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An Assessment of Hydropower Potential for Electrical Energy Harvesting in Water Distribution Network in Buea-Cameroon

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Abstract: ***Significant amount of energy is consumed in water supply systems resulting in reduced sustainability of these systems. Measures to reduce their energy demand are strongly needed. In this study, an estimation of the intrinsic hydro energy potential of the water supply system of a Cameroon municipality was made in order to propose an energy-potential map useful to identify the most interesting sites where excess energy in the network can be harvested to improve the energy efficiency of the network. A geodatabase to store network data was developed using Geographic Information Systems. The shapefiles resource data were explored and the hydraulic simulator EPANET software was used to create a model. Calculations were performed to determine the energy recovery values at different locations in the network. The resulting digital map presented 18 candidate sites which show a total annual energy potential of 635 MWh, realizable at capacity factor and efficiency of 41 % and 65 % respectively. This potential can offset the energy footprint of the network by about 34 % while 127 tons of carbon-dioxide emission reductions are achieved. The results of this investigation highlight that development of renewable energy resource on water supply network infrastructure is an innovative technology that can contribute significantly to improve the energy efficiency, economic and environmental sustainability of the water supply system.***

Keywords: ***Water supply system, Hydro Energy Potential, Energy potential map, Carbon dioxide, Energy efficiency, Sustainability.***

I. INTRODUCTION

Water and energy are essential for sustainable human life. United Nations sustainable goals 6, 11 and 12[1] aim to ensure everyone's access to safe water and improve resource efficiency including energy in water systems [2]. Nevertheless, in the water-energy nexus water pressurized networks account for 3% of the energy used worldwide [3].

The expected increase in population in the coming years [2] especially in Cameroon [5] will not only lead to increase of water abstraction and higher volumes of treated water needed to be distributed in urban areas, but will also put additional pressure on water and energy resources. Population growth will increase global electricity intensity within the water supply sector from 0.2 kWh m^{-3} in 2014 to 0.3 kWh m^{-3} in 2040 [3] with associated emissions of carbon dioxide (CO_2) from fossil fuel combustion for electricity generation. The aforementioned challenges highlight the need to reduce energy consumption in the water industry sector, using green energy sources. More so, the sustainable use of water and energy resources is crucial [6-8]. Leakage management can play a major role in the reduction of energy consumption in the water sector. Hence, pressure management in water distribution networks (WDN) is key to improving the use of water and energy resources [9].When excessive pressures in water networks are prevented, water leakages are reduced, resulting in lower amounts of water treatment and pumping, and hence a reduction of the energy involved in the water supply process. Some investigations have evaluated pressure management in WDN. References [10], [11] used real time control to guarantee the required pressure at all nodes in the water system. Pressure reducing valves (PRVs) are used to control pressure values [12]-[15]. Energy dissipation usually takes place in the forms of heat, noise and vibration during PRVs operation [16],[17].In a similar manner, in a break pressure tank (BPT) a break is created which dissipates the flow and the pressure in the pipeline, resulting in pressure reduction [18]. Because the operation of the PRVs and BPTs involves waste of potential energy, they can be replaced by turbines or pumps as turbines (PATs) to harvest renewable energy without reducing the level of service to customers. [16], [19]-[26].While generating the energy, pressure is also reduced in the pipes [4],[23],[27],[28].Any surplus pressure contributes to water and energy inefficiencies and shortens the average lifespan of pipes [29].Recovered energy can not only be used to reduce the energy demand and increase the energy efficiency of the water network, it can also contribute to the local energy needs, reduce carbon dioxide emissions and used to counteract rising energy prices thus improving the sustainability of the water supply system. In the investigation carried out in Kildare, Ireland, 7 BPTs were found to produce power in the range of 27 to 2kW and those with potentials to generate electrical power as little as 13kW were also shown to be financially viable [25].

