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Energy Audit On Primary Municipal Facilities: Reflection of Municipality's Energy Consumption as a Direct Consumer of the Energy Utility (Eskom)

Melusi Nhleko and Professor Freddie L. Inambao*

Department of Mechanical Engineering, University of Kwazulu-Natal Durban South Africa.

ORCID: 0000-0001-9922-5434 (Freddie L. Inambao)

** Corresponding author*

Abstract

Due to excessive electricity bills as a result of Eskom's high tariff increases (higher than CPI) and South Africa's electricity supply crisis, institutions have begun to consider alternative short-to-medium strategies in an attempt to curb energy consumption and reduce energy bills. Wastewater and water treatment works are municipal facilities that are amongst the biggest energy consumers after industry. Municipalities, therefore, need to focus their efforts on how to save energy in their operations in order to reduce their environmental impact, improve resource efficiency, and avoid excessive electricity bills. Energy audits are a useful tool in this regard, leading to the implementation of effective strategies and installation of more energy efficient technologies. In this paper a municipal water scheme is used for the purpose of illustrating consumption and bills incurred by a category A or B or C municipality and the results of an energy audit exercise are discussed and recommendations presented to assist municipalities to reduce energy consumption and bills.

Keywords: Energy audit, energy utility, energy consumption, energy demand, energy bills.

I. INTRODUCTION

A water scheme is used to illustrate municipal consumption and energy management through providing in-depth understanding and details of energy demand, energy consumption, and corresponding charges and bills that keep these essential municipal plants operational to produce and supply potable water to communities. The focus of this paper is the expenditure by the municipality as a direct consumer of energy to keep its basic operations functional. In this paper municipal buildings are also incorporated as the head office expenses paid for by the municipality. Water plant(s) from abstraction to treatment works and subsequently to pumping (supply) plant are used as the basis for this paper. An energy audit was undertaken to observe operations and verify measurements on all sites mentioned above. Possible generic solutions are proposed to improve municipal energy consumption and reduce energy bills

II. METHODOLOGY

A. Background

Water and energy are inextricably linked and are both essential commodities at the very core of life [10]. Water is used to generate energy and energy to provide water [3]. Users are grappling with measures to transition from heavy dependence on fossil fuels so as to address global climate change by capping carbon emissions [3]

Global energy and water demands are increasing demand for more energy which drives demand for more water and vice versa; thus, a holistic understanding is necessary to model the adverse impact that industrial, agricultural and domestic water and energy uses have on the ecosystem [3]. The majority of water problems in South Africa are symptomatic of the gap between national policies on the supply of reliable and quality water by municipalities, and the support offered by national government institutions to municipalities to keep their infrastructure in an acceptable condition for good performance and efficiency [1]. Furthermore, the drive to achieve universal access to water and sanitation sets municipalities in a reactive mode of attending to breakages when they occur to keep the infrastructure operational at all times for basic services to be delivered. Thus, municipalities do not pay enough attention to infrastructure performances and the economy of providing such services [1], [2]. However, for suitable access to reliable supply and distribution of water, infrastructure must be effectively operated and maintained in order to obtain high performance and optimal reduction in energy bills [1].

Ashton [4] states that "we cannot simply walk away from problems and expect our descendants to bear the burden of solving them" and goes on to state that South Africa's future growth and development depends entirely on how water and energy resources are used and managed. Considering that these complex problems cannot be dealt with by a simple quick-fix one-size-fits-all solution, the prevailing conditions that result from the excessively burdened water and energy resources together with corresponding processes must be carefully evaluated and risk managed and a series of affordable solutions must be designed and effectively implemented [4]. It is clear that shortages of skills and funds to support efficient performance of municipal facilities reduces municipalities' ability to effectively and efficiently render affordable provision of services. This is compounded by the lack of implementation of advanced infrastructure performance and energy management and monitoring technologies.

Technological research is one of the four main branches of sustainability science which aims to reduce environmental harm [3]. Energy-related technologies with sensitivity to energy management and capacity to monitor high consuming municipal facilities can lead to efficient and economical provision of water and produce energy savings and a gain in efficiency yields [3]. Sustainability science is a systematic approach to innovation and learning that ensures ecological and social sustainability. This approach seeks to understand the relevant technological, sociological, ecological, economic, and institutional complexity and develop assessment frameworks and methods to assist decision- and policy-makers of energy and water technologies [3].

Because of the high energy consumption at municipal water and wastewater treatment facilities it is crucial to reduce energy consumption and possibly achieve energy independence at these facilities [5]. This paper reports on activities undertaken in an attempt to reflect the true energy management and bills of keeping a municipal water scheme, where the municipality itself consumes energy and pays for energy consumed to be able to deliver basic services to the community. Energy management in this case refers to management at the levels of abstraction of water at the weir, treatment of the same at the treatment plant, and pumping plants. This study involved an energy audit comprising: site screening and observation of operations and infrastructure condition, viewing of maintenance and operations records, analyzing of energy management (demand and consumption) records and energy bills, and proposal of generic recommendations that will assist the municipality in arresting high energy consumption and reduction of energy bills where possible. It was disappointing to notice that most energy saving initiatives in place were conducted in municipal buildings that have far less consumption levels than the above-mentioned plants.

Zhang and Wang [14] state that there are three effects to consider in the analysis of electricity consumption: economic activity effect, sector electricity share effect, and energy intensity effect. The authors further state that rapid growth in electricity consumption can lead to supply constraints and costly brownouts if uncontrolled, thus the driving forces governing energy consumption levels and their evolution must be investigated and managed or considered for possible risk mitigation. To mitigate this rapid energy growth, according to the authors, deconstructing the growth of electricity consumption into the possible affecting factors needs to occur.

The factors that influence electricity consumption in South Africa include the nature and pace of economic growth, the upward trend in real electricity prices, the evolution and adoption of more energy-efficient process and technologies, and supply-side surpluses or constraints [15]. Based on data compiled by the Department of Energy (DoE) on South Africa’s national energy balances, [15] reflects that households in South Africa are responsible for 20 % of total electricity consumption while government services institutions servicing commercial sectors in aggregate are responsible for a further 15%. In a nutshell, municipalities have an energy consumption of 35% part of which is directed at supplying households and commercial institutions and the other at providing basic commodities (water supply and sewer discharge) to communities. [15] defines electricity intensity as the amount of electricity consumed (e.g. in kWh) to produce a given unit of output (e.g. GDP in South African Rands). The South African economy has gradually transitioned away from its historical dependence on relatively energy-intensive economic or sector activities such as mining and manufacturing to a more diverse and increasingly services-related range of activities which accounted for just over two thirds (67 %) of the GDP in 2015 [15]. [15] indicates that the energy intensity of the country has declined significantly together with the decline of the primary and secondary sectors (mainly mining manufacturing and construction) that once accounted for almost half of GDP (45 %), but today contributes just under a third of GDP (30 %).

Municipal water and wastewater plants contribute on average of between 30 % to 40 % of the total energy consumed by a municipality [5]. The primary purpose of energy auditing is to postulate interventions that improve the energy footprint of municipal facilities. This paper thus reflects a scenario of two consecutive years of general energy profile of municipal water facilities. Detailed energy analysis was conducted and the overall energy consumption of the municipal water scheme was reviewed. Consumption and demand of the municipal buildings referred to as ‘head office’ was included as part of the direct energy consumptions payable by the municipality to administer delivery of services from the same water scheme. In a nutshell, in order to satisfy the objects of this paper, only the municipal energy consumption directly paid for by the municipality from the selected water scheme was examined. Energy supplied and/or distributed by the municipality and paid for by municipal clients did not form part of the aim of this paper.

