenue (i.e., $BC_{ratio} < 1$), a BC ratio of 1 was employed for the sake of break-even condition.

For the electricity driven systems under the small town water scheme, the results show that for a break even condition to occur, 10% decrease in energy prices requires 3.23%, 2.65% and 2.74% decrease in revenues for Wenchi, Kuntunase and Bekwai water systems accordingly (Table 7). Wenchi has the highest reduction factor hinting that Wenchi water system is most sensitive to electricity price changes. For the system to break even, 100% increment in the electricity driven systems under the small town water scheme requires a 32.27%, 26.54% and 27.34% increment in revenues for Wenchi, Kuntunase and Bekwai water systems accordingly (Table 7).

For Atebubu small town water system to at least break even, 30% decrease in diesel prices requires 10% decrease in revenues accordingly. The situation is different for Aburi water system, where a 30% decrease in diesel prices still requires 13% increment in revenues for a break even condition to occur (Table 7). This shows the burgeoning crisis associated with the Aburi water system. The OPEX of the Aburi water system is high but receives less revenue as a result of low tariffs and high UFW.

Table 7 Coefficients of revenues from small town water systems

	Electricity-driven			*Diesel-driven*	
(US\$/m³)	*Wenchi*	*Kuntunase*	*Bekwai*	*Atebubu*	*Aburi*
		αE = 1			
BC ratio	1.42	1.3	1.5	1.08	0.79
	αE = -10%			αE = -30%	
Coefficient of revenues (%) – αT	–3	–3	–3	–10	13
	αE = 20%			αE = -10%	
Coefficient of revenues (%) – αT	7	5	7	–3	23
	αE =50%			αE = 20%	
Coefficient of revenues (%) – αT	17	13	14	7	38
	αE = 100%			αE = 50%	
Coefficient of revenues (%) – αT	33	26	29	17	53
	αE = 200%			αE = 100%	
Coefficient of revenues (%) – αT	66	53	56	34	78

The study reveals that for the service to break even, a 100% increase in diesel prices requires 34% and 78% increments in revenue for Atebubu and Aburi water systems respectively.

For the urban water systems, the results show that, for the service to break even, 10% decrease in energy prices requires 3.24%, 2.59% and 2.78% reduction in revenues for ATMA, Kumasi City and Ashanti water systems accordingly (Table 8).

For the service to break even in the urban water supply system, a 100% increment in energy prices requires 32.41%, 25.91% and 27.87% increments in revenue for ATMA, Kumasi City and Ashanti water systems accordingly (Table 8).

Table 8 Coefficients of revenues from urban water systems

(US$/m³)	*ATMA*	*Kumasi City*	*Ashanti rural*
	αE = 1		
Coefficient of revenues – αT	1.55	1.44	1.29
	αE = –10%		
Coefficient of revenues – αT	–3	–3	–3
	αE = 20%		
Coefficient of revenues – αT	6	5	6
	αE = 50%		
Coefficient of revenues – αT	16	13	13
	αE = 100%		
Coefficient of revenues – αT	32	26	28
	αE = 200%		
Coefficient of revenues – αT	65	52	55

4.5 Sustainability of water facilities

Sustainability can only be guaranteed if operational cost (OPEX) and CAPEX (depreciation) cost are fully recovered. This study focused only on the OPEX and did not consider the CAPEX because they are defrayed by government. For water systems to be sustained in Ghana, operational income must be adequate enough to defray OPEX, and the surplus is the profit (Pt) before depreciation and tax. The study sought to find out to what extent energy increases would make the system breakeven (where revenue is equal to Opex). The point one (1) (current coefficient of energy) serves as the reference point (base year) on all the figures discussed below.

The results as depicted from the figure show that currently, the small town water systems powered by electricity motors are sustainable and can withstand up to 145% increments in the current electricity prices when all other OPEX components are held constant (Figure 4). Any further increment beyond the 145% mark will render the system unsustainable.