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A few studies can be found in the literature for energy recovery in the consumption nodes. A daily range of 43 to 231 kWh of energy were recovered in 25-Node network [16]. Many works have investigated in-conduit hydropower harvesting in the main water supply and distribution lines. About 40 MWh/day of energy could be recovered along the water main of the Italian Alpine valley [30] while approximately 1 GWh could be recovered in BMI and BMD irrigation networks in Andalusia, South of Spain [31].In his works, [32] found that only hydraulic power potential higher than 50 kW were feasible with PAT at the inlet of storage tanks of the Portuguese water transmission system. According to his study [16], PATs were used to replace energy dissipating devices wherein the energy produced was used to reduce the energy demand of the network by 21 and 23 %. In a similar study in the Polokwane Central District Metered Area network,roughly annual 2.3GWh of energy was harvested [33].Other annual energy savings potentials investigated include: 10 GWh in the City of Tshwane, South Africa [34]; 94 MWh in Pompei, Italy [28];2.3GWh in Portugal [35]; 254 MWh in new jersey, USA [36].

Energy recovery is the beginning of the solution for the quest for economic, energy self sufficient and a sustainable network. It also involves green energy replacing fossil fuels in order to minimize the effects of global warming as well as enabling a sustainable development for future generations. Several works have highlighted energy recovery in water distribution networks, yet there is no literature on energy potential maps useful for the identification of the most interesting sites for renewable energy harvesting. More so, as much as these research works contributed to the frontier of knowledge on energy recovery in WDN,nothing has been reported as per water distribution system in cameroon.Thus our study proposes to assess potentially recoverable energy in the WDN of the Buea city in Cameroon,which if harvested will reduce both the energy footprint,water loss and greenhouse emissions of the network.

This work is comprised of nine main sections: The first being an introduction in which the main background of the study is presented and all related works are summarized; then follows section II in which the challenges in the Buea water distribution network are outlined. The methodology and materials used in the research are presented in section III, while in section IV, the concept of excess pressure in the break pressure tanks and the nodes in water supply system is explained. In section V, information extracted from the geodata base is used to estimate the potential energy that can be recovered in the main pipelines. Section VI contains results of the hydraulic simulation of the network and also hydropower potentials that can be recovered in the sub-grid pipelines. The methodology to generate the energy potential map of the network is described in section VII. Section VIII summaries the results and discussion of the potential energy in the main pipelines and sub-grid pipelines and finally, in section IX, the main conclusions are drawn, including perspectives for further research in the domain.

II. SPECIFICITIES OF THE BUEA CITY WATER DISTRIBUTION NETWORK (WDN)

The Buea city which is the south-west regional headquarter of Cameroon (Fig. 1) sits at the base of mount Cameroon and lies within latitude and longitude of 4 09° 34’’N and 9 14° 12’’E respectively. It is at an elevation of about 1000 m above sea level and harbors about 200000 people in a total coverage area of about 870 km2 [37],[38].

In general, the elevation drops towards the south and with this topography, the large drop in elevation produces an excessively large static pressure in the network resulting in pipe damage and water leakage problems in the pipelines. Due to extensive geodetic height differences the WDN is operated with three high supply pressure zones (Fig. 2): The Upper farm, lower farm and Molyko neighborhood consisting of zones 1,2 and 3 respectively. The network is supplied by three main springs: The German spring at the upper farms, Small Soppo and Mosel. The low-lying populations are served by high-elevation water tanks: German Tank in zone 1, Metallic tank in zone 2 and Mosel spring Tank in zone 3 at elevations of 1061 m, 995 m and 823 m respectively, all with the three tanks at a total storage capacity of 3250 m3. The water supply system also includes 4 pumping stations and two main treatment plants (Fig. 2).The network is fully gravity-driven, supplying about 6000 subscribers and in all, there are 65 nodes and 117 pipes covering about 135 km of pipeline. The water network is managed and maintained by the Cameroon water utility Company, CAMWATER. According to the branch manager, network engineer and network operators, the network works for about 3650 hours per year.