A study report conducted by van Zyl et al. for the Council for Science and industrial Research (CSIR) [7] found that the majority of challenges faced in water and energy security of supply, especially at municipal and water boards (government water supply agents) level, are mainly energy performance of plants delivery capacity of infrastructure based on infrastructure integrity and the energy usage index. A CSIR report [9] on the state of municipal infrastructure in South Africa and its operation and maintenance further indicated that many municipalities have highly inadequate or no records of any formal broad-based audits or information of municipal infrastructure performances. The report by [9] indicates that there is no care of infrastructure integrity and energy management by municipal personnel which can be seen from the lack of interest displayed by personnel during site-visitations. This ad hoc and inadequate information on infrastructure performance means there is a lack of performance trends regarding municipal infrastructure and the state of infrastructure from the point of view of maintenance. The CSIR report [9] indicates that the current municipal records on infrastructure performance and condition in many municipalities in South Africa are very poor. In addition, there is a lack of capacity (skills and finances) to support effective maintenance of state infrastructure [1].

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According to [15], there are several factors that influence the demand for electricity, including: the price of electricity growth in relation to the level of economic production or output, population growth, climate vulnerability and weather patterns, and technological change. The dynamics and influences of these factors on energy demand are not discussed in this paper as the focus is on reflecting energy expenditure incurred by municipalities based on assessment of water and wastewater plants and uMhlathuze municipality plants as a basis and making recommendation regarding what can be done to reduce energy related expenditures at uMhlathuze municipality and other municipalities in South Africa in the same or higher category.

According to the uMhlathuze municipality's annual report of 2018/2019 [8] the municipality as a customer of the energy utility (Eskom) and directly consumes and distributes or supplies energy received from Eskom, the total energy required for the municipality to be able to perform both of its functions was as follows in terms of energy demand: municipal customers consumed a total of 978 GWh (a decrease of 12 GWh from the 2017/2018 financial year of 990 GWh of electricity). The 1040 GWh that was purchased from Eskom in the 2018/2019 financial year was less than the 1054 GWh purchased in the 2017/2018 financial year, a 14 GWh decrease. The report further accounts for total losses indicating that the total energy loss made up of both technical and non-technical losses amounted to 63 GWh, an average loss of 6% over the 2018/2019 financial year. In addition, although the energy consumption profile of the municipality is the focus in this study, it is important to compare the energy ordered from Eskom and the notified maximum demand (NMD), which is the actual demand from month to month. The municipality's provision of electricity for its total NMD to the various areas (without taking into account new household or industrial connections) is as follows:

- Richards Bay 151 MVA a decrease from 230 MVA due to Richards Bay Alloys reducing its operations due to financial constraints on account of among other things, the depressed state of the South African economy;
- Empangeni Main 20 MVA: Maximum (11 MVA);
- Empangeni Western 20 MVA: Maximum (20 MVA);
- Felixton 0.7 MVA: Maximum (0.5 MVA);
- Vulindlela 1 MVA: Maximum (0.86 MVA);
- Esikhaleni 16 MVA: Maximum (19 MVA of which 11 MVA is Eskom load);
- Nseleni 2.7 MVA: Maximum (2.65 MVA); and
- Ngwelezane 7 MVA: Maximum (6.43 MVA).

On account of the above information and the objectives of this paper, a baseline energy consumption analysis was established based on visits (assessments) and measurements conducted at the various plants of a water scheme. The energy consumption exercise was conducted as follows:

- A synoptic visual assessment of the conditions of the infrastructure to factor in or account for any infrastructure condition or influence to energy consumption and wastage.
- Installation of a power meter to take a 24-hr recording of all power parameters at the various plants of the water scheme.
- Review of electricity consumption and power quality data.
- Review of energy bills for the various plants of the water scheme that the municipality manages and pays for directly in order to provide service delivery.
- Compare results with best practices and establish how to improve each plant performance and/or the energy efficiency of each plant.

For the verification process the detailed operation of each plant was ascertained and the audit process comprised the following steps:

- Confirmation of the induction motor data of each pump from the motor label/tag.
- Review of other electricity consuming components of each of the municipal facilities.
- Inspection of the motor control centres (MCCs) and switchgear.
- Installation of power measurement recorder.
- Tabulation and analysis of results obtained then comparison of these results with energy bills and discussion of energy readings and/or measurements and energy efficiency (energy output or performance) based on energy bills and recordings obtained.

In view of the conventional method of operation of the municipal facilities and the type of technology installed at each of the plants, the instrument used for independent on-site measurement of consumption was the A-EBERLE PQ BOX 100 (Fig. 1) which was used to take a 24-hour recording of the consumption at each of the plants. The instrument defined by SANS 474 [11] as a watt-hour meter is an instrument used to measure active energy by integrating active power with respect to time.

Fig. 1. A-EBERLE PQ BOX 100 used for the power audit

Before proceeding to the numbers relating to energy usage at the municipal facilities, it is important at this stage to reflect on the make-up of a utility in order to provide a perspective on energy related charges.

Generally speaking, the main utility bill consists of the following charges as per electricity pricing definitions by Eskom:

- Administration Charge. That is a standard fixed rate charge that is levied to all energy consumers. This charge is levied to cover the cost of administration of consumers' accounts irrespective of whether electricity is consumed or not. Services charged for under administrative charges are services such as meter reading, billing, and meter capital.
- Network Capacity Charge. This charge is levied to all consumers for the electrical infrastructure over which reserved energy from the utility is transported from source to the consumption point. That is the network capacity costs of providing the required energy. Associated costs include capital costs, operations costs, maintenance and refurbishment costs.
- Network Demand Charge. This is a variable monthly charge that is based on the actual demand measured in all peak and standard periods. That is the actual energy demand incurred in that particular month.
- Ancillary Service Charge. This is also known as reliability charge that is concerned with providing the right services for energy supply. This charge is allocated for services such as frequency control, voltage control, generation, standby plant emergency reserves, and black-start capability generation.
- Standard energy consumption charge. This charge regards to the active energy in kWh used by customers during a specific period in peak off-peak and standard times. In other words, this charge depends on the season when energy is consumed.
  - ✓ High Season Energy Charge. This charge is levied during the winter and spring seasons. The charge varies with times of consumption as follows:
    - ➢ Energy charges during peak times;
    - ➢ Energy charges during standard times; and
    - ➢ Energy charges during off-peak times.
  - ✓ Low Season Energy Charge. This charge is levied during the summer and autumn seasons. The charge varies with times of consumption as follows:
    - ➢ Energy charges during peak times;
    - ➢ Energy charges during standard times; and
    - ➢ Energy charges during off-peak times.
- Energy Demand Charge. This charge is seasonally differentiated and is based on chargeable demand registered during the month in order to recover peak energy costs. Energy demand is normally measured in kVA.
- Service Charge. This charge is levied to all consumers; it is a compulsory fixed charge payable per account to recover service-related costs.

The consumption details of the Eskom energy bills are as follows:

- Energy consumption measured in kWh. This charge pertains to energy consumption and is the charge levied regarding active energy consumed by a customer during a specific period on a month to month basis. This charge comprises the following:
  - ✓ Baseline. This is the minimum considered charge levied to all customer accounts whether electricity has been consumed or not;
  - ✓ Energy consumption charge for energy consumed during peak times;
  - ✓ Energy consumption charge for energy consumed during standard times; and
  - ✓ Energy consumption charge for energy consumed during off-peak times.
- Demand reading which relates to the reading of electricity meters for the average value of power that must be planned for and allocated over a specified interval of time such as on a monthly basis.
- Reactive energy charge is basically a charge based on the amount of reactive energy used and this charge consists of the following:
  - ✓ Baseline charge. This is a flat rate that is charged independent of when the electricity is consumed;
  - ✓ Peak charge;
  - ✓ Standard charge; and
  - ✓ Off-peak charge.
- Load factor. This is a ratio that reflects the potential use of supply capacity based on maximum demand. This ratio is of the average load (actual energy consumed) over a given period to the maximum demand (peak load) occurring at that time, or the energy that could have been consumed had the demand remained at the maximum for a period. It measures the efficiency of electricity usage. If the load factor is high this means that the system uses energy efficiently and that there is no underutilisation of energy.

