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Energy Efficiency in Water Utilities: The Case of Guyana

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Water and Sanitation Division

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The Case of GUYANA

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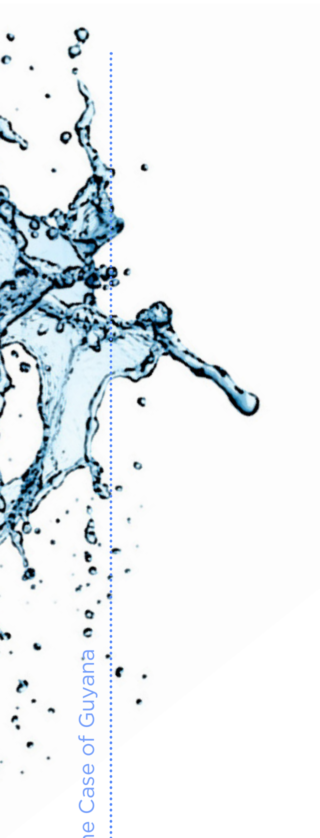

Abstract

Energy consumption in the water sector is extremely important. Energy is needed throughout the entire process of drinking water generation and treatment.

Estimates indicate that electricity expenses may represent as much as 40% of the total operating costs of a water and sanitation (W&S) utility. Conversely, energy consumption of W&S utilities often represent an important proportion of the total electricity generated in a country. Yet, energy consumed by W&S utilities is not always used efficiently.

This technical note aims to highlight how water and sanitation utilities can increase their energy efficiency, reducing operational costs and impacting positively the overall operational efficiency of W&S utilities. To illustrate this, the technical note takes as an example a pilot project carried out in the Guyana Water and Sanitation Utility – Guyana Water Incorporated (GWI).

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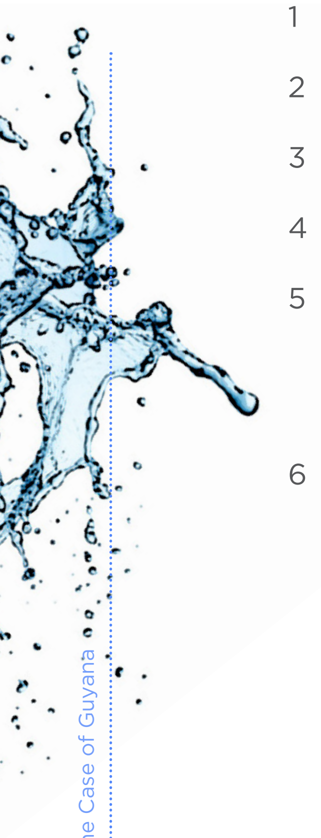

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1. Introduction

Guyana Water Incorporated (GWI) is the company responsible for providing water and sanitation (W&S) services to the population of Guyana. The utility faces many of the challenges found in other facilities of the Latin American and Caribbean (LAC) region, including high energy costs, deteriorating equipment, high water losses, and low energy efficiency.

Particularly important is the energy consumption at GWI facilities. Figures speak for themselves: In 2014, GWI spent more than US$12 million on electricity and GWI' electricity consumption was approximately six percent of the total electricity generated by the country's electric utility (GWI, 2015). In order to cope with this financial burden, GWI receives a direct subvention from the government of Guyana.

In this context, and in order to address some of these challenges, the Inter-American Development Bank (IDB) supported GWI in the assessment and implementation of energy efficiency initiatives in its water distribution and transmission facilities.

Between 2008 and 2012, several auditing campaigns were carried out in the scope of a regional project in the Caribbean, with the goal of identifying energy-saving opportunities in W&S facilities. The audits were conducted according to a methodology that allows, through field measurements, the detection of energy losses in each component of GWI facilities. Audits identified that energy losses occurred mainly due to: inefficient pumps and motors, low values of electrical power factor, and high head losses. These areas, then, are potential points of intervention for introducing energy-saving initiatives.

After the 2012 energy audit, GWI proceeded with the replacement of 10 borehole submersible pumps as a pilot project, which received financial and technical support from the IDB. Given the positive results of the pilot project, GWI expanded the project with IDB financial support and continued with the implementation of additional measures in 2014 and 2015.

This case study presents a description of Guyana's energy and water sector, as well as the challenges of the water utility, the methodology adopted for the audit, the main results of the audit, the energy-saving opportunities identified, and the implementation and results of the 10 pilot projects. The overall results of all implemented projects are presented with the lessons learned and conclusions.

2. Background

The main objectives of water and sanitation (W&S) utilities are to supply clean drinking water to the population and ensure proper disposal of wastewater. Energy is a critical input throughout this process. Electricity is needed to carry out all of the activities of W&S utilities. Electricity is required for raw water extraction and conveyance; water purification[1]; drinking water storage and distribution; and wastewater collection, treatment, and discharge (Water Research Foundation, 2011).

Energy expenses are thus extremely important to W&S utilities. Estimates indicate that electricity expenses may represent as much as 40% of the total operating costs of W&S utilities (Ferro and Lentini, 2015).

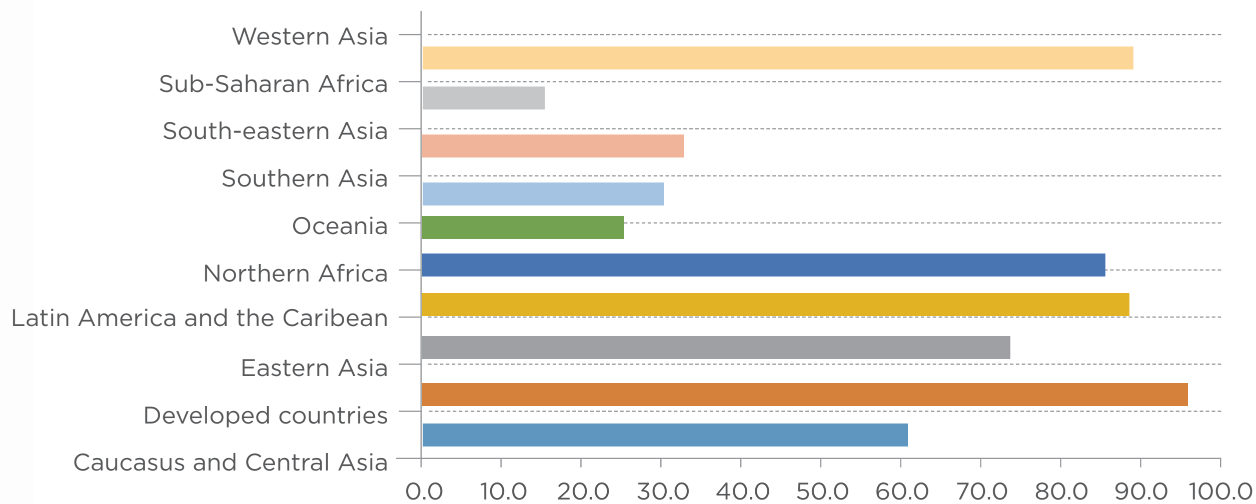
W&S utilities are important customers for electric utilities. The Electric Power Research Institute (EPRI) estimated that three to four percent of energy consumption in the United States is used for drinking water and wastewater services (EPRI, 2002). Energy needs in W&S utilities will naturally increase, in part due to the trend of continuous population growth, which usually requires more complex systems to distribute water (more distance between the water source and water demand, and in some cases, with greater systems elevations). Additionally, an increase in water demand also requires new energy-consuming technologies, such as membranes and desalination, to cope with lower quality sources (Water Research Foundation, 2011).

Energy is also a scare resource. In many countries, energy prices are increasing and there are limited energy alternatives promising minimal environmental impact. Therefore, it is critical to focus on how to improve energy efficiency. W&S utilities can benefit significantly from energy savings: energy efficiency improvements in W&S utilities are a worthy investment because these can yield returns in the form of operational cost savings by increasing the level of service and extending financial sustainability to the W&S company (IDB, 2011).

1 Including water disinfection and fluoridation processes.

The Latin America and Caribbean (LAC) region has one of the highest coverage rates of piped water on premises compared to other regions of the world (Figure 1). This means that in the LAC, close to 89% of the population has access to water through a water connection located inside the user's dwelling, plot, or yard.

Figure 1: Percentage of Population with Piped Water on Premises by Region



Source: Data from WHO/UNICEF (JMP), 2016.

Yet, water utilities in the LAC region face a number of challenges that impact directly the overall energy consumption, including high levels of physical and commercial non-revenue water (NRW), deteriorating infrastructure, low levels of electromechanical efficiency,[2] and a high reliance on groundwater (Rosas, 2011; WWAP, 2014).As seen in other regions, energy is an important component of the total costs of W&S utilities (between 10-60%) (Rosas, 2011); therefore, energy efficiency is increasingly regarded by the sector as a strategy to improve the operational and financial performance of utilities.

But where are the savings opportunities? In W&S facilities there are several opportunities for energy-saving throughout the water production and distribution systems (See Figure 2). The main areas include:

- **Reducing electric losses**: These losses might be related to losses in facilities' transformers, low power factor, or overloaded conductors.

- **Reducing motor losses**: These losses might be related to poor motor maintenance; the operation of an inefficient/re-wounded motor; by an imbalance of energy source coming from the power supply company; or from the facility transformer.

2 Electromechanical efficiency corresponds to the efficiency of the joint motor-pump.

- **Reducing pump losses**: These losses might be related to pumps operating out of their optimum range due to inadequate hydraulic operation; to oversize pumps; pump wear; inefficient impellers; or inefficient pump controlling systems[3] (IDB, 2011).

- **Reducing head losses**: These are losses related to friction within pipes or resistance caused by pipe configuration. Over years of use, water pipes corrode and minerals build up on the inner surface of pipe walls. These pipe impairments create resistance to water flow. In some cases, head losses are due to inadequate practices, for example, throttling valve operation, which are normally associated with oversized equipment. The more the resistance, the more energy required to move water through the distribution system (Denig-Chakroff, 2008).

- **Reduction of NRW**: When NRW decreases, so does the need for pumping and distribution. In Brazil, the estimated average energy use for pumping is 0.75 kWh/m^3 of water produced (World Bank, 2016). To tackle NRW reduction can bring significant energy savings to utilities. However, in many cases, the detection of physical losses might be a resource-consuming task, since leaks might be small and dispersed.