Fig. 3 and Fig. 4 are an evidence of the elevation gradient in the water system of the municipality while its pressure gradient is illustrated by Fig. 5 and Fig. 6. As can be observed, there are high topographic gradients across the network. Elevations are above 100 m (Fig. 3 and Fig. 4) which present large hydraulic heads in the main pipelines and distribution networks. Fig. 5 depicts the pressure gradient imposed by the German water tank in zone 1. Water pressures range from 25m in upper farms through 100 m in lower farms. Meanwhile pressure gradients due to Mosel water tank in zone 3 range from 50 m from the Baptist high school through 100m (Fig. 6) in the Molyko neighbourhood.

These high-pressure gradients require PRVs or BPTs for water leakage control. The pressure gradients can however be recovered through hydroelectric power generation. The network which lacked base data information was still at the analogic map stage and consisted of the traditional paper plans which are difficult to manipulate.

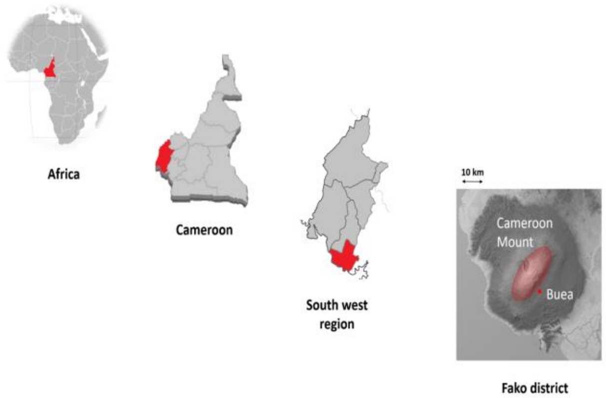

Fig. 1. Location of the Buea Municipality in the Southwest Region in Cameroon [39].

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The operation of the network is not economically attractive as a substantial amount of energy is used for water distribution. The annual energy footprint of the network was estimated at 1894 MWh (Tab. 1).

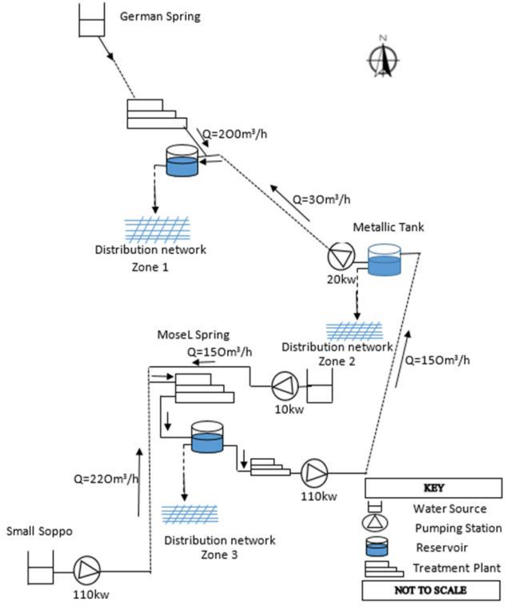

Fig. 2. Zones, tanks and pumping stations of the network.

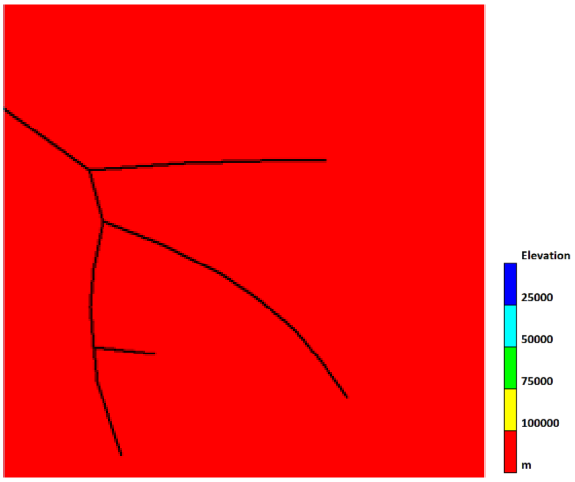

Fig. 3. Elevation gradient for Zone 1.