Thus, the average price for electricity is based on the overall cost of supply. The common cost drivers of energy supply are: administration costs (Rands/customer/month), network costs (Rands/kVA or Rands/kW), energy costs (cost/kWh), reactive energy costs (cost/kvarh), and energy loss costs that take into account all supply and transmission factors that contribute to energy loss [13]. The cost of providing electricity to customers according to [13] varies according to the quantity of electricity used, the period (time or season) when the electricity is used, the size or capacity of the supply required, the geographic location of the customer, the voltage at which supply is provided, the cost of connecting the supply, and the density of the points of delivery where the customer's supply is located. [13] comments that the effective management of electricity

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bills saves money through effectively managing energy consumption.

[13] states that electricity is billed as a charge per kilowatt hour (kWh) and describes and distinguishes measurement units of energy consumption and demand, stating that energy consumption measured in kilowatt-hour (kWh) is the total energy that is transmitted or used at a constant rate (power) over a period of time. It is the electrical power in kilowatts multiplied by the time in hours, electrical power (kW) being the energy per unit time or energy rate at which electrical energy is transmitted. The authorized maximum energy demand measured in kVA is defined by [11] as maximum load that the customer is authorized by the licensee to take from that point of supply (POS). The above indicated fixed costs cannot be redirected or avoided as these costs are related to the utility (Eskom) for costs related to generating electricity. Changes in consumption and periods (seasons) and duration of consumption (peak or off-peak or standard), and adopting and incorporating energy saving methods and devices are variables that can be manipulated for optimal energy usage.

Basic energy usage according to [13] is the actual energy consumed. The real time electricity usage index is the performance measurement of a plant whereby the throughput of a plant is measured versus electricity consumption of the same [13]. Another way of putting it is to say that the measurement of energy utilisation index or use index is the amount of energy consumed to produce a desired output or condition [10]. The electricity usage index reflects the energy efficiency of a plant and acts as a tool that aids the monitoring of energy performance. [18] comments that any installation of a power consumption monitoring tool in each individual inductive device such as motors have significant positive impacts on energy savings in the long run. [20] states that energy efficiency must be viewed as an energy resource that can reduce the need for new energy supplies and infrastructure as energy efficiency is also viewed as a major element that enables the reduction of emissions of carbon dioxide emissions and attendant global climate change. Thus, the initial energy audit exercise related to this study was conducted to determine suitable recommendations that not only focus on assisting with energy saving but also with monitoring the energy usage trend of each municipal primary plant.

B. *Measurements and Results*

The measurements obtained using the A-EBERLE PQ BOX100 and records of readings taken from the flow meters and data-loggers at each of the respective municipal facilities are shown in Table I.

TABLE I. 24-HR RECORDINGS AT EACH PLANT OF KNOWN THROUGHPUT THAT REFLECT THE ENERGY CONSUMPTION AND CORRESPONDING COMPUTED ELECTRICITY USAGE INDEX (PERFORMANCE)

No	Municipal facilities	Throughput (kl/day)	Duration of recording (hrs)	Measured - kWhrs consumed	kWhrs consumed/day	Electricity usage index (Performance) kl/kWhrs
1	Abstraction at weir (capacity)	225 000	-	Not applicable	-	-
	Abstraction at weir (actual)	≈42 000	23.15	1 658.50	38 394.28	1.09
2	Water treatment plant (capacity)	180 000	-	Not applicable	-	-
	Water treatment plant (actual)	38 000	23.3	1 589.75	37 041.10	1.03
3	Pump station (capacity)	180 000		Not applicable		
	Pump station (actual)	3 8000	22.75	1 698.50	38 640.88	0.98
4	Municipal building	-	24	125.64	3 015.35	-

Regarding the interpretation of the above table: when considering performance, the higher the performance (kl/kWhr) the more efficient the specific plant is. From the above table it is evident that the pump station is the least efficient plant when compared with the other two plants.

It is important to note that measurements are based on the actual flows (actual demand for portable water) and not the design capacity of each of the municipal facilities as indicated in Table I. Thus, the measurements in that table reflect the actual consumption for that particular day. Attention is drawn to the fact that the water system reflected in the table relates to the supply of potable water (drinking water) and excludes the supply of both clarified water and raw water. For clarity, clarified water is water that is mainly supplied to industries. This type of water does not undergo such stringent treatment processes as potable water. Raw water is chemically untreated water that has undergone physical treatment such as screening to remove solid debris. Raw water is generally supplied to customers whose operations are not sensitive to water quality such as the agricultural and mining sectors.

Although the power audit exercise was conducted using the A-EBERLE PQ BOX100 instrument, it is notable that electricity consumption (kWhr) meters (STRIKE TECHNOLOGIES' ENERMAX meters) are used by the municipality to measure consumption of each primary municipal facility or plant. The ENERMAX meters are wirelessly connected to a central site and readings obtained from the SCADA system.

In order to obtain a holistic view of energy usage the key component factors required to conduct a holistic analysis of the municipality's monthly energy management include energy demand, energy consumption, and energy bills. Table II illustrates the key components considered for the monthly billing of these facilities. Readings for the month of March 2020 (a 31-day period) are reflected in Table II.

TABLE II. THE THROUGHPUT ENERGY DEMAND, ENERGY CONSUMPTION, AND CORRESPONDING ENERGY BILLS FOR EACH OF THE RESPECTIVE MUNICIPAL FACILITIES

No	Municipal facilities	Design capacity: throughput (kl/day)	Monthly energy demand: kVA/month	Monthly consumed energy: KWhrs/month	Total cost (R)
1	Water treatment plant (actual)	65 000	2 762.50	1 216 560	1 142 083.00
2	Pump station (actual)	70 000	1 938.40	1 362 808	1 479 454.00
3	Weir (abstraction)	85 000	2 427.85	1 142 585	1 234 596.80
4	Municipal building	Gravity feed from 60 Ml reservoirs	349.50	97 210	256 787.50

The throughput values were obtained from the SCADA system and verified using onsite records obtained from data-loggers together with respective pressure readings. Thus, average daily throughput or pump rates are averages of the actual flow rates or typical flow rates.

It is important to note that each plant's performance measure is specific to that plant and although some comparison can be made between similar plants the objective is for each plant to measure itself with a view to improving itself.

A two-year data cycle is collected to reflect the relative demand consumption and bills of the municipal facilities. This is conducted to indicate the general efficiencies of the plants and assess whether there are any abrupt changes in efficiencies and also in order to enable the prescription of solutions that can improve consumption and reduce energy bills. The data in Table III and Table IV and Fig. 1 reflect consumption and together with on-site observations reveal any possible contributing factors to high energy consumptions (low efficiencies) and/or energy wastages.

TABLE III. AVERAGE ENERGY DEMAND PER ANNUM OF EACH MUNICIPAL FACILITY (WEIR, WATER TREATMENT PLANT [WTP], PUMP STATION AND MUNICIPAL BUILDING HEAD OFFICE])

Description	WTP	Pump station	Weir	Head Office
2019/20 Annual demand	32 730.81	24 091.21	28 609.87	3 565.25
2018/19 Annual Demand	30 687.39	24 181.03	23 226.93	3 067.30
Energy Demand Increase	6.24 %	-0.37 %	18.81 %	13.97 %

TABLE IV. MONTHLY ENERGY DEMAND FOR EACH MUNICIPAL FACILITY

MONTHS	kVA	kVA	kVA	kVA
	WTP	**Pump station**	**Weir**	**Head Office**
Jan-18	1 949.58	1 983.00	1 658.47	235.20
Feb-18	2 259.00	2 013.00	1 736.89	215.00
Mar-18	1 909.00	2 018.00	1 645.20	312.14
Apr-18	2 124.00	2 025.00	1 615.42	321.94
May-18	2 416.00	2 003.00	1 567.04	292.06
Jun-18	2 808.50	1 979.70	1 699.32	223.65