BOX 1

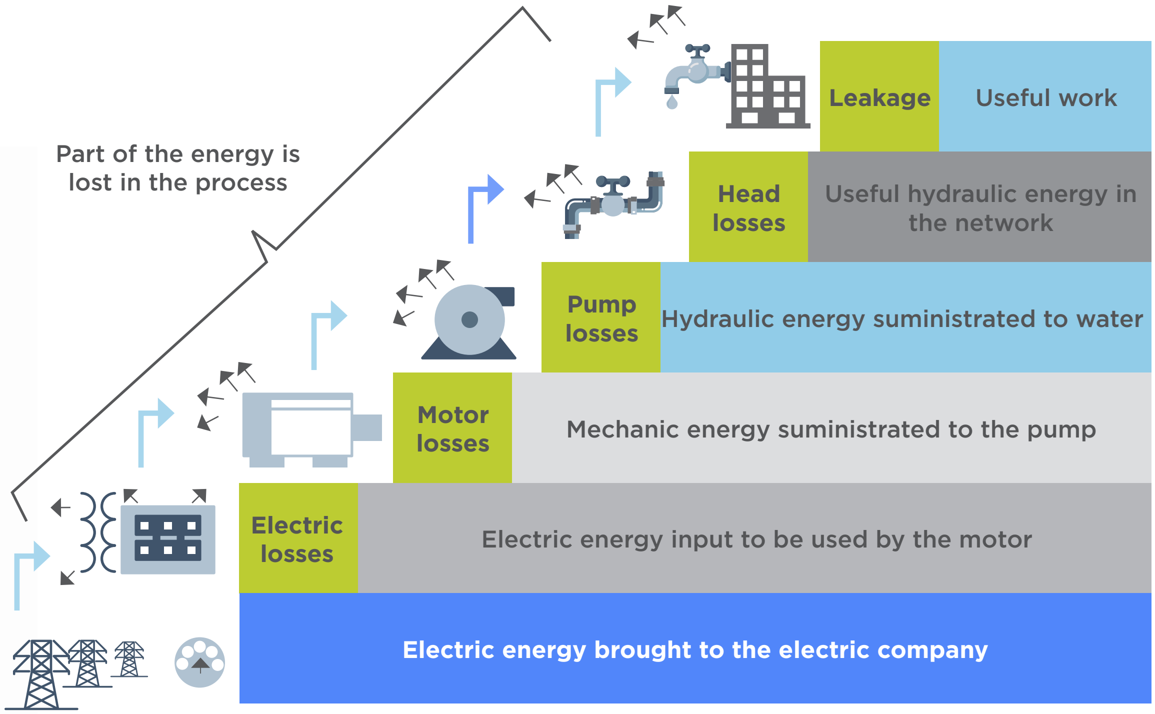
Definition of Non-Revenue Water (NRW)

Non-revenue water (NRW) is the difference between the volume of water put into a water distribution system and the volume that is billed to customers. NRW comprises three components, which are as follow:
Physical (or real) losses comprise leakage from all parts of the system and overflows at the utility's reservoirs. They are caused by poor operations and maintenance, the lack of active leakage control, and poor quality of underground assets.
Commercial (or apparent) losses are caused by customer meter under-registration, data handling errors, and theft of water in various forms.
Unbilled authorized consumption includes water used by the utility for operational purposes, water used for firefighting, and water provided for free to certain consumer groups.

Source: Frauendorfer and Liemberger, 2010

3 Pump control methods include simple start-stop settings, control valve operation (or throttling), variable-speed operation, multiple-speed motors, or parallel operation of multiple pumps (Dufresne, and Ferrel, 2016).

Figure 2: Typical Energy Consumption and Losses in W&S Systems

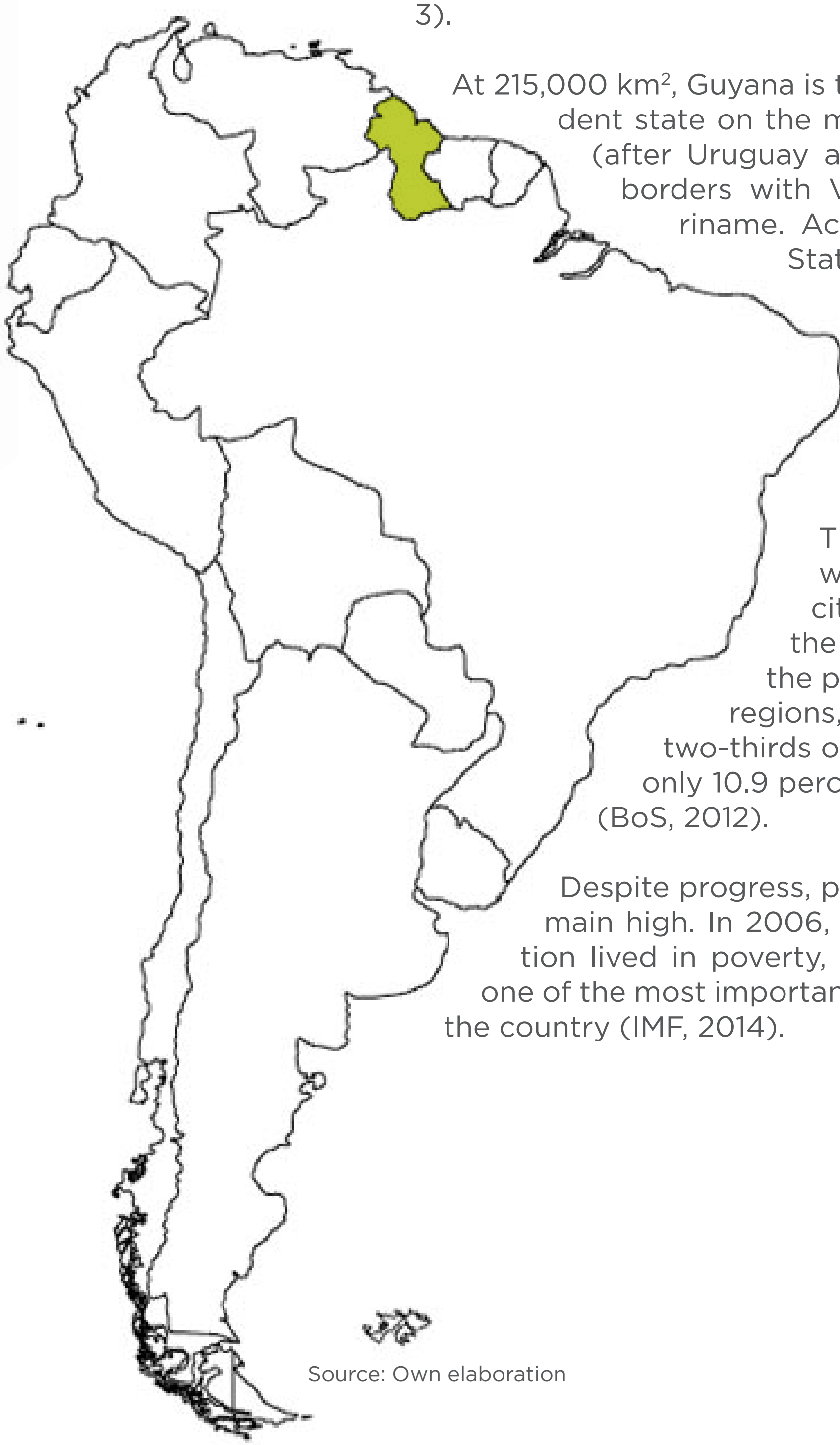


Source: IDB, 2011

An important opportunity that should not be neglected when looking for savings related to energy consumption is a detailed review of the electricity supply conditions and the existing contract with the electricity utility. Depending on the country's electricity regulation, some W&S might be able to negotiate new tariffs with current or new providers (charge per electricity and/or power), thus providing new opportunities for savings.

3. Country overview

Figure 3: Guyana Geographic Map



Source: Own elaboration

Guyana, officially the Co-operative Republic of Guyana, is a state on the northern coast of South America that is culturally part of the Anglophone Caribbean (See Figure 3).

At 215,000 km^2, Guyana is the third-smallest independent state on the mainland of South America (after Uruguay and Suriname), and shares borders with Venezuela, Brazil, and Suriname. According to the Bureau of Statistics (BoS), its population was estimated at 747,884 people as of September 2012 (BoS, 2012), which represents a density of only 3.5 people per square kilometer.

The coastland regions, which include the capital city, comprise 89.1 percent of the total population; whereas the population of the hinterland regions, comprising more than two-thirds of the land area, constitutes only 10.9 percent of the total population (BoS, 2012).

Despite progress, poverty levels in Guyana remain high. In 2006, 35 percent of the population lived in poverty, making poverty reduction one of the most important issues to be addressed in the country (IMF, 2014).

4. Electricity Sector Outlook

The main stakeholders of the country's electricity sector are: (i) Guyana Power & Light Inc. (GPL), originally named the Guyana Electricity Corporation, which is the main supplier and is entirely owned by the government of Guyana; (ii) The Ministry of Public Infrastructure, which is responsible for policy-making and regulatory control in the energy sector; and; (iii) the Public Utilities Commission (PUC), a multi-sectorial regulatory body, which is responsible for monitoring and enforcing operators' compliance with commitments to customers emanating from licenses and standard terms and conditions for operations. The PUC is also responsible for confirming and approving tariffs charged by public suppliers[4] (GEA, 2014).

GPL supplies electricity in populated areas along the coast and in some islands and isolated ground areas. Whereas electricity coverage in the coastal zone is close to 90%, electrification of hinterland communities remains relatively low, and more than 80% of the Amerindian population (the largest demographic in the hinterland) lacks access to electricity, driving overall coverage in the country down to 81% as of 2010 (IDB, 2012).

Electricity generation in Guyana is mostly thermal-based, using heavy-fuel oil or diesel for power generation. As a result of the country's dependence on imported petroleum-based fuels for electricity generation, the cost of electricity in Guyana is among the highest in the LAC region, with tariffs ranging from ¢US0.28 to ¢US0.32 per kWh. In addition, high technical and commercial losses are exacerbated by low collection rates and institutional capacity challenges within GPL (IDB, 2012).

In 2012, GPL had a nominal generation capacity of 158 MW with an annual electricity production of 690 GWh (GPL, 2012). Electricity demand is expected to grow in the next decade, which will further stress GPL's operations and infrastructure (IDB, 2014).

The tariff structure faced by W&S utilities is crucial to determine the cost-effectiveness of energy efficiency measures to be proposed or implemented. As mentioned previously, electricity tariffs in Guyana are one of the highest in the region, affecting not only residential, but also industrial and commercial clients, including GWI. Table 1 shows tariffs as of 2008, at the time the first audit was performed, and as of April 2016, after GPL readjusted tariffs due mainly to the drop in oil prices.