The results as depicted from Figure 4 show that small town water systems powered by diesel motors cannot withstand the current energy prices (Figure 5). For diesel-driven systems to fully recover their OPEX, there has to be a corresponding reduction of 25% in the current diesel prices. Reduction in domestic energy prices is dependent on the variation of global oil prices, as such water tariff may be reviewed and other challenges like high UFW tackled to save the burgeoning crisis associated with the systems.

Figure 4 Sustainability of small town water systems (electricity-driven) (see online version for colours)

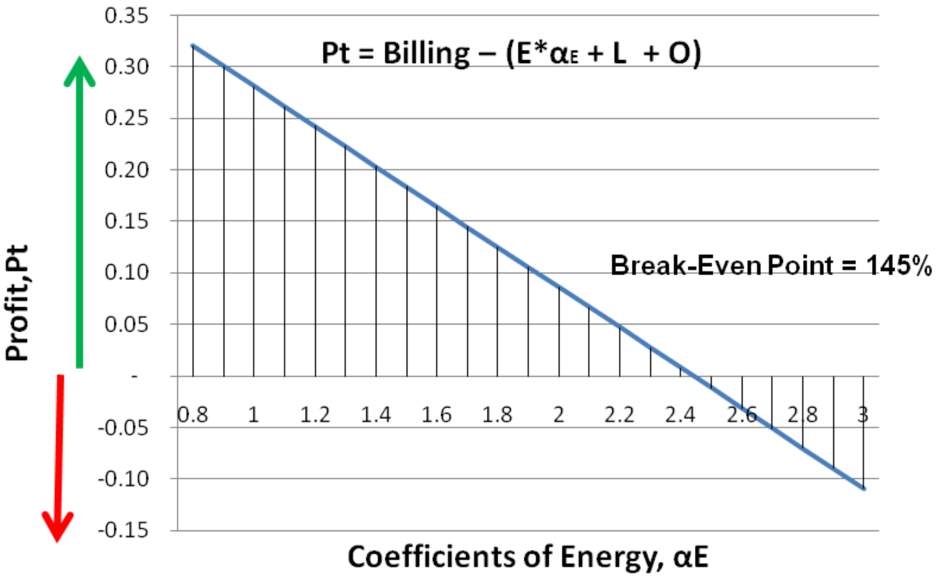
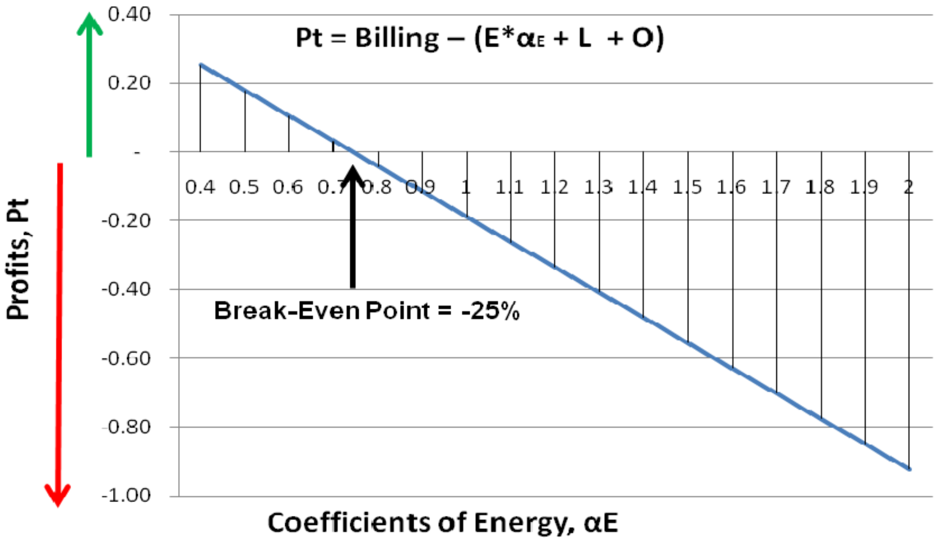
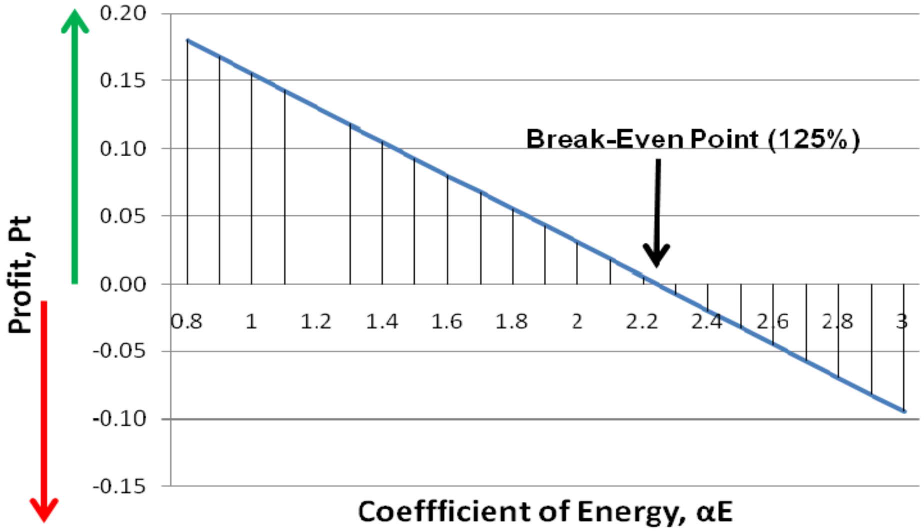