MONTHS	kVA	kVA	kVA	kVA
	WTP	Pump station	Weir	Head Office
Jul-18	2 656.00	1 997.00	1 671.98	215.22
Aug-18	3 409.00	2 039.00	2 236.66	203.37
Sep-18	2 845.62	2 043.51	2 328.08	231.48
Oct-18	2 958.66	2 038.12	2 414.26	276.12
Nov-18	2 473.74	2 020.85	2 280.16	250.96
Dec-18	2 878.29	2 020.85	2 373.45	290.16
Jan-19	2 832.70	2 020.94	2 373.46	309.55
Feb-19	2 937.64	2 064.22	2 411.86	340.55
Mar-19	2 703.54	2 022.08	2 242.45	344.22
Apr-19	2 638.21	2 037.95	2 424.71	316.01
May-19	2 859.64	2 033.23	2 378.94	270.65
Jun-19	2 915.52	1 978.89	2 354.05	238.28
Jul-19	2 626.26	2 033.15	2 262.06	226.08
Aug-19	2 582.14	1 935.97	2 580.50	266.91
Sep-19	2 807.68	2 004.58	2 343.37	282.94
Oct-19	2 480.55	2 014.35	2 414.56	306.35
Nov-19	2 382.93	1 950.52	2 409.11	322.97
Dec-19	2 964.00	1 995.33	2 414.80	340.74

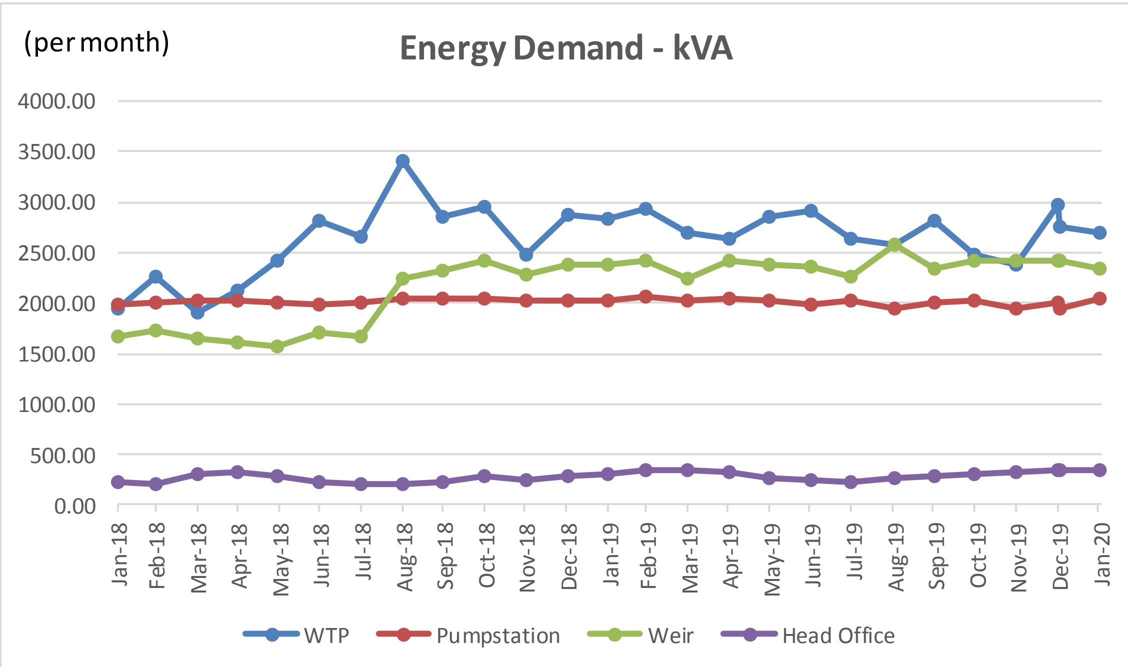

Fig. 2. Energy demand per month of each municipal facility for a two year period

The above tables and corresponding figure show that the municipal facilities responsible for high energy demand are the plants responsible for abstraction of raw water treatment of water, and distribution plants. The municipal head office is the lowest with almost insignificant demand.

The municipality is responsible for both consumption and supply (and/or distribution) of energy but for the purposes of this paper the aspect of the municipal function is the municipality itself consuming energy and paying for the energy used. The municipality supplying or distributing energy to citizens and industries is considered as outside the scope of this paper as the bills are not paid for by the municipality but by the municipal clients.

The average demand for the plants as indicated in Fig. 1 indicate that the demand by the pump station plant together with that of the weir are relatively constant, whereas that of the treatment plant varies. The variations in energy demand has little to do with water demand but the treatment process of raw water depends on environmental factors such as high turbidity due to recorded rainfalls seasons and etcetera. The average annual energy demand reflects a 9.66 % increase within the two financial years.

In order to illustrate the amount of energy usage by the municipality in keeping its facilities operational, monthly energy demand and energy consumption measurements are reflected in the tables and figures below to reflect the amount of energy the municipal facilities consume at their condition in providing portable water. Monthly energy bills are also indicated to reflect the exorbitant amount of bills payable by the municipality to ESKOM for this water scheme.

The municipality has 3 relatively sized water schemes and the below tables assist in estimating the relative amount of bills for the water schemes, excluding the amounts paid for 5 wastewater treatment plants, 2 macerators and 68 pump stations of which 5 are main sewage discharge pump stations.

The below table is the monthly energy consumption by the water scheme reflecting the amount of energy required from ESKOM by the municipality.

TABLE V. MONTHLY ENERGY CONSUMPTION RECORDINGS OF EACH MUNICIPAL FACILITY. KWHR READINGS ARE AN ACCURATE RECORDING OF THE CONSUMPTION (WEIR, WATER TREATMENT PLANT [WTP], PUMP STATION, MUNICIPAL BUILDING [HEAD OFFICE])

MONTHS	kWh	kWh	kWh	kWh
	WTP	Pump station	Weir	Head Office
Jan-18	956 588.00	1 338 000.00	649 279.00	157 711.00
Feb-18	1 064 923.00	1 415 052.00	629 942.26	82 172.00
Mar-18	922 669.00	1 048 990.00	721 779.21	88 616.00
Apr-18	1 022 701.00	1 395 830.00	816 899.85	82 653.00
May-18	1 129 635.00	1 380 705.00	647 804.83	1 348.00
Jun-18	1 247 737.68	1 377 015.00	821 306.00	69 197.00
Jul-18	1 227 842.00	1 270 442.00	703 102.00	61 135.00
Aug-18	1 529 499.00	1 301 646.00	1 160 069.00	64 684.00
Sep-18	1 420 637.62	1 451 345.51	1 162 650.59	66 986.48
Oct-18	1 346 877.00	1 381 614.00	1 412 534.00	67 634.00
Nov-18	1 365 574.00	1 282 417.00	1 033 575.00	68 881.00
Dec-18	1 305 039.00	1 292 500.00	1 285 265.90	71 129.00
Jan-19	1 429 817.00	1 430 597.00	1 413 911.00	85 305.00
Feb-19	1 479 475.00	1 355 058.00	1 193 425.00	91 525.00
Mar-19	1 265 401.00	1 265 354.00	1 337 133.38	82 670.00
Apr-19	1 290 926.00	1 359 651.00	1 275 158.93	96 696.00
May-19	1 350 997.00	1 386 976.00	1 370 220.13	73 466.00
Jun-19	1 364 346.00	1 352 333.00	1 30 0940.95	42 734.00
Jul-19	1 253 310.00	1 064 779.00	1 295 103.10	69 441.00
Aug-19	1 226 521.00	1 191 869.00	1 215 968.96	71 865.00
Sep-19	1 161 646.00	1 289 567.00	1 326 399.20	72 030.00
Oct-19	1 237 978.00	1 362 324.00	1 23 4310.04	83 300.00
Nov-19	1 158 970.00	776 178.00	1 210 456.03	76 809.00
Dec-19	1 266 410.00	1 331 782.00	1 195 126.82	95 994.00

TABLE VI. AVERAGE ENERGY CONSUMPTION PER ANNUM OF EACH MUNICIPAL FACILITY (WEIR, WATER TREATMENT PLANT [WTP], PUMP STATION, MUNICIPAL BUILDING [HEAD OFFICE])