4 Telecommunications, Electricity, and Water and Sewerage.

Table 1: GPL Tariff Structure[5]

Type	Tariffs	Previous Rate (2008) $GYD/kWh	New Net Tariff (2016) $GYD/kWh	Previous Tariff (2008) ¢US/kWh	New Net Tariff (2016) ¢US/kWh
Residential: Lifeline (A)	< 75 kWh	48.42	39.1	23.6	19.1
Residential (A)	>75 kWh	53.78	43.43	26.2	21.2
Commercial	B	69.82	56.38	34.1	27.5
Industrial	C	63.07	56.76	30.8	27.7
Industrial	D	60.41	54.37	29.5	26.5
Government	B	72.85	65.57	35.5	32.0
Government	C	65.81	59.23	32.1	28.9
Government	D	63.04	56.74	30.8	27.7

Source: GPL, 2016b

As part of the industrial and commercial rates, there is an additional monthly charge for demand (apparent power - measured in kilo volt-ampere (kVA)), that will impact those clients with a low power factor (PF) (see Table 2). The water utility of Guyana will therefore face two charges-- an electricity charge (kWh-based) and a demand charge (kVA-based)-- in their facilities.

Table 2: GPL Demand Charge

Type	Tariffs	Demand Charge (2008) $GYD/kVA	Demand Charge (2016) $GYD/kVA	Demand Charge (2008) US$/kVA	Demand Charge (2016) US$/kVA
Residential: Lifeline (A)	< 75 kWh	n/a	n/a	n/a	n/a
Residential (A)	>75 kWh	n/a	n/a	n/a	n/a
Commercial	B	2,596.8	2,467.0	12.7	12.0
Industrial	C	1,852.9	1,760.2	9.0	8.6
Industrial	D	1,852.9	1,760.2	9.0	8.6
Government	B	2,709.0	2,574.3	13.2	12.6
Government	C	1,933.4	1,836.8	9.4	9.0
Government	D	1,933.4	1,836.8	9.4	9.0

Source: GPL, 2016b

5 Conversion at an exchange rate of 205 GYD= 1US$. Source: Bank of Guyana, 2016. https://www.bankofguyana.org.gy/bog/

BOX 2

Definition of Power Factor

The power factor of an alternate current electric power system is defined as the ratio between the real power to the apparent power, and is a number between zero and one. Real power (measured in watts) is the capacity of the circuit to perform its work within a particular time. Apparent power (measured in volt-amps - VA) includes the reactive power that utilities need to distribute even when power accomplishes no useful work. Low-power-factor loads can increase losses in a power distribution system and result in increased energy costs.

Source: World Bank, no date

5. Water Sector Outlook

5.1 Institutional and Legal Framework

Established in 2002, Guyana Water Incorporated (GWI) is the utility responsible for the design, construction, operation, and maintenance of the water supply systems (WSS) in the capital of Georgetown, in the coastal area, and for community WSS in the hinterland regions. GWI is also responsible for the operation and maintenance (O&M) of the sewerage systems in Georgetown (IDB 2014c).

GWI operates in accordance with the regulations of the Water & Sewerage Act of 2002, under a license issued by the Ministry of Housing and Water, now called the Ministry of Communities. The Ministry of Communities is responsible for the development of water sector policies and for issuing licenses to utilities. Along with the PUC, the Ministry of Communities is in charge of monitoring services provided by GWI (IDB 2014, PUC, 2016).

5.2 Water Availability

Groundwater fulfills about 90% of the domestic water needs of the country, while most of the water supply for agriculture (sugarcane and rice) and industry comes from surface water.

The Guyana groundwater system comprises three aquifers:

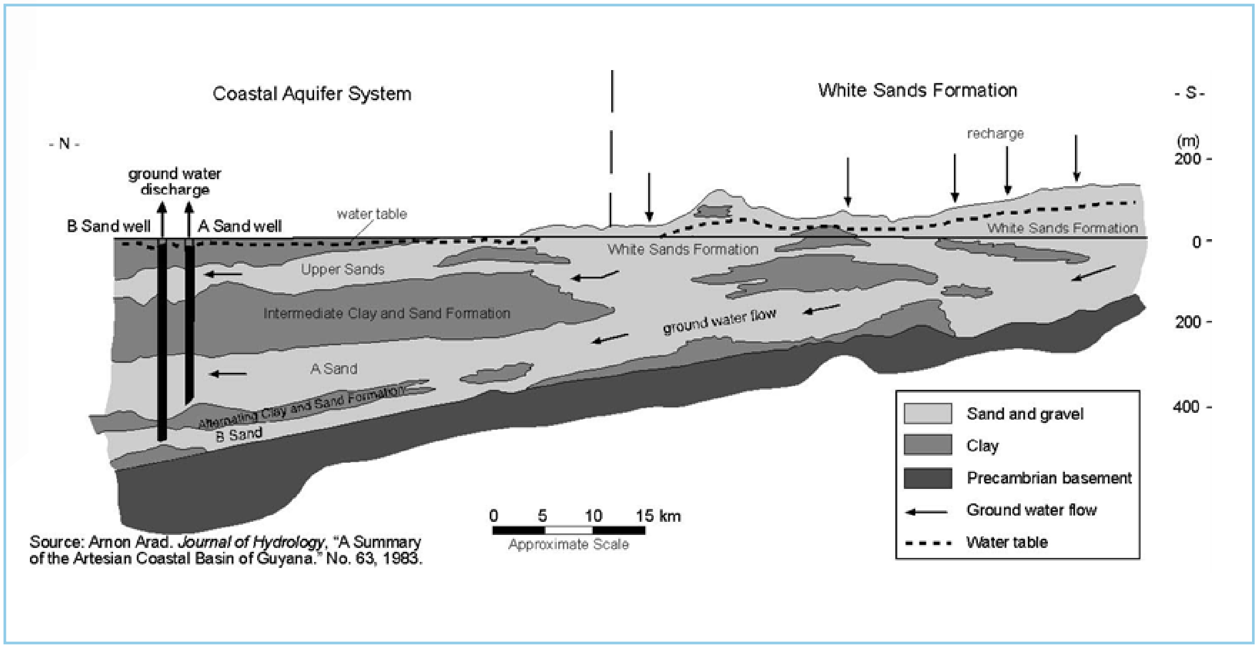
- The "upper" sand is the shallowest of the three aquifers and its depth varies from 30 to 60 m, with thickness ranging from 15 to 120 m. It is not used as a source of water because of its high iron content (>5 mg/l) and salinity (up to 1,200 mg/l).

Therefore, most potable water is obtained from the two deep aquifers:

- The “A” sand is typically encountered between 200 and 300 m below the surface, with thickness ranging from 15 to 60 m. Water from the “A” aquifer requires treatment for the removal of iron.

- The “B” sand is found at about 300 to 400 m, with thickness of between 350 and 800 m. Water from this aquifer has very little iron, a high temperature, and a trace of hydrogen sulphide, which can be treated with aeration.

Figure 4: Groundwater General Scheme in Guyana



Source: Arad, 1983.

One of the challenges GWI faces is related to lack of data on the aquifers. Coupled with increasing demand, this creates the risk of potential depletion of groundwater reserves and intrusion of saline water (IDB, 2014c).

5.3 Water and Sanitation Access

Increasing W&S services to the population in Guyana is another significant challenge. According to the World Health Organization (WHO) and the UNICEF Joint Monitoring Programme (JMP), in 2009, only 33% of the population had access to piped water[6] and only 4.2% of the population had access to sewer systems (WHO/UNICEF, 2016).

Wastewater is discharged untreated through an outfall at the mouth of the Demerara River. In unsewered areas of Guyana, households use septic tanks and pit latrines. In the housing schemes on the coastal area, the use of flush toilets located in houses is the preferred solution, and is on the increase. However, there remain pockets of the population using traditional pit latrines. Previous studies suggest that these, largely used in low-income areas, are in poor conditions and below WHO standards (IDB, 2014c).

6 Piped water into dwelling or piped water into yard/plot or public tap, standpipe.

6. Energy Efficiency and the Guyana Water Utility

GWI's service area is apportioned into five divisions along the coast, numbered one to five from west to east. Additionally, Division 3 is further apportioned into four sub-divisions (see Table 3).

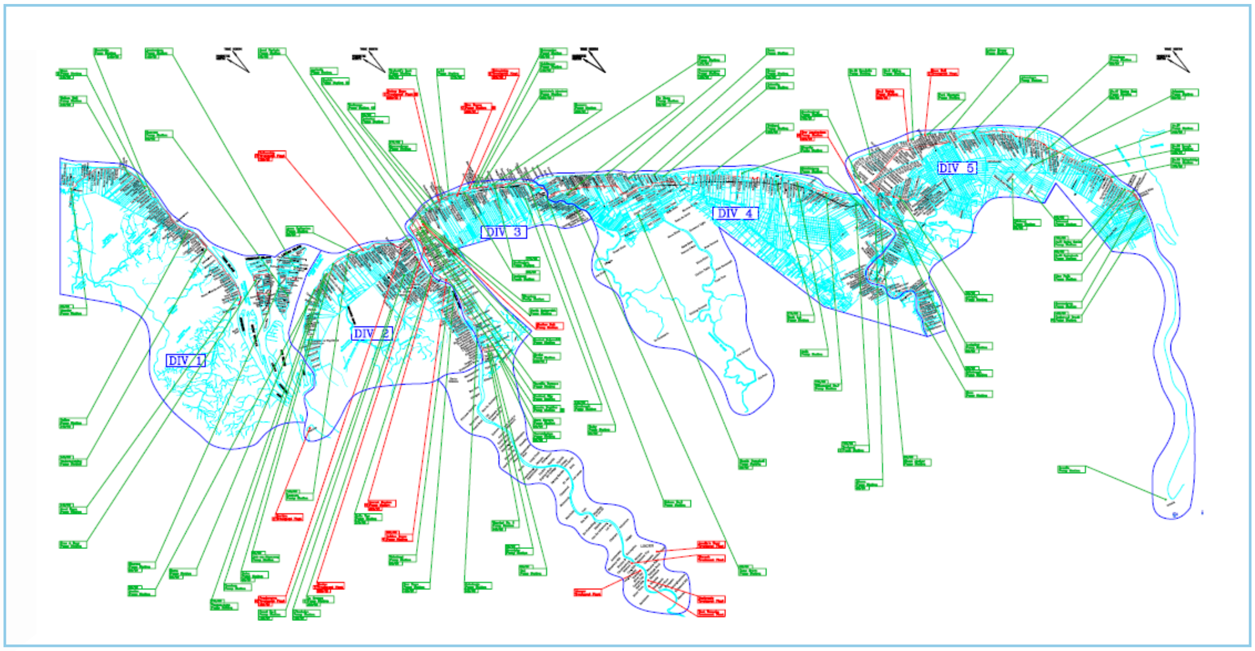
Table 3: GWI Divisions & Names

Division	Name/Location
Division 1	Essequibo Coast
Division 2	West Coast Demerara
Division 2	West Bank Demerara
Division 3-EBD	East Bank Demerara
Division 3-ECD	East Coast Demerara
Division 3-LIN	Linden
Division 3-GT	Georgetown
Division 4	West Coast Berbice
Division 5	East Berbice

Source: Own elaboration

The distribution of the water facilities along the populated area and the five main divisions are shown in Figure 5.