Figure 5 Sustainability of small town water systems (diesel-driven) (see online version for colours)



The results as depicted in Figure 6 shows that urban water systems can withstand up to 125% increments in the current electricity prices without effect on the sustainability of the water systems. A further increment will render the system unsustainable.

Figure 6 Sustainabilty of urban water systems (see online version for colours)



4.6 *Energy elasticity of profit*

The sensitivity of profit change ratio (Δp) to diesel and electricity price changes (α_E) is expressed in terms of elasticity of profit (ε) for each water system (Table 9 and Table 10). The results show that Wenchi, Kuntunase, Bekwai, Atebubu and Aburi water systems recorded energy elasticity of profit values of –1.37, –0.19, –0.63, –1.64 and 2.54 respectively (Table 9) suggesting that profits from Wenchi, Atebubu and Aburi small town water systems are sensitive to energy price changes, therefore an elastic relationship exist between profit and energy price changes.

Again, the study reveals that profits from Kuntanse and Bekwai small town water systems are inelastic to electricity price changes because they recorded absolute energy elasticity of profit values less than one (1).

The results show that ATMA, Kumasi City and Ashanti rural water systems recorded energy elasticity of profit values of –0.71, –0.62 and –1.14 respectively (Table 10) implying that profit from Ashanti rurals water systems is sensitive to energy price changes but that from ATMA and Kumasi City water systems are inelastic to electricity price changes.

Table 9 Energy elasticity of profit from small town water systems

	Electricity-driven			*Diesel-driven*	
	Wenchi	*Kuntunase*	*Bekwai*	*Atebubu*	*Aburi*
Energy elasticity of profit, ε	–1.37	–0.19	–0.63	–1.64	2.54

Averagely, small town water systems driven by electricity and diesel recorded values of –0.73 (–2.70–2.16) and –3.64 (–5.56–4.78) respectively (Table 10). The absolute values of the figures above show that profits from small town water systems driven by electricity are inelastic to electricity price changes but that from diesel-driven ones are elastic to diesel price changes.

Table 10 Energy elasticity of profit from urban water systems

	ATMA	*Kumasi City*	*Ashanti rural*
Energy elasticity of profit, ε	–0.71	–0.62	–1.14

The energy elasticity of profit value recorded for urban water system suggests that profits from water production within the urban community are inelastic to electricity price changes.