	WTP	Pump station	Weir	Head office
2019/20 annual consumption	15 485 797	15 166 468	15 368 153.54	941 835
2018/19 annual consumption	14 539 722.3	15 935 556.51	11 044 207.64	882 146.48
Energy consumption increase	6.11 %	-5.07 %	28.14 %	6.34 %

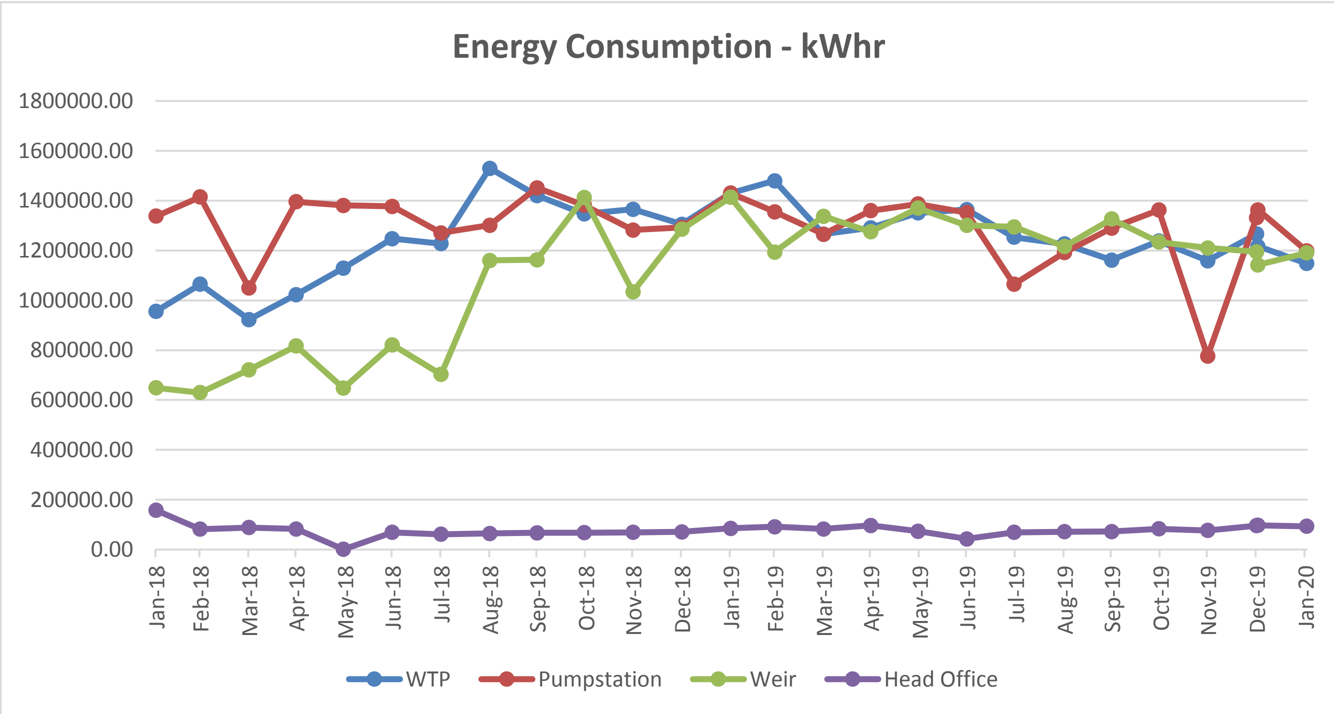

Fig. 3. Energy consumption per month of each municipal facility for a two year period

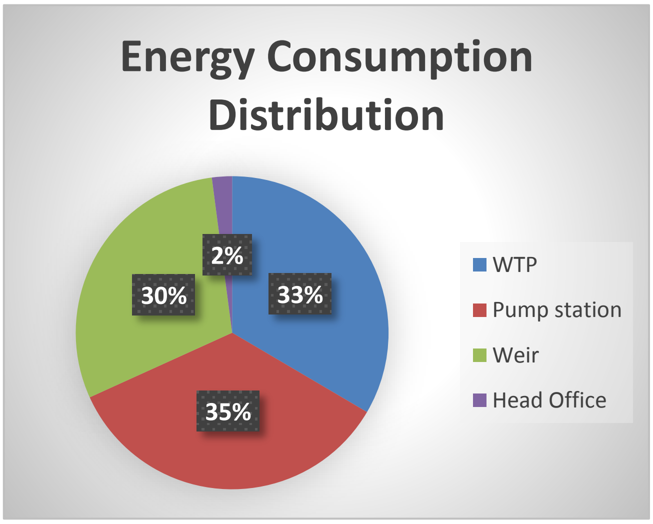

Fig. 4. Monthly energy consumption distribution of each of the municipal facilities

From Fig. 3 and Fig. 4 it is evident that the municipal head office is the lowest almost insignificant contributor to energy consumption compared to the other municipal facilities, accounting for only 2 % of consumption. These figures also reflect that the highest municipal energy consuming plants are the weir treatment plant and the pump station plants recording an annual average energy consumption of slightly above 15 million kWhr. The total energy consumption of the three plants is slightly above 46 million kWhr. This reflects how much electricity the municipality consumes in order to provide services to citizens (residential), commercial and industrial institutions. The energy consumption of the weir in the 2018/2019 financial year accounts for the period where there were low water levels at the river and the pumps had to be stopped for longer periods. The average annual municipal energy consumption reflects an 8.88% increase from the 2018/2019 financial year to the 2019/2020 financial year. The plants used by the municipality to provide basic services have almost the same percentage consumption indicating equal importance of these plants. The municipal head office is the lowest energy consumer.

When considering the energy consumption profiles of category A, category B, and category C municipalities as spelled out in section 155 of the Constitution of the Republic of South Africa (RSA) [21] and the Municipal Structures Act 117 of 1998, [22] the energy consumption distribution of most of these municipalities follow a similar pattern to the above reflected energy consumption profile. The CSIR [9] report on condition assessments of water and wastewater plants across South Africa the report indicates that most municipal facilities' treatment plants together with pump stations are in poor conditions receiving little or no maintenance attention. What was observed in this municipal plant under study is that the plants are at average to poor condition with some components missing in some of the equipment. In terms of technology, most municipal plants have not undergone technological upgrades or been installed with the latest technology that is energy management sensitive. When viewing the municipality's capital project(s) plan it was of concern to see that there is no sight or hint of any future upgrade or installation of the latest energy management technology that would arrest energy wastage and improve energy consumption. In other words, most municipalities in South Africa, like the one under study, conduct energy audits and implement energy conservation or saving strategies on municipal buildings but pay less attention to or no attention at all to municipal facilities that have high energy consumption.

Table VII and Table VIII and Fig. 4 reflect the energy bills that the municipality incurs on a month-to-month basis and corresponding annual bills for the two year period.

TABLE VII. MONTHLY ENERGY BILLS FOR EACH MUNICIPAL FACILITY FOR ENERGY CONSUMED (WEIR, WATER TREATMENT PLANT [WTP], PUMP STATION, MUNICIPAL BUILDING [HEAD OFFICE]) (SOUTH AFRICAN RAND).