Figure 5: Facilities Distribution Map



Source: GWI

GWI manages 19 water treatment plants (WTPs) (shown in red in Figure 5) and 122 boreholes (shown in green in Figure 5), and the corresponding pumping stations and transmission and distribution systems. It also operates 24 sewerage pumping stations in Georgetown (IDB 2014c).

6.1 Water and Sewerage Tariffs

GWI currently charges tariffs that were approved in 2005. The tariff structure varies for domestic and commercial customers and for metered and unmetered customers, ranging from US$0.30 to 0.46 per cubic meter for residential customers. Since these tariffs did not provide an adequate revenue base on which GWI can cover its operational costs, the PUC approved in 2013 a new tariff scheme that would increase tariffs to a range of US$0.30 to 0.55 per cubic meter, depending on the consumption metered. and including as well a fixed rate for unmetered customers ranging from US$3.41-1085 per month (GWI,2012).[7] This tariff could help reduce the financial vulnerability of the utility by providing extra revenue. Estimates from GWI indicate that these new tariffs could be as important as the government subsidy, which was approximately, on average, US$8 million between 2013 and 2015. This tariff scheme is currently under implementation.

7 In addition, the new tariff introduces a fixed rate for all customers of US$0.98 per month. Conversion at an exchange rate of 205 GYD= 1US$. Source: Bank of Guyana, 2016. https://www.bankofguyana.org.gy/bog/

6.2 GWI's Main Challenges

GWI operates under constant challenges, mainly caused by aging pipes and equipment (some laid in the 1920s and never replaced, due to lack of planning and budget); insufficient asset management and maintenance; and limited data on aquifer yields (IDB, 2014c). As a result, the water service is unreliable, with pressure as low as one to three meters, and an average operating period of 16 hours per day (IDB, 2014c).

Moreover, GWI faces additional challenges, including: (i) extremely high NRW levels, which by 2013, were close to 70 percent; (ii) high electricity prices (GWI, 2015); and (iii) low levels of metered customers (only 46% of GWI customers are metered). All these factors have an impact on the financial situation of the company, which in 2014 showed a net operating loss of US$15 million (GWI, 2015). The most important item of the overall cost structure is energy: Electricity accounts for more than 60% of GWI's operating costs. It thus has a significant impact on the total costs of supplying W&S services to the population (GWI, 2012).

The current tariff structure does not allow the company to recover its operational costs; therefore, GWI's financial situation is very dependent to the annual subvention the government provides to offset electricity costs. The total subvention GWI received in 2014 was close to US$12 million (GWI, 2015).

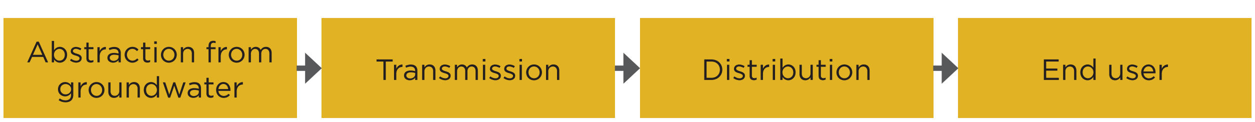
Within this context, the need to introduce energy savings measures is clear. A reduction in energy costs would improve the company's financial situation. At the same time, it would reduce the need for financial support from the government, which would in turn allow a more efficient allocation of resources. In order to identify the energy savings opportunities, a detailed energy audit was performed between 2008 and 2012, with the specific goal of identifying the main opportunities for improving energy efficiency. The results of the audit provided GWI with a set of opportunities to improve the energy efficiency of its main facilities.

6.3 Process Description

GWI provides two types of services – treated or untreated water - through two different processes:

i. **Untreated Water.** The customer received service that comes from a borehole through the distribution network directly to their taps without passing a WTP. The process of water production and distribution for boreholes is shown in Figure 6.

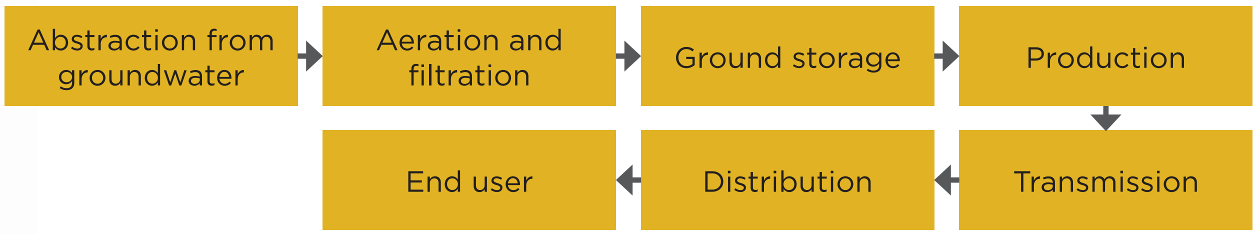
Figure 6: Untreated Water Process Schema



Source: Own elaboration

ii. **Treated water.** In this case, after the abstraction from groundwater, the water passes into an aeration and filtration process to reduce organic and solid materials. It is then stored before entering the treatment process and being introduced to the transmission and distribution network. The process is shown in Figure 7.

Figure 7: Treated Water Process[8]



Source: Own elaboration

6.4 Production and Energy Consumption

Water production levels have been relatively constant over the last four years (see Table 4). In 2015, the total water production of GWI was 122 million m^3 with a customer base of 183,000 customers, almost half of them unmetered (GWI, 2015).

Table 4: GWI Summary of Water Production

	2012	2013	2014	2015
Total (m^3/year)	126,776,564	125,387,658	120,457,196	122,743,829

Source: GWI, 2015.

Table 5: Energy Consumption and Water Production in GWI-controlled Areas (2011)

	Energy Used (kWh)	Water Produced (m^3)	Energy Index (kWh/m^3)
Division 1	2,144,133	6,336,206	0.34
Division 2	4,291,132	14,858,714	0.29
Division 3-EB	5,176,225	16,504,925	0.31
Division 3-ECD	5,219,424	16,669,471	0.31
Division 3-LIN	3,286,124	7,880,477	0.42
Division 3-GT	7,655,081	26,054,224	0.29
Division 4	2,359,399	16,604,842	0.14
Division 5	8,729,482	29,094,588	0.30
TOTAL	**38,861,000**	**134,003,448**	**0.29**

Source: Own elaboration

8 Water treatment includes disinfection.

The energy index was calculated using the data of energy used and water production, which represents the relationship between the energy used by the pumping system in a drinking water system and the total volume of water produced and supplied to the distribution network (See Box 3).

In 2011, a total of 38,861,000 kWh were used to produce 134,003,448 m^3 of water, with a resulting overall average energy index of 0.29 kWh/m^3.

The energy index was calculated by division in order to rank the divisions according to their respective efficiencies. The highest energy index was found in Division 3-LIN, with 0.42 kWh/m^3, and the lowest energy index was found in Division 4, with only 0.14 kWh/m^3.

Information given by GWI shows that in 2011, total electricity consumption (38,861,000 kWh) had total equivalent costs of US$12 million(GYD$2,487,104,000). This translates to an average cost of water production of GYD$18.56 (US$0.093) per m^3.

BOX 3

Energy Efficiency Indicators

When assessing the energy efficiency of any W&S facility, it is crucial to establish what indicators will be used to evaluate and monitor results. The main indicators recommended are:

Energy Index

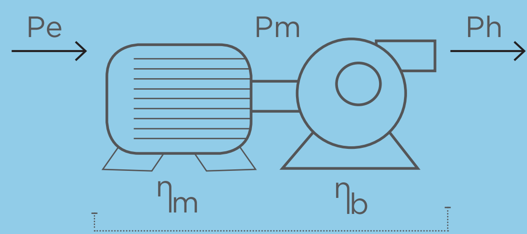
The energy index represents the relationship between the energy used by the pumping system in a drinking water system and the total volume of water produced and supplied to the distribution network. The higher the number, the more electricity is needed to produce one unit of water. The energy index value depends on the type of water source available in the water supply system and the topography of the city; therefore, there is no energy index baseline value. Systems located in hilly topographies that supply water by using pumping stations only will have higher energy index values. Also, systems with many leaks in the network will show an increase in the production and supply of water, and thus greater consumption of energy. A water company's energy index will go down by installing/operating their equipment efficiently and by minimizing leakage in the network.

Unitary Energy Cost Indicator (UEC)

The cost per unit of energy consumed depends on several factors, such as the type of electricity tariff contract, specific load factor (reflecting actual operation hours with respect to full-time operation of 24 hours a day), and other factors affecting energy charges, such as penalties or billing credits due to the power factor (PF) of the electrical installations. Unitary energy cost (UEC) is calculated based on the total annual consumption of electricity (kWh/year) and the total of the electricity bills (US$/year) received by the water utility during the year. This indicator is based on the electromechanical infrastructure and respective costs, and has to be set for each water utility.

Electromechanical Efficiency of Pumping Systems[9] (%)

The electromechanical efficiency corresponds to the efficiency of the joint motor-pump and is the energy that is imparted to the water, divided by the energy that came in over the electrical wires.
This indicator is often used to evaluate the electromechanical efficiency of the motor-pump assembly, given the difficulty of measuring the mechanical power separately, and then determining the overall efficiency of the pump.



$$\eta_{em} = Ph/Pe$$

Where
η_{em} is the electromechanical efficiency,
Ph is the hydraulic power (kW), and
Pe is electrical power (kW).

Source: IDB, 2011.