Table 1: Energy footprint of the network.

N°	Pumping station	Head (m)	Flow rate (m³/h)	Power (kw) of the pump	Annual Energy consumption E(MWh)
1	Small Soppo-Mosel	115	220	110	963.6
2	Mosel Catchment-Treatment station	10	150	7,5	65.7
3	Mosel-Metallic tank	80	150	90	65.7
4	Metallic-German	90	150	15	76.6
	Total	180	670	112.5	1894.3

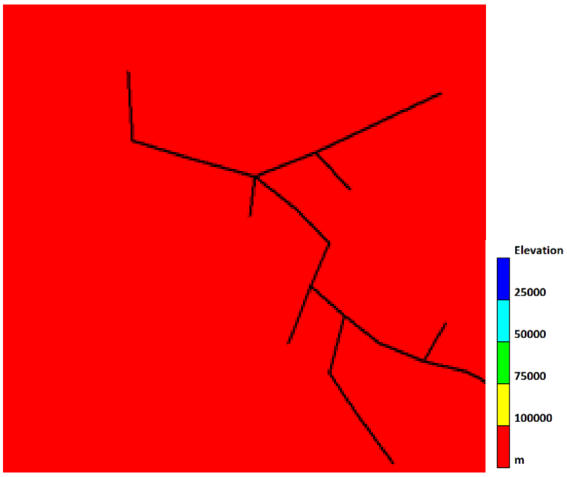

Fig. 4. Elevation gradient for Zone 3.

Fig. 5. Pressure gradient for Zone 1.

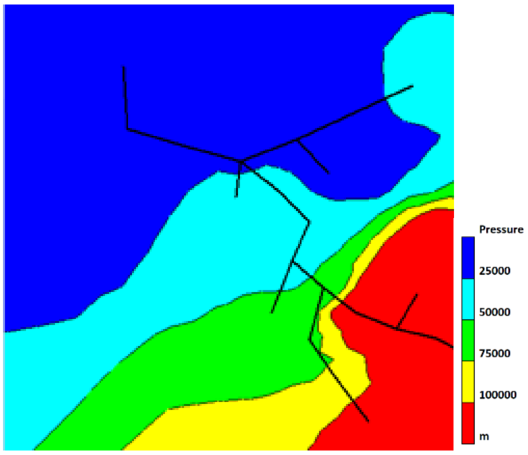

Fig. 6. Pressure gradient for Zone 3.

III. METHODOLOGY

In this paper, a Hydro-energy Potential map useful to identify the most interesting sites for energy recovery, was generated for the Buea water distribution network. A geodatabase containing data relevant to the capturing of excess or wasted energy in the main and sub-grid pipelines of the network was created using Geographic Information System technology (GIS functionalities).

The hydraulic simulator EPANET software was used to create a model based on flow and pressure distribution in the pipelines and nodes of the network. Determining instant values of flow and pressure allowed performing the analysis of energy recovery in any node of the network. Furthermore, in this paper, the associated carbon dioxide emission reductions were evaluated using the RETCREEN software.

The methods and material used in this work are presented in the flowchart of fig 7.