Month	Energy Costs	Energy Costs	Energy Costs	Energy Costs
	WTP	Pump Station	Weir	Head Office
Jan-18	R751 279.00	R1 177 815.00	R610 967.55	R226 338.00
Feb-18	R852 409.00	R1 199 227.80	R605 919.15	R184 940.00
Mar-18	R742 444.00	R1 032 903.00	R655 612.65	R185 293.00
Apr-18	R806 319.00	R1 19 5634.00	R766 672.97	R18 361.00
May-18	R885 040.00	R1 203 034.00	R648 790.95	R216 127.96
Jun-18	R995 559.00	R1 172 499.00	R1 056 497.10	R15 6388.00
Jul-18	R1 399 699.00	R1 609 518.00	R962 467.05	R171 024.00
Aug-18	R2 024 915.00	R1 862 374.00	R1 456 783.15	R183 411.00
Sep-18	R1 743 963.17	R1 92 3780.46	R1 097 350.45	R186 918.72
Oct-18	R1 094 656.00	R1 278 899.00	R1 265 123.75	R200 878.00
Nov-18	R1 100 297.08	R1 252 537.95	R989 771.70	R178 679.11
Dec-18	R1 042 700.12	R1 249 658.00	R1 175 348.95	R182 920.88
Jan-19	R1 125 648.80	R1 337 635.00	R1 260 863.60	R194 546.00
Feb-19	R1 173 757.00	R1 290 269.00	R1 119 688.70	R203 895.00
Mar-19	R1 026 077.00	R1 232 165.00	R1 194 907.40	R199 939.00
Apr-19	R1 041 679.00	R1 304 337.00	R1 324 094.30	R202 611.00
May-19	R1 069 364.00	R1 305 380.00	R1 394 901.55	R180 429.00
Jun-19	R1 092 938.00	R1 294 755.64	R1 791 784.55	R157 560.96
Jul-19	R1 836 221.00	R1 845 373.00	R1 774 574.45	R214 123.00
Aug-19	R1 736 253.53	R1 944 378.91	R1 341 051.90	R224 192.03
Sep-19	R1 130 913.00	R1 461 758.00	R1 352 299.95	R207 779.00
Oct-19	R1 182 556.00	R1 523 875.00	R1 289 673.90	R233 350.00
Nov-19	R1 182 555.27	R1 523 874.96	R1 284 064.10	R233 349.82
Dec-19	R1 198 403.00	R1 500 438.00	R1 272 449.45	R255192.00

TABLE VIII. AVERAGE ENERGY CONSUMPTION PER ANNUM OF EACH MUNICIPAL FACILITY (WEIR, WATER TREATMENT PLANT [WTP], PUMP STATION, MUNICIPAL BUILDING [HEAD OFFICE])

Description	WTP	Pump station	Weir	Head office
2018/19 Average monthly Costs	13 439 280.37	16 157 880.21	11 291 305.42	2 091 279.67
Total 2018/19 Annual Costs				42 979 745.67
2019/20 Average monthly Costs	14 796 365.60	17 564 239.51	16 400 353.85	2 506 966.81
Total 2019/20 Annual Costs				51 267 925.77

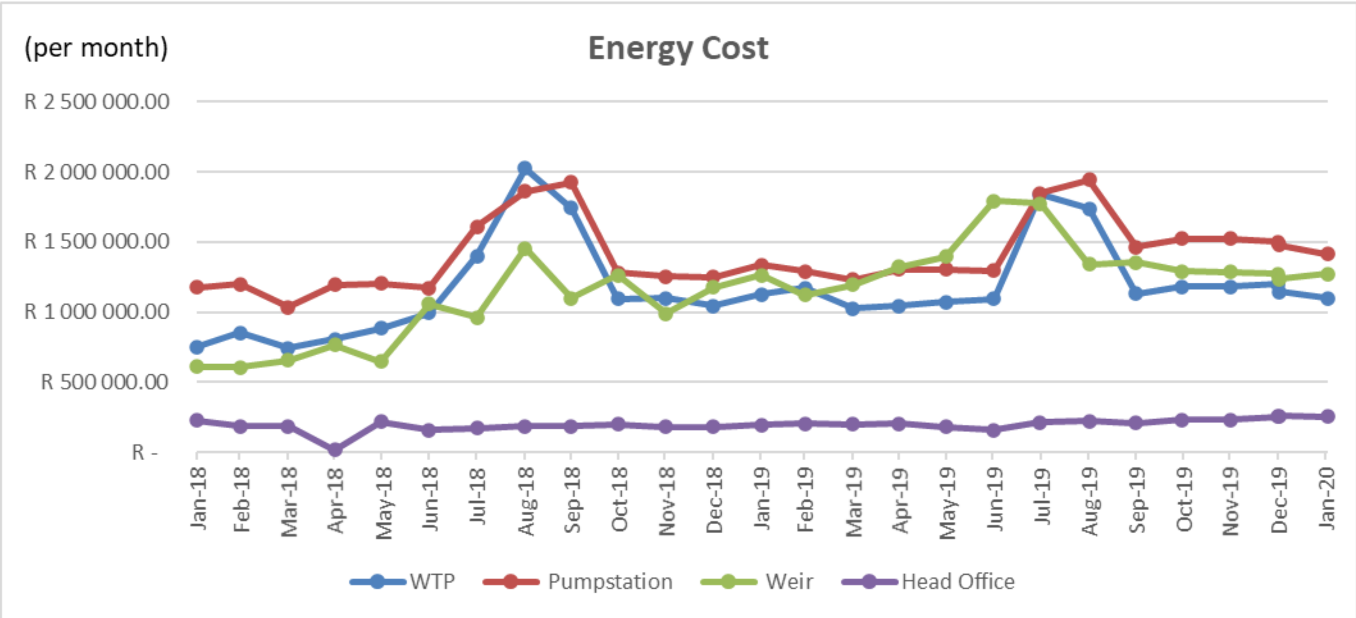

Fig. 5. Monthly energy consumption bills for each municipal facility for a two year period

In view of the financial cost of each of the municipal facilities (plants) above, it is evident that the water treatment plant together with the pump station and the weir carry the majority of the municipal expenditure. Table VII and Table IX depict that about R50 million per annum must be dedicated by the municipality to keep this essential water system running so as to be able to provide basic services from this water scheme. This examination of the energy bills excludes energy bills of other water supply schemes, distribution and reticulation networks, municipal wastewater schemes responsible for removing sewerage from residents, commercial and industrial institutions, discharging of sewage from municipal pump station plants, macerators, wastewater treatment plants, and effluent discharge systems.

The above tables and corresponding figure reflect that the three plants of this water scheme consume energy worth slightly over a million Rand each a month, with the municipal head office having an average bill of little more than R175 000. In a nutshell, the municipality pays about R3.5 million for this water scheme per month. The municipality under study for this paper has three water schemes with similar plants, five wastewater schemes with each having no less than twelve sewer pump station plants, two macerators and a final effluent discharge pump station plant. Without getting into details of the amount of energy consumption and energy bills that this municipality incurs, the municipal total energy expenditure to keep the above mentioned plants operational is slightly less than half a billion Rands. The question is, then, how much does this municipality together with other municipalities across the country allocate towards electricity to keep all it’s essential plants operational in order to provide basic services? It must be born in mind in the context of this paper that the bills associated with the above operations are apart from energy charges that the municipality incurs to be able to provide energy to its clients that the clients pay for.

In view of Tables IV and Table VI, it is evident that there is an average positive increase in energy demand and energy consumption, except the pump station plant which reflects a negative increase when comparing 2018/19 with 2019/20. The negative energy demand and consumption at the pump station is due to the number of breakages (pump failures) that had been experienced. The percentage energy increase of the treatment plant, the weir and head office, was on average greater than 5 %. The head office and treatment plant had an

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average increase of 6 %, implying that general 'low hanging fruits' interventions are required, for example a change of lights to LED, and installation of a timer on the geyser at the municipal building (head office). However, energy savings from the municipal building resulting from implementation of interventions is very minute when compared to possible savings at primary plants.

The weir exhibits the highest average energy demand and consumption, indicating that major energy saving interventions are required such as improving power factors, installing capacitive components on inductive loads, and other possible technical-, human resource- and technology-related interventions. Since the weir abstracts raw water from the river, river level and concentration of objects may contribute to demand and consumption, thus project-oriented interventions in addition to general seen-as-fit interventions must be undertaken to reduce demand and consumption to less than 5 %.

The review of the connected load, demand factor and energy supply type are of importance. Connected load is the rating at the name plate of the apparatus installed on the consumer's premises (municipal primary facilities), measured either in kW or kVA. Maximum demand is the highest average kVA that is recorded using a digital energy meter or tri-vector meter during any demand interval within a specified time. The demand factor is the maximum demand over the connected load.

Equation 1: Load-factor (l.f.) equation

The load factor is computed as: Load Factor (l.f) =

$$\frac{\text{Average load}}{\text{Maximum load}} = \frac{\text{Energy consumed during 24hrs}}{\text{Max. load recorded X 24hrs}}$$

The l.f. is basically the average energy consumed over the maximum recorded demand during the duration of measurement.