6.5 Auditing Methodology and Results

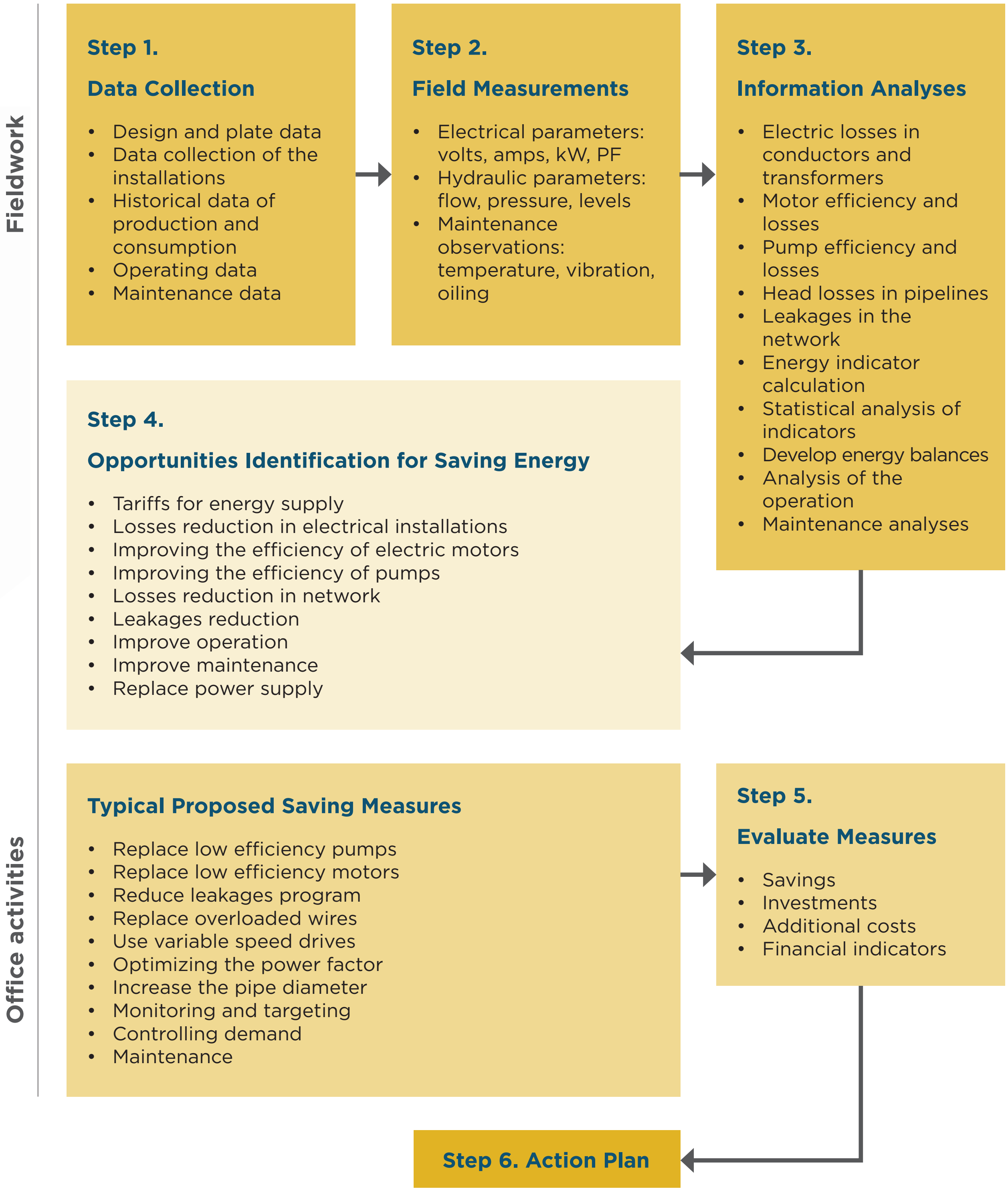
One methodology used to determine the main opportunities for energy savings is a detailed round of energy audits. The scope of the energy audit[10] is to assess the efficiency and amount of wasted energy in high energy-consuming equipment of water facilities. To do this, the methodology requires activities both in the field and in the office. Field work required collecting all relevant information from the audited systems, including field measurements of electrical and hydraulic parameters, data from the equipment plates, and information about the operation and maintenance of equipment, among others.

Office work consists of analyzing the information collected in the field, calculating the energy balance of the system, and identifying specific projects and recommendations. The energy balance estimates then the energy losses and efficiencies of all the pumping system components. It indicates the distribution of energy, as well as where the major energy saving opportunities can be found (IDB, 2011).

A diagram of the methodology used for the energy audit is shown in Figure 8.

9 Also called wire-to-water efficiency.
10 A detailed description of the methodology used for the audits can be found in the document "Evaluation of Water Pumping Systems: Energy Efficiency Assessment Manual". URL :https://publications.iadb.org/handle/11319/2814

Figure 8: Audit Methodology Diagram



Source: IDB 2011

Once the projects and recommendations are made, an energy efficiency investment program can be designed.

The energy efficiency audit methodology focuses on the following typical energy efficiency measures:

- Pump optimization or replacement;
- Increase of efficiency motors and/or use of variable speed drives (VSD)[11];
- Power factor optimization;
- Reduction of head losses in pipes;
- Selection of the optimal size of electrical conductors.

Other savings opportunities that can result from this type of analysis include the following: adjusting electricity tariffs, operating equipment during off-peak hours, generating energy on-site during peak demand hours, and optimizing hydraulic operation.

BOX 4

Energy Balance

The energy balance estimates the energy losses and efficiencies of all the pumping system components. Through field measurements (temperature readings, excess vibrations, lubrication of mechanical components, leakage in valves, etc.), the energy efficiencies of the pumping system components are evaluated and the energy balance of the system can be determined. The main indicators of an energy balance are:

- **Useful work:** Is the energy actually used by the system for water pumping? Anything that is not useful work is lost energy.
- **Electric losses:** This refers to energy losses in electrical items that are due, for example, to the conductor's electric losses.
- **Motor losses:** This refers to energy losses in the motor based on real motor efficiency.
- **Pump losses:** This refers to energy losses due to pump inefficiency.
- **Suction and discharge losses:** These are energy losses caused by friction of the fluid in the suction and discharge pipes.
- **Total network head losses:** Head losses are calculated by the difference between the total head losses and the suction and discharge losses.
- **Leakage losses:** These types of losses are an estimate of water lost through leaks in the distribution network, according to previous studies of the net-work.

Source: IDB, 2011

11 Variable-speed drives (VSDs), also called variable-frequency drives (VFDs), adjust the motor's rotational speed by changing the frequency and voltage of the electric power delivered to the motor. VFDs can be used to match the motor speed and power to the specific system demands. Source: Dufresne and Ferrel, 2016.

6.6 Energy Balance in Boreholes

In 2012, 116 out of the 122 boreholes were audited. Electrical and hydraulic measurements of equipment were performed to evaluate the operating conditions (flow and head) and efficiency of equipment. A summary of the audited facilities by division is shown in Table 6.

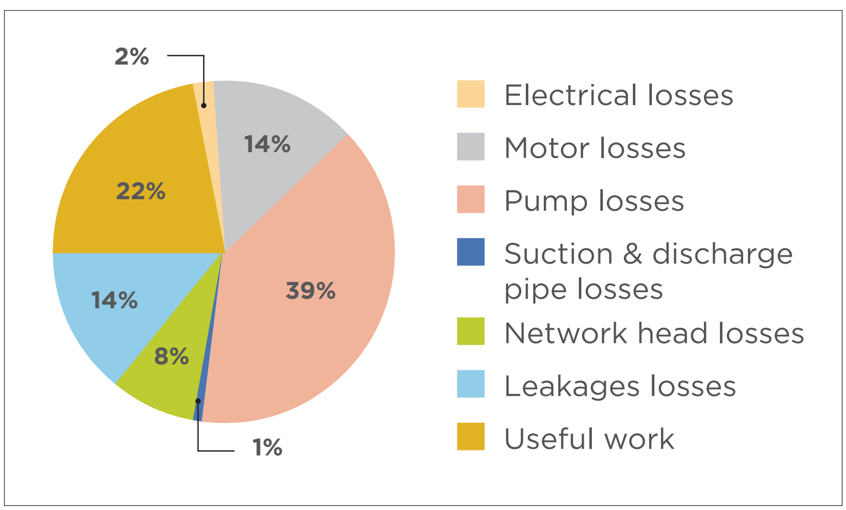
Table 6: Audited Borehole Facilities per Division

Division	Audited Boreholes
Division 1	11
Division 2 WCD/WBD	23
Division 3 EBD	10
Division 3 ECD	20
Division 3 Georgetown	17
Division 3 Linden	0
Division 4 WBD	12
Division 5 (East Berbice)	23
	116

Source: Own elaboration

Following the energy efficiency audit methodology, and with the field measurements obtained, the energy losses and useful work along the elements of the water pumping systems were calculated to obtain the energy balance of each facility. The global energy balance and the total losses in each element of audited facilities are shown in Figure 9.

Figure 9: Energy Balance of Audited Facilities



Source: Own elaboration

Motor and pump losses represented 53% of the total energy balance throughout the whole water supply system, with only 22% of useful work left. The data showed that these high losses are mainly due to the low electromechanical efficiency of the motor-pump assemblies in boreholes.

6.6.1 Pump and Motor Efficiency

The electromechanical efficiency of the motor-pump assemblies was calculated based on the field measurements. The average of motor, pump, and electromechanical efficiencies of the evaluated equipment per division is shown in Table 7.

Table 7: Average of Motor, Pump and Electromechanical Efficiencies

Division	Pump efficiency	Motor efficiency	EM efficiency
Division 1	63%	81%	51%
Division 2 WCD/WBD	60%	87%	52%
Division 3 EBD	51%	87%	44%
Division 3 ECD	50%	87%	44%
Division 3 Georgetown	54%	85%	46%
Division 4 WBD	48%	84%	41%
Division 5 (East Berbice)	48%	87%	42%
Total	**54%**	**85%**	**46%**

Source: Own elaboration

The overall average electromechanical efficiency was only 46%, which is a low value compared to new borehole submersible pumps. The industry standard for electromechanical efficiency is 57% for borehole submersible pumps with a capacity of up to 40 HP, and 60% for pumps with capacity higher than 40 HP.

The low electromechanical efficiency is due primarily to the age of the equipment, pumps operating out of their Best Efficiency Point (BEP), and re-wounded motors. These factors produced low electromechanical efficiencies and represent high energy-saving opportunities.

During the auditing process, it was detected that the fluctuations of voltage supplied by the power company was causing GWI to use more energy than required in the operation of equipment. This explains the difference in the energy consumed by the motor-pump assembly when comparing nominal efficiency and the actual electrical power input of the motor.