All the surveyed systems that are powered by electricty motors can withstand even doubling of the current electricity prices (Figure 4 and Figure 6).

5 Conclusions

Following global oil price variation in the past years, energy expenses have increased tremendously. Energy expenses have susbstantial impact on the financial profit from the water systems and form a substantial component of the total money expended in providing water to consumers. Increased energy prices reduce profits from the water systems and threatened their sustainabilities. On the other hand, decreased energy prices increased profits and might encourage in extending the distribution pipe network to areas that are not covered, thereby improving the water service.

The study shows that urban water systems are more efficient than small town water systems in terms of both energy and unit production cost. The energy cost per cubic metre of water supply from small town systems is about four times higher than for urban water systems. This further suggest that water consumers in small towns will have to pay relatively higher tariffs than consumers in urban communities. The surtax or levy on urban water supply may need a review to relieve water consumers within the small town communities. Additionally, electricity driven systems are more sustainable to run than diesel driven systems because diesel driven systems are more susceptible to global oil price changes. This suggests improvement of electricity infrastructure in areas of water systems and creating awareness on the enormous payback of converting the diesel driven systems into electricity driven ones.

Policy makers may adopt the outcomes and methodologies of this study and utilise them during reform of water pricing policies and subsidies to the energy sector. Continuity of this research in assessing the impacts of the other variables (labour cost and O&M cost) on the sustainabilty of water facilities may enhance the operations and efficiency of the water sector.

References

Abu-Madi, M. (2010) ‘Impacts of changing energy prices on the financial viability of agricultural groundwater wells in Tulkarm district- Palestine’, *International Journal of Water*, Vol. 5, No. 3, pp.205–222.

Adombire, M.A. (2007) *Water Supply for the Consumer: A Concise Practical Guide*, ISBN: 9988-582-37-4.

California Energy Commission (2005) *California's Water Energy Relationship*, CEC-700-2005-011-SF Sacramento, CA.

Carter, R., Tyrrel, S. and Howsam, P. (1999) 'The impact of sustainability of community water supply and sanitation programs in developing countries', *J. Chartered Institute, Water Environment Management*, Vol. 13, pp.292–296.

CWSA (2003) 'Design guidelines for small towns water systems', *Community Water and Sanitation Policy*, Ministry of Water Resources, Works and Housing, pp.4–5.

CWSA (2004) 'Operations and maintenance guidelines for small towns water systems', *Community Water and Sanitation Policy*, Ministry of Water Resources, Works and Housing, pp.2–17.

CWSA (2005) 'Operation and maintenance guideline for small towns', Ministry of Water Resources, Works and Housing, Small Communities Water & Sanitation Policy.

Forbes, L. (2008) 'The impact of peak oil on international development', *House of Commons*, The All Party Parliamentary Group on Peak Oil (APPGOPO). Reset.

Ghana Statistical Service (GSS) (2008) 'Ghana inflation rates (1998–2008)', *Ghana Statistical Service*, Ashanti Region, Government of Ghana.

Goldstein, R. and Smith, W. (2002) *Water and Sustainability*, Electric Power Research Institute, Vol. 4, USA, Electricity Consumption for Water Supply & Treatment – The Next Half Century, 1006787, PaloAlto, CA.

Nyarko, K.B., Oduro-Kwarteng, S. and Adama, I. (2007) 'Cost recovery of community managed piped water systems in Ashanti region, Ghana', *Water and Environment Journal*, Vol. 21, pp.92–99.

Nyarko, K.B., Awuah, E. and Owusu, P.A. (2008) *Water and Sanitation in Ghana*, Ghana, Desalination, 000 (2009), pp.1–8.

Stockholm International Water Institute (SIWI) (2005) *Health, Dignity and Development*, What will it Take? Stockholm International Water Institute and United Nations Millennium Project, New York.