Load factor = Energy Consumed / (Maximum Demand x Time Period in Hours). Table IX indicates the values of monthly demand and consumption used to compute the average load factors of each primary municipal facility.

TABLE IX. MONTHLY ENERGY DEMAND (KVAH) AND CONSUMPTION (KWH) FOR EACH MUNICIPAL FACILITY

MONTHS	kVAh	kWh	kVAh	kWh	kVAh	kWh	kVAh	kWh
	WTP	WTP	Pump station	Pump station	Weir	Weir	Head Office	Head Office
Jan-19	2 107 528.80	1 429 817.00	1 503 579.36	1 430 597.00	1 765 854.24	1 413 911.00	230 305.20	85 305.00
Feb-19	1 974 094.08	1 479 475.00	1 387 155.84	1 355 058.00	1 620 769.92	1 193 425.00	228 849.60	91 525.00
Mar-19	2 011 433.76	1 265 401.00	1 504 427.52	1 265 354.00	1 668 382.80	1 337 133.38	256 099.68	82 670.00
Apr-19	1 899 511.20	1 290 926.00	1 467 324.00	1 359 651.00	1 74 5791.20	1 275 158.93	227 527.20	96 696.00
May-19	2 127 572.16	1 350 997.00	1 512 723.12	1 386 976.00	1 769 931.36	1 370 220.13	201 363.60	73 466.00
Jun-19	2 099 174.40	1 364 346.00	1 424 800.80	1 352 333.00	1 694 916.00	1 300 940.95	171 561.60	42 734.00
Jul-19	1 953 937.44	1 253 310.00	1 512 663.60	1 064 779.00	1 682 972.64	1 295 103.10	168 203.52	69 441.00
Aug-19	1 921 112.16	1 226 521.00	1 440 361.68	1 191 869.00	1 919 892.00	1 215 968.96	198 581.04	71 865.00
Sep-19	2 021 529.60	1 161 646.00	1 443 297.60	1 289 567.00	1 687 226.40	1 326 399.20	203 716.80	72 030.00
Oct-19	1 84 5529.20	1 237 978.00	1 498 676.40	1 362 324.00	1 796 432.64	1 234 310.04	227 924.40	83 300.00
Nov-19	1 715 709.60	1 158 970.00	1 404 374.40	776 178.00	1 734 559.20	1 210 456.03	232 538.40	76 809.00
Dec-19	2 205 216.00	1 266 410.00	1 484 525.52	1 331 782.00	1 796 611.20	1 195 126.82	253 510.56	95 994.00
Average	1 990 195.70	1 290 483.08	1 465 325.82	1 263 872.33	1 740 278.30	1 280 679.46	216 681.80	78 486.25
Total	23 882 348.40	15 485 797.00	17 583 909.84	15 166 468.00	20 883 339.60	15 368 153.54	2 600 181.60	941 835.00

TABLE X. AVERAGE LOAD FACTOR OF EACH OF THE MUNICIPAL FACILITIES

Facilities	Load factor
WTP	0.648
Pump station	0.863
Weir	0.736
Head office	0.362

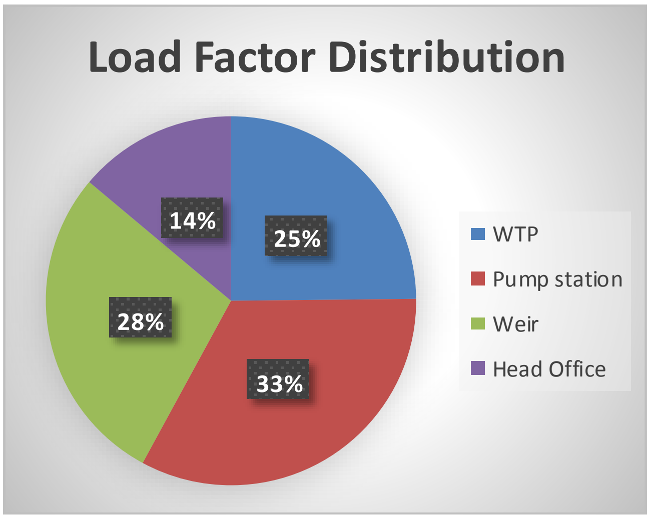

Fig. 6. Distribution of load factor contribution of the municipal facilities

The average load factor for all the municipal facilities listed above is 0.652. Table X shows that the pump station and weir have the highest load factors which indicates that the municipality has no underutilization of energy and the general power usage is relatively constant, thus the municipality attracts less charges from the utility. Because the water treatment plant, pump station and weir are not operating at full capacity for the entire duration of the day and/or month, and also because the maximum energy demand is always higher than the average energy demand, the load factor is less than 1. With regards to the municipal building (Head office), the load factor indicates that there is strong underutilization of energy. The important factor to note is that the municipal building contributes 14% of the load factor which shows that the least contribution to energy utilization is the municipal head office.

In ascertaining the energy efficiencies of each of the plants, Eq. 2 is used.

Equation 2: Energy efficiency (e.e.) equation

$$\text{Energy Efficiency} = \frac{(\text{consumption} - \text{demand})}{\text{consumption}}.$$

TABLE XI. AVERAGE ENERGY EFFICIENCIES OF THE MUNICIPAL PLANTS TOGETHER WITH THE HEAD OFFICE

Plant efficiency	WTP	Pump station	Weir	Head office
2019/20 efficiency	0.998	0.998	0.998	0.996
2018/19 efficiency	0.998	0.998	0.998	0.997

Table XI indicates that, in terms of how the plants are supposed to run, they have an average of 99.8% efficiency and 99.7% for the municipal head office. The question is, then, how will the municipality craft and implement energy saving strategies in order to harvest a decrease in consumption and bills? Laid out below are generic recommendations together with brief explanations that municipalities should employ in order to control energy consumption and arrest possible energy wastage.

III. RECOMMENDATIONS

Energy improvement strategies recommended for the municipality to implement are in line with world class energy saving strategies. Bearing in mind the whole water network and how each is uniquely operated, and detailed operations of other municipal plants and/or schemes, the following generic strategies are proposed for municipalities with similar functions. The recommendations are grouped into: generic energy efficiency equipment related interventions or strategies, generic energy conservation strategies based on human behaviour, and generic energy saving strategies based on technology. It must be born in mind that the core is the in-depth understanding of all water and wastewater schemes and plants operated by the municipality for effectiveness in the prescription of recommendations. This aids the municipality in being able to ascertain if the prescribed strategies will result in energy efficiency improvements and savings, and by how much. These energy saving and energy bills reducing strategies are grouped and recommended as follows:

A. Generic Energy Efficiency Equipment Related Strategies

- Power factor correction installation. Power factor, according to [17], describes how effectively a facility utilizes all of the electrical power it consumes. [17] further states that the demand components (kVA) within the bulk electricity tariffs perspective are directly affected by the power factor of operation. That is, the power factor in the interest of the consumer, in this case the municipality, must be kept as close to unity as possible because the kVA of operation increases as the power factor decreases resulting in the customer paying higher network demand charges and higher network access charges than necessary. Low power factors are caused by inductive loads such are induction motors, and in order to compensate for these inductive loads, capacitive components commonly known as power factor correction capacitors are introduced into the system. In other words, the municipality must improve the typical power factor of 0,85 to 0.95 or 0.995 for all induction motor dominant loads.