BOX 5

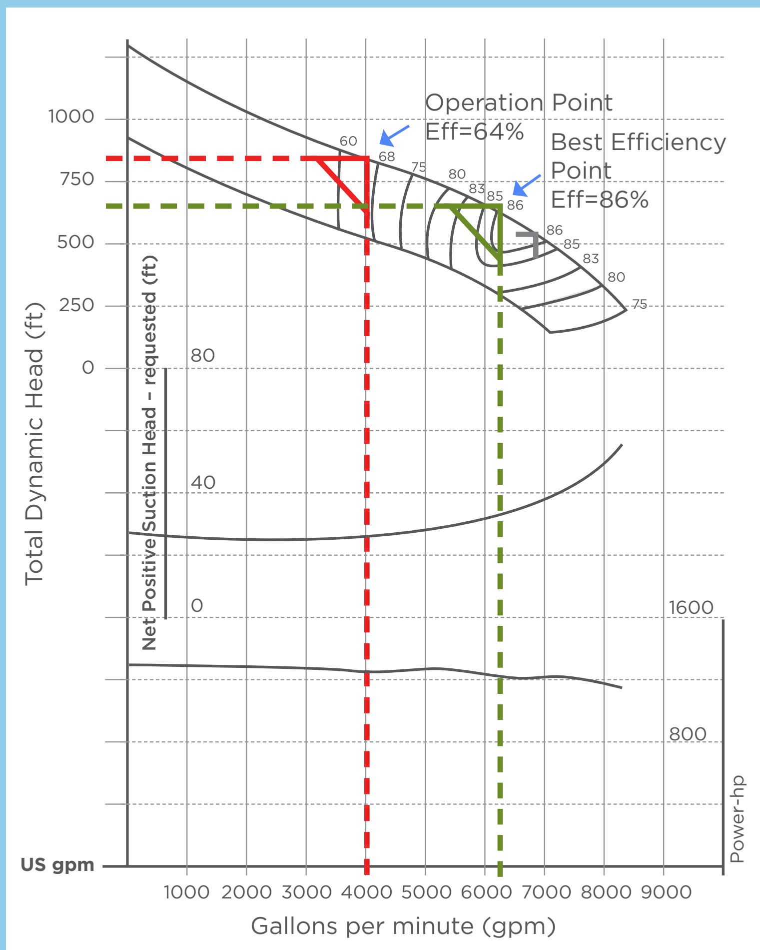
Best Efficiency Point

Each pump has a pump efficiency curve, which shows the pump efficiency at various flow conditions and defines the range of operating conditions for the pump. Pump efficiency curves are generated by the manufacturer and represent pump performance in new condition.

At a given flow and Total Dynamic Head (TDH), the pump will reach its Best Efficiency Point (BEP). At or near its BEP, a pump operates most cost-effectively in terms of both energy efficiency and maintenance. Therefore, selecting and operating a pump close to its BEP can result in significant operating cost savings (Dufresne and Ferrel 2016; Sustainability Victoria 2009).

An example of a pump operating outside of its BEP is shown in Figure 6. The graph represents a typical submersible pump curve of hydraulic head as a function of the flow.

Figure 10: Example of Efficiency Loss Due to Changes in Operating Conditions



Source: Own elaboration

Figure 10 shows that when operating a pump, up to more than a 10% deviation of its BEP can result in a drop of the pump efficiency by at least 22%.

The audit revealed that many pumps were working outside of their BEP. The number of pumps operating at a deviation of more than 10% of BEP during the audit is shown in Table 8.

Table 8: Number of Pumps Operating out of BEP

Division	# of equipment with over 10% deviation from design flow	# of equipment with over 10% deviation from design head
Division 1	6	9
Division 2 WCD/WBD	14	13
Division 3 EBD	8	7
Division 3 ECD	9	11
Division 3 Georgetown	15	14
Division 4 WBD	9	12
Division 5 (East Berbice)	13	17
Total	**74**	**83**

Source: Own elaboration

6.6.2 Power Factor Optimization

The power factor for each audited borehole submersible motor was also measured (for definition, see Box 2). Motors with a low power factor cause additional energy losses, thus increasing the total apparent power (kVA) values. This will in turn, generate additional charges to the utility when a kVA charge is in place.

The average values of motor power factor based on field measurements of all audited facilities by division are shown in Table 9.

Table 9: Average Power Factor Values Obtained from Motor Field Measurements

Division	Average Power Factor in Audited Facilities (%)
Division 1	72.2%
Division 2 WCD/WBD	78.4%
Division 3 EBD	80.8%
Division 3 ECD	78.8%
Division 3 Georgetown	75.7%
Division 4 WBD	79.3%
Division 5 (East Berbice)	74.6%
Total Average	**76.9%**

Source: Own elaboration

6.6.3 Total Head Losses

According to the measures, a total of eight percent of the total energy is lost due mainly to pressure losses in pipes. Head losses larger than seven percent can be considered significant.

6.7 Measures Proposed and Cost-Effectiveness Results

Based on the previous results, the main problems and energy-saving opportunities in audited borehole facilities are as follow:

- Pumping systems operating out of BEP
- Low electromechanical efficiencies
- Low power factor
- High head losses

Thus, for those facilities with low pump efficiency, the recommendation was to replace the pump. In those facilities where the power factor was low (<0.9) the recommendation was to install capacitor banks that could improve the power factor. In order to reduce head losses, it was recommended to replace the suctions and/or discharge pipes. Also, on those facilities where electric losses were significant, the recommendation also included the replacement of electrical conductors. In some cases, the results showed that the motor was working poorly due to significant voltage imbalance. In those cases, the recommendation was to work with the utility to reduce those imbalances.

6.7.1 Prioritization

A cost-benefit analysis was carried out in order to prioritize the measures to be implemented.

The simple cost-benefit analysis of the saving measures proposed was done by considering:

- **Direct savings -** The expected savings from replacing the pump and motor system and reducing energy losses. The amount of direct savings is obtained by multiplying the electricity saved by the cost of electricity[12]
- **Investment costs -** The total investment costs were estimated. The total costs included the removal of the existing pump and the installation costs associated with the new equipment.
- **Payback analysis -** The payback period refers to the period of time required to recover the initial investment.

The measures that were proposed were those that had a payback period of less than 2.6 years. A summary of the proposed measures is shown in Table 10.

12 The electricity cost used for the evaluation was GYD$64.00/kWh (US$0.31). In this analysis, the savings due to reduction of apparent demand (kVA) was not included. Nevertheless, this item should be considered in future assessments, since it represents a direct benefit of the project.

Table 10: Summary of Proposed Measures

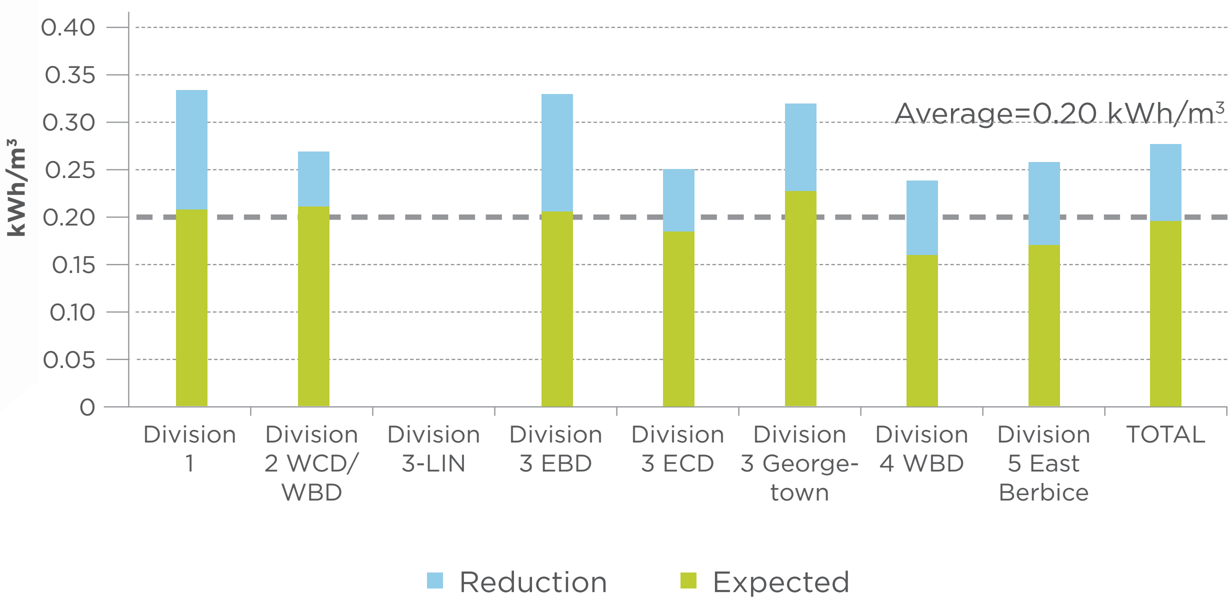
Division	Total Energy Cons. kWh/yr	Proposed Measures	Expected Saving kWh/year	Expected Saving $GYD	Estimated Investment $GYD	Pay-back (yr)	Energy Savings (%)
Division 1	1,562,895	2	100,562	6,435,967	3,447,237	0.54	6.4%
Division 2 WCD/WBD	5,484,336	10	652,057	41,731,661	22,884,708	0.55	11.9%
Division 3-LIN	982,143	-	-	-	-	-	-
Division 3 EBD	4,445,305	9	883,884	56,568,556	23,359,360	0.41	19.9%
Division 3 ECD	6,872,072	12	687,776	44,017,635	27,313,084	0.62	10.0%
Division 3 Georgetown	9,033,128	13	1,648,722	105,518,239	43,076,052	0.41	18.3%
Division 4 WBD	2,606,025	11	767,087	49,093,567	21,757,000	0.44	29.4%
Division 5 (East Berbice)	7,086,504	11	905,175	57,931,213	35,934,262	0.62	12.8%
Total	**38,072,408**	**68**	**5,645,263**	**361,296,836**	**177,771,703**	**0.49**	**14.8%**

Source: Own elaboration

The total investment required to implement all the measures proposed (replacement of motor-pump assemblies; installation of capacitor banks; replacement of cables; and changing the suction/discharge pipes) is close to US$900.000. This investment would produce savings of over US$1.5 million/year, with an estimated payback close to six months and savings equivalent to 15% of the total electricity consumed by GWI.

Consequently, the energy index would go from 0.26 kWh/m³ to 0.20 kWh/m³. The expected energy index (yellow bars) and the reduction of the index (in blue) per division are shown in Figure 11.