- Automate all component systems or components that can be automated in each of the plants.
- Due to low performing and poor infrastructure conditions, refurbish and/or replace all redundant or aged infrastructure with parts or components that have improved allowable life.
- Install energy management and performance monitoring systems or devices. Also include the installation of bulk check meters and/or zone meters to configure a baseline.
- Installation of variable speed drives where possible.
- Check and lubricate all moving components and change and/or refill oil in gearboxes and cylinders. Check, repair and refill all leaks in hydraulic cylinders and tubes.
- Repair and maintain all mechanical components, and audit conditions of all electrical components and check for efficiencies and replace where necessary.
- Recondition or replace aged or weak windings as they tend to be a major source of energy wastage. Also replace aged and faulty circuit breakers.
- Recondition or replace pumps with new and improved pumps with improved pumping system efficiency. Pump efficiency can differ in definition depending on the various parameters used to determine efficiency, however, pump efficiency is critically dependent on maintenance and operational aspects. Decision-making and pump selections must take into consideration energy efficacy and low operational and maintenance costs. Optimal energy savings can be achieved by combining newer, more efficient pumps with variable speed drives and with EFF1 (high efficiency) motors.

B. Generic Energy Conservation Based on Human Behaviour Strategy

- Capture accurate data of plant performances in terms of plant efficiency, management (including maintenance work scheduling) and modelling in order to achieve optimal performances based on extensive historical records.
- Schedule periodic auditing of plant and corresponding energy performances, and arrange for appropriate works.
- Conduct annual benchmarking exercises with similar type world class institutions for latest best practices and new standards.
- Allocate adequately skilled labour to detailed operations functions, and allocate competent skilled and semi-skilled labour to repair and replace faulty or dilapidated parts or fixtures for water treatment plants, water abstraction weirs and pump station plants. Skilled operators must at all times use the electricity usage index and consumption measurements as tools at the various plants to identify problem areas as this exercise facilitates more efficient energy management (cost saving) and improved environmental impacts
- Adoption of an established, detailed organizational Energy Management Strategy (EMS) that links throughput, plant processes and energy management, and other areas of facility management into an integrated approach especially during unplanned emergencies and load-shedding.
- Upgrade electricity grid and installation of consumption metering in real time, and a management system. Identify units with high energy consumption during maximum demand periods when high tariffs apply.
- Negotiate and have an annual review of tariffs and supply lines where possible for reduction of energy bills.
- Shift the off-work periods of identified equipment to time spans when lower tariffs apply.
- Maintain supply MVA against set point MVA, revert to load shedding when exceeding set point.
- Install energy sensitive devices where necessary. Include energy saving devices on high energy consuming parts and parts that have high maximum energy demand during periods when tariffs are high.

IV. CONCLUSION

Excessively high amounts of energy bills are incurred by municipalities in order to provide basic services. This results in excessive demand in the national grid, and yet some measures can be implemented to arrest energy wastage and uncapped consumptions. The recommendations above indicate three key strategies that institutions such as municipalities should use as a guide for effective introspection in terms of how they conduct and monitor their operations and energy management systems. Unchecked performances generally lead to disastrous outcomes that, unfortunately municipalities choose to live with rather than find meaningful solutions that ensure that basic services are provided at affordable rates. If a single unmodified water scheme with only three main consuming facilities is capable of such exorbitant bills, what effects do municipal actions country-side have on the national grid, end-users or beneficiaries of basic services provided by municipalities, and what is the economic impact on municipalities? The importance of periodic audits is highlighted together with possible measures of addressing identified challenges or issues using the above listed recommendations.

REFERENCES

[1] K. Wall. “Water infrastructure for human and economic development,” CSIR Report: A CSIR Perspective on Water in South Africa, 2010. http://researchspace.csir.co.za/dspace/handle/10204/5760

[2] Financial and Fiscal Commission, 2009. Submission on Division of Revenue Act 2010/2011. https://ffc.co.za/15-submissions/commission-

submissions

[3] A. Brent. CSIR. “Water, energy and climate change,” CSIR Report: A CSIR Perspective on Water in South Africa, 2010. https://researchspace.csir.co.za/dspace/bitstream/handle/10204/5760/Wall11_2010.pdf?s

[4] P.J. Ashton. “The Road Ahead,” CSIR Report: A CSIR Perspective on Water in South Africa:, 2010. https://researchspace.csir.co.za/dspace/bitstream/handle/10204/5760/Wall11_2010.pdf?s

[5] C. Nguyen, K. Tang, and Y. Won. Reaching Zero-Net Energy at Water and Wastewater Treatment Facilities. Worcester Polytechnic Institute, Massachusetts, 2014. https://digitalcommons.wpi.edu/iqp-all/343/

[6] Eskom. Electricity Pricing Definitions (standard). www.eskom.co.za › Documents › Eskom: NRS000 and NRS057

[7] F. Van Zyl, N. Manus, and C. Pensulo. Water Services Infrastructure Asset Management for Municipal Managers and Management. Department of Water and Forestry, 2008.

[8] uMhlathuze municipality 2018/2019 annual report. https://www.umhlathuze.gov.za/index.php/financial-statutory-reporting/35-financial-statutory-reporting/136-annual-report

[9] Council for Scientific and Industrial Research (CSIR) andCIBD. The State of Municipal Infrastructure in South Africa and its Operation and Maintenance: An Overview. Pretoria: South Africa, 2007. http://www.cidb.org.za/publications/Documents/State%20of%20Municipal%20Iinfrastructure%20in%20South%20Africa.pdf

[10] Energy Utilization Index (EUI). n.d. http://dossin.weebly.com/uploads/7/9/8/6/7986350/14-16.pdf

[11] South African National Standard. (ed.1). SANS474, 2006 and NRS057, 2005: Code of Practice for Electricity Metering. Pretoria: Standards South Africa.

[12] South African National Standard. (ed.1). SANS1524-1, 2013 and NRS009, 2013: Electricity payment systems: Mounting and terminal requirements for payment meters. Pretoria: Standards South Africa.

[13] National Cleaner Production Centre. Resource Efficiency and Cleaner Production: A Guide to Understanding your Iindustrial Electricity Bill. n.d. http://ncpc.co.za/files/Guides/How%20to%20Read%20Your%20Electricity%20guide%20Book.pdf

[14] M. Zhang, and W. Wang. “Decoupling analysis of electricity consumption from economic growth in China,” J. Energy Southern Africa, 24(2), pp. 57-66, 2013. http://www.uct.ac.za/sites/default/files/image_tool/images/119/jesa/24-2jesa-zhang-wang.pdf

[15] Eskom Holdings SOC Ltd. An Overview of Electricity Consumption And Pricing in South Africa: An Analysis of the Historical Trends and Policies, Key Issues and Outlook in 2017. Deloitte, 2017.

[16] S. Houde, A. Todd, A. Sudarshan, A.F. Flora, and A. Armel. Real-time Feedback and Electricity Consumption: A Field Experiment Assessing the Potential for Savings and Persistence. Stanford University: Department of Management Science and Engineering. Califonia https://pdfs.semanticscholar.org/8975/1c64ffca7320246214f819a735424d9c79a0.pdf

[17] A. Kowalska-Pyzalska, and K. Byrka. “Determinants of the willingness to energy monitoring by residential consumers: a case study in the city of wroclaw in Poland,” Energies, 12(907), pg1-20, 2019.

[18] M.K.A. Elamvazuthi, A. Khan, S.B.B. Shaari, R. Sinnadurai and Amudha, M. Electrical Power Consumption Monitoring using a Real-time System. Conference on Sustainable Utilization and Development in Engineering and Technology (STUDENT). pp295-298. IEEE, 2012. https://www.researchgate.net/publication/261431668_Electrical_power_consumption_monitoring_using_a_real-time_system/link/54c9923d0cf2807dcc273a4d/download

[19] E. Zvingilaite, and M. Togeby. Energy Analyses: Impact of Feedback about Energy Consumption. Denmark, 2015. https://ens.dk/sites/ens.dk/files/Analyser/impact_of_feedback_about_energy_consumption_final.pdf

[20] D.B. Belzer. A Comprehensive System of Energy Intensity Indicators for the U.S: Methods, Data and Key Trends. U.S Department of Energy: Pacific Northwest National Laboratory. Washington, 2014. https://www.pnnl.gov/main/publications/external/technical_reports/PNNL-22267.pdf

[21] Constitution of the Republic of South Africa, 1996 and Regulations. South Africa: LexisNexis, 2013.

[22] Municipal Structures Act No.117 of 1998 and Regulations. South Africa: LexisNexis, 2013.