Figure 11: Energy Index - Before/After Proposed Measures



Source: Own elaboration

7. Implemented Energy Efficiency measures in Boreholes

Following the energy efficiency audit, 10 projects were chosen to be implemented. These pilot projects were mainly focused on improving the electromechanical efficiency at facilities; therefore, new motor-pump assemblies were selected for each facility based on optimum conditions. Out of the 10 pilot projects, six were financed by the IDB and four were financed directly by GWI.

7.1 Pilot Project Selection and Expected Results

The selected facilities and technical specifications of the new motor-pump assemblies are shown in Table 11. The rows in green are the measures financed by GWI.

Table 11: Pilot Project Facilities' Selected Technical Specifications

Div. /Name	Facility	Model	HP	Motor Eff.	Pump Eff.	EM Eff.	Flow (m^3/h)	Load (mwc)
Division 3 EBD	Caledonia	1100S600-2-AA	60	87.6%	70.5%	61.6%	213.8	50.7
Division 3 EBD	Kuru Kururu	475S300-3	30	84.3%	72.8%	61.0%	111.4	46.6
Division 3 Georgetown	Central	800S500-2-A	50	87.3%	73.8%	64.3%	175.6	51.3
Division 3 Georgetown	Agricola	1100S750-2A	75	88.1%	76.5%	65.7%	225.0	62.5
Division 2 WCD/WBD	Leonora	1100S600-2AA	60	87.6%	71.9%	62.9%	258.0	47.6
Division 2 WCD/WBD	Nouvelle Flanders	475S300 - 3	30	85.0%	74.7%	62.9%	101.9	53.2
Division 4 WBD	No. 7	800S500-2A	50	87.3%	55.3%	47.9%	228.6	24.6
Division 3 EBD	Eccles TP	In Stock GWI	75	86.0%	69.0%	60.0%	104.0	52.8
Division 4 WBD	Weldaad	Impeller change	75	87.0%	70.0%	60.5%	222.0	59.4
Division 3 EBD	Covent Garden TP	1100S750-2-A	75	88.1%	73.9%	63.8%	230.4	54.5

Source: Own elaboration

After the installation, GWI conducted field measurements to verify the operating conditions and energy savings in each facility (see Figure 12).

Figure 12: Field Measurements of Hydraulic and Electrical Parameters

Source: Own elaboration

With the field measurements of hydraulic and electrical parameters, and following the methodology from the energy efficiency audit, the implemented pilot projects were evaluated to calculate the final savings results and to document the increase of energy efficiency.

Table 12 shows a summary of the final savings results for the implemented pilot project facilities.

Table 12: Summary of Pilot Projects' Results

#	Name of Facility	Consumption (kWh/yr)		Energy Index (kWh/yr)		Eff. increase[13] %	Investment (GYD)	Total Savings[14] (GYD/yr)	Pay back (mths)
		Before	After	Before	After				
1	Caledonia Well	365,512	295,368	0.29	0.22	24%	$1,530,393	$4,419,050	4.2
2	Kuru Kururu Well	272,648	229,303	0.28	0.21	25%	$1,087,380	$3,157,684	4.1
3	Central Ruimveldt Well	588,241	390,321	0.38	0.25	34%	$1,433,530	$12,666,912	1.4
4	Agricola Well	466,265	393,364	0.37	0.28	24%	$1,952,040	$4,665,696	5.0
5	Lenora Well	554,928	419,666	0.26	0.22	15%	$1,952,040	$4,048,764	5.8
6	Nouvelle Flanders Well	250,481	225,694	0.28	0.23	18%	$1,310,375	$1,805,677	8.7
7	No. 7 Well	314,986	244,586	0.24	0.18	25%	$1,433,530	$4,505,569	3.8
8	Eccles WTP Well	583,442	436,425	0.28	0.22	21%	$1,952,040	$9,409,081	2.5
9	Weldaad Well	386,308	259,421	0.30	0.19	37%	$1,530,393	$8,120,728	2.3
10	Covent Garden WTP Well	549,955	392,385	0.34	0.21	38%	$1,952,040	$10,084,432	2.3
	TOTAL	**4,332,766**	**3,286,533**	**0.30**	**0.22**	**27%**	**$16,133,761**	**$62,883,593**	**3.1**

Source: Own elaboration

The consumption in implemented facilities represents about 11% of the global energy consumption of GWI. A 27% increase in energy efficiency was obtained. The total savings for these pilot projects were US$306,750/yr (62,883,593 GYD/yr), with a total investment of US$78,700 (16,133,761 GYD) and a payback period of only 3.1 months.

13 The gain in energy efficiency is calculated as a function of the energy index.
14 These savings and payback periods were calculated based on the energy consumption before and after implementation, without considering the new water output of the pumps. As such, they reflect real savings.

8. Overall Results and Lessons Learned

As mentioned initially, GWI expanded the energy efficiency program to other facilities, based on the positive results obtained during the pilot project phase.

The overall energy savings results obtained by GWI are shown in Table 13, and were calculated by combining all implemented projects' results, from both the pilot projects and GWI's own implemented projects.

Table 13 - Summary of Energy Efficiency Projects' Results as of 2016

Implemented	Pilot Projects (10)	GWI Implemented (24)	TOTAL
Cons. Before (kWh/yr)	4,332,766	6,206,526	10,539,292
Cons. After (kWh/yr)	3,286,533	5,150,387	8,436,920
Energy Index Before kWh/m^3	0.3	0.25	0.28
Energy Index After kWh/m^3	0.22	0.19	0.20
EE Increase % [15]	33%	24%	29%
Investment (GYD)	$16,133,761	$17,279,750	$33,413,511
Total Savings[16] (GYD/yr)	$62,883,593	$70,235,132	$133,118,725
Pay back (mths)	3.1	3.0	3.0

Source: Own elaboration

15 The gain in energy efficiency was calculated as a function of the energy index.
16 These savings and payback periods were calculated based on the energy consumption before and after implementation, without considering the new water output of the pump.

The overall projects implemented represented 25% of the energy consumption of GWI. It achieved an energy saving of approximately two million kWh and 2,000 tCO_2 emission reduction.[17] The average increase in energy efficiency was 29%, which represents a savings of 133,118,725 GYD per year (US$649,360), with a total investment of 33,413,511 GYD (US$ 162,990) and an average simple payback of three months.

Some of the lessons learned during the audit and implementation processes were:

- The accuracy of measurements is a key element to the successful selection and implementation of pump projects. Since these measurements are very specific, it is necessary that they be conducted by trained, specialized persons. Technical assistance during the process of assessment and definition of solutions was critical to ensure a successful implementation of the measurements.

- The availability of an established audit methodology was likewise a fundamental part of the project since it ensured comparability of results. The methodology developed and implemented during this project can now be replicated for future activities by GWI or other W&S utilities in the region.[18]

- As discussed, one main cause of pump inefficiency is an operation out of their BEP. In order to reduce this risk and to ensure that energy savings measures are consistent over time, it is essential to include as a regular task, a monitoring scheme that tracks regularly the equipment operation conditions and evaluates its performance.

- In order to carry out the measurement and monitoring activities, it is extremely important to train staff locally and to ensure resources for these tasks are available in the long run. In the case of this project, most of the staff was trained as electrical or civil engineers, with some of the staff also trained to act as energy champions.

17 Emission factor is 0.9483 tCO2/MWh, according to "Analysis of grid Emission factors for the electricity sector in Caribbean countries", UNEP, 2015

18 For more information on audits measurements, see https://publications.iadb.org/handle/11319/2814.

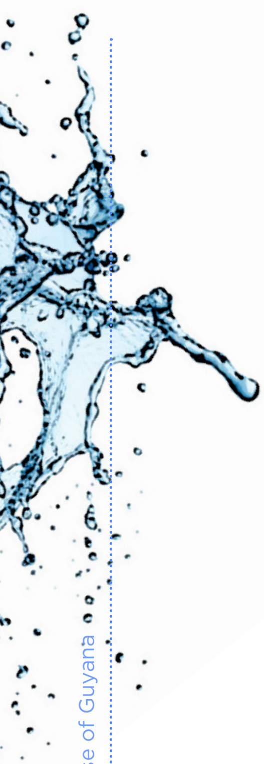
- There are opportunities for savings that go beyond the equipment efficiency itself, which need to be included in the technical and financial analysis. For example, although the introduction of capacitor banks will reduce energy losses, the main financial savings will be linked to the reduction of charges associated with apparent power consumed, which in turn will be directly linked to the conditions on which electricity is being supplied by the energy company.

- As seen in this pilot project, there are several measures that can be implemented in the short run that will bring direct energy and monetary benefits. However, energy efficiency measures should be considered as a pillar for improving the overall operational efficiency of the utilities. A holistic approach should consider the reduction of additional inefficiencies that can impact, in turn, on the efficiency and performance of electromechanical equipment such as pipe layout optimization or reduction of NRW. These activities, however, often require the commitment of more significant resources and involve longer periods of implementation.

- An important part of the process in this pilot project was the creation of an energy efficiency committee, responsible for coordinating and following up on the auditing activities, implemented measures, and assessment of results. This committee had specific responsibilities and reported to the chairman of GWI. This commitment of GWI allowed the project to be implemented successfully. This committee is now able to identify, implement, and monitor new projects on its own.

- Globally, the IDB project served as a capacity-building project for GWI, allowing the transfer of knowledge on energy efficiency auditing and project implementation methods.

9. Conclusion



Energy efficiency in the water sector is extremely important. Energy is a key input for water processes; therefore, it usually represents one of the most important costs of W&S utilities. On the other hand, water utilities consume a significant fraction of the energy generated countrywide.

In the case of Guyana, figures speak for themselves. With an annual electricity production of 690 GWh, GWI consumes almost six percent of the total electricity generation of the country. This represents for GWI a total cost of approximately US$12 million annually, or close to 60% of the overall operational costs.

Energy savings opportunities were detected through a detailed auditing process, during which more than 100 boreholes were assessed. As a result, identified energy savings opportunities involved mainly the replacement of motor-pump assemblies operating at low efficiency as compared to newly-available equipment.

In 2013, 10 pilot projects were implemented in boreholes with financial and technical support from the IDB. All the projects were profitable, with a payback period of less than a year. Following these good results, GWI continued in the years 2014 and 2015 with the replacement of 24 additional pumps, also with good results.

GWI also installed capacitor banks to reduce the electrical power factor and thus increase financial savings associated with the current electrical tariff structure. The overall average increase in energy efficiency was 29%, which represents a savings of 133,118,725 GYD per year (US$649,360), with a total investment of 33,413,511 GYD (US$163,000) and an average simple payback of three months.

In order to ensure long-term energy savings benefits, two key elements should be incorporated into similar programs. These are: (i) trained staff and resources should be allocated to monitor and evaluate operational conditions of the facilities frequently; and (ii) an energy efficiency committee should be created, which should report progress to the highest level possible in order to ensure long-term commitment with energy efficiency activities.

Increasing energy efficiency in W&S utilities is a win-win situation. As seen in this case, energy efficiency measures can help not only the water utilities to reduce its operational costs and improve its operational performance, but energy efficiency measures can also contribute to a better allocation of energy resources in a context of high prices and limited offers.

Additionally, significant reduction of greenhouse gases should also be considered as a direct benefit of this program, especially in countries, such as Caribbean nations, where electricity generation is primary fossil fuel-based.

The introduction of energy efficiency measures will improve the overall operational efficiency of the utility. However, in many cases these measures alone cannot resolve the operational challenges faced by W&S utilities. When aiming at operational efficiency, other activities should also be included in a long-term plan, such as the reduction of NRW levels and the assessment of the overall performance of the water companies (optimization of water/demand balance).

10. References

Arad, Arnon. "A Summary of the Artesian Coastal Basin of Guyana." *Journal of Hydrology 63,* no. 3-4 (1983): 299-313.

Bureau of Statistics. Guyana. Guyana Population and Housing Census 2012. Preliminary Report. 2012.

Central Housing & Planning Authority. https://chpa.gov.gy/. 2016.

Denig-Chakroff, David. "Reducing Electricity Used for Water Production: Questions State Commissions Should Ask Regulated Utilities." *Water Research and Policy*. National Regulatory Research Institute. 2008.

Dufresne, Laura and Ferrel, Lee. *Energy Management for Water Utilities.* American Water Works Association. 2016.

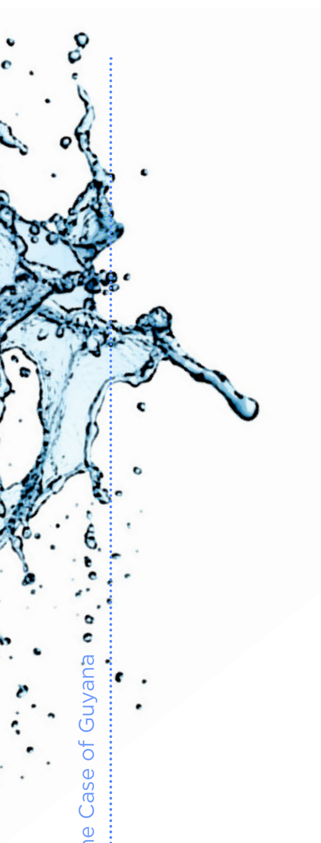
Inter-American Development Bank. (IDB). "Evaluation of Water Pumping Systems." *Energy Efficiency Assessment Manual, First Edition*. 2011.

----------------- (IDB). *Country Strategy with Guyana: 2012-2016.* 2012.

----------------- (IDB). Power Utility Upgrade Program. Proposal for a Loan and a Non-reimbursable Investment Financing. 2014a.

----------------- (IDB). "Water Supply and Sanitation Infrastructure Improvement Program. Technical Options and Design. April, 2014. Unpublished. 2014b.

----------------- (IDB). "Guyana. Water Supply and Sanitation Infrastructure Improvement Program. GY-L1040. Proposal for a Loan and a Non-Reimbursable Investment Financing." 2014c.



International Monetary Fund. (IMF). "2013 Article IV Consultation—Staff Report; Press Release." *IMF Country Report 14, no. 294. 2014.*

Electric Power Research Institute. (EPRI). "Water and Sustainability: U.S. Electricity Consumption for Water Supply & Treatment – the Next Half-century." 2002.

Ferro, Gustavo, and Lentini, Emilio. "Eficiencia Energética y Regulación Económica en los Servicios de Agua Potable y Alcantarillado." Serie Recursos Naturales e Infraestructura. 2015.

Frauendorfer, Rudolf, and Liemberger, Roland. *The Issues and Challenges of Reducing Non-Revenue Water.* Asian Development Bank. 2010.

Guyana Energy Agency. (GEA). *Strategic Plan 2014-2018.* 2014.

Guyana Power & Light, Inc. (GPL). *Annual Report*. 2012.

----------- GPL website. URL: http://www.gplinc.net/node/311. 2016a.

----------- GPL website. URL: http://www.gplinc.net/node/2398. 2016b.

Guyana Water Inc. (GWI). "Tariff Harmonisation Proposal." 2012.

----------- (GWI). "Internal Audit Report." Internal Audit Department. 2015.

Minnesota Rural Water Association. (MRWA). *Minnesota Water Works Operations Manual, 1994.*

Public Utilities Commission. (PUC). URL: http://www.puc.org.gy/. 2016.

Rosas, Ramón. "La Eficiencia Energética en Empresas de Agua y Saneamiento en Países de América Latina y el Caribe." Banco Interamericano de Desarrollo. Nota Técnica No. 328. 2011.

Sustainability Victoria. *Energy Efficiency Best Practice Guide Pumping Systems*. 2009.

United Nations World Water Assessment Programme (WWAP). *The United Nations World Water Development Report 2014: Water and Energy*, UNESCO. 2014.

Water Research Foundation. "Energy Efficiency Best Practices for North American Drinking Water Utilities." 2011

World Health Organization/UNICEF Joint Monitoring Programme (JMP), (WHO/UNICEF). http://www.wssinfo.org/data-estimates. 2016.

World Bank, no date. "Energy Efficiency Household Lighting Toolkit. Key Issues." http://wbi.worldbank.org/energy/Data/energy/files/Power%20factor_0.pdf

----------- "Using Performance Based Contracts to Reduce Non-Revenue Water." PPIAF. 2016

11. Abbreviations

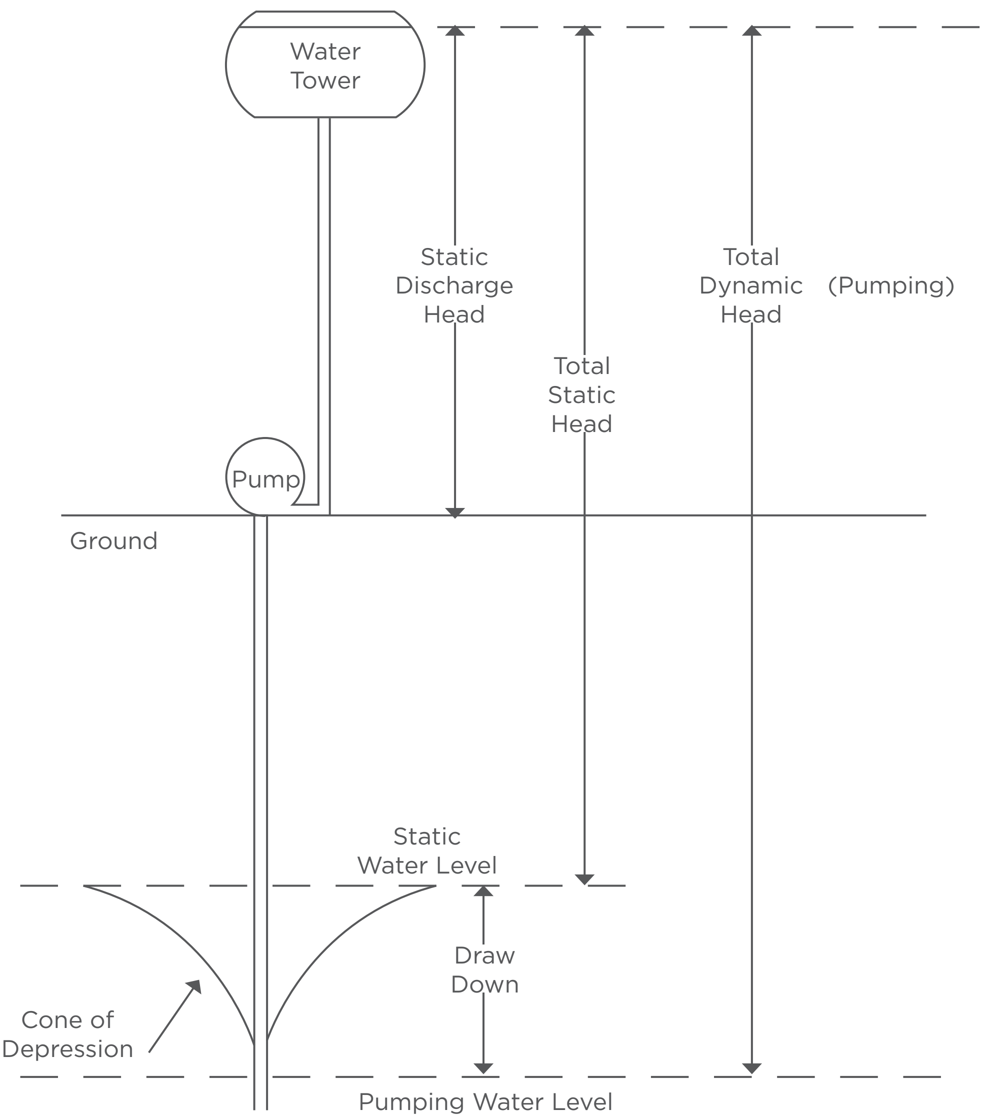
BEP	Best Efficiency Point
CH&PA	Central Housing & Planning Authority
¢US	US dollar cents
EPRI	Electric Power Research Institute
gpm	Gallons per minute
GEA	Guyana Energy Agency
GPL	Guyana Power & Light, Inc.
GWI	Guyana Water Incorporated
hp	Horsepower
IDB	Inter-American Development Bank
kVA	kilo volt ampere
kW	kilo-watt
kWh	kilo-watt hour
LAC	Latin America and the Caribbean
NPSHr	Net Positive Suction Head – requested
NRW	Non-Revenue Water
PUC	Public Utilities Commission
TDH	Total Dynamic Head
VSD	Variable Speed Drives
W&S	Water and Sanitation
WSS	Water Supply Systems
WTP	Water Treatment Plants

12. Glossary

Suction and discharge pipe losses: Energy losses caused by friction of the fluid in the suction and discharge pipes.

Total head losses: Total losses due to friction that occurs all along a pipe. It includes the losses due to valves and other fittings that are necessary to a piping system.

Total head or total dynamic head: The total height difference plus friction losses and demand pressure from nozzles, etc. Usually expressed in feet (ft) or meter (m).



Source: MRWA, 1994

IDB

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