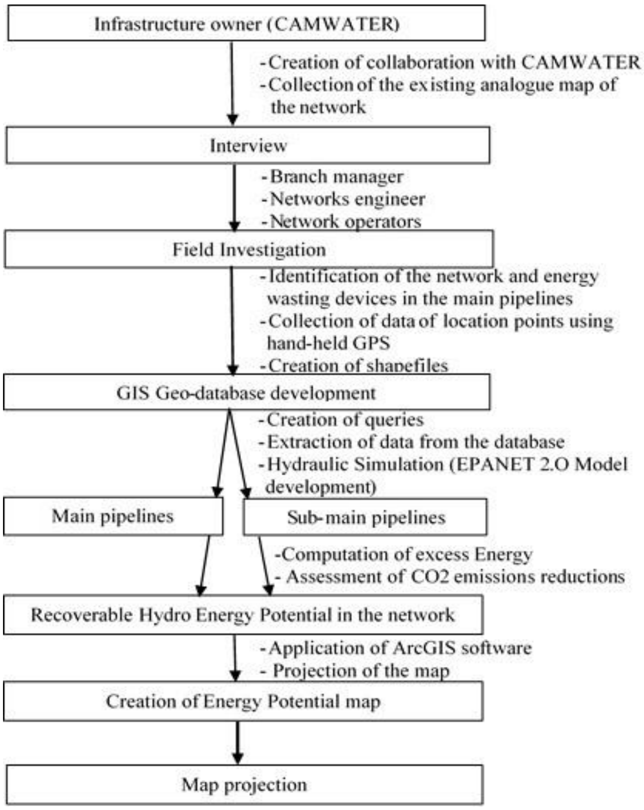

Fig.7. Flow chart of design methodology and materials

The database contained information on:

- Pipes: identity (Id), diameter, length (m), coordinates (longitude, latitude), Connecting nodes, Roughness coefficient.
- Break pressure tanks: Altitude (m), coordinates (longitude, latitude).
- Nodes: identity (Id), Altitude (m), coordinates (longitude, latitude), Water demand ($m^3.s^{-1}$).
- Tanks: Altitude (m), coordinates (longitude, latitude), Initial tank storage level, minimum tank storage level, and maximum tank storage level (m), Discharge ($m^3.s^{-1}$).
- Intakes of reservoirs and sources: Altitude (m), coordinates (longitude, latitude), flow rate ($m^3.s^{-1}$)
- Treatment (stations) plants: Altitude (m), coordinates (longitude, latitude).

IV. EXCESS PRESSURE IN BREAK PRESSURE TANKS AND HARVESTING NODES AS HYDROPOWER SOURCE

In the main water supply lines, where the difference in elevation between two points is high, the excess pressure head is dissipated in a break pressure tank (BPT) (Fig.8 and Fig.9) wherein the excess pressure head is dissipated to atmospheric pressure by creating water jets. The excess energy can also be converted into electrical energy using micro hydropower turbines installed at the lower level [35].

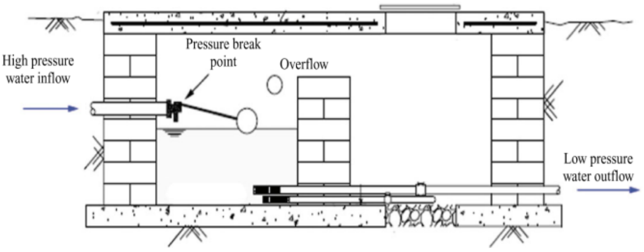

Fig. 8. Break pressure tank [40].

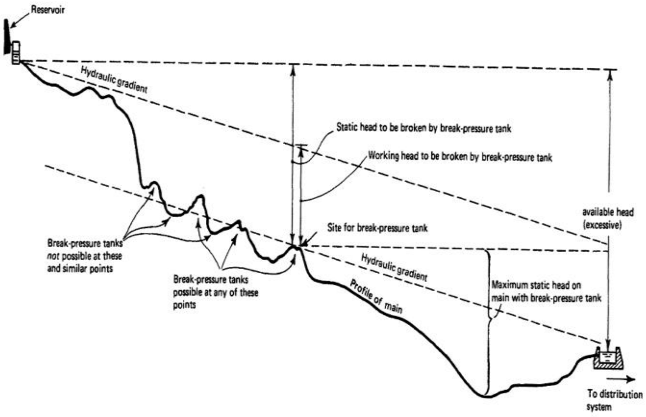

Fig. 9. Excess pressure in a pipeline [40].

In the main water supply pipeline, the excess energy is due to the pressure that has been built up in the pipeline between either a tank and the following BPT or between two successive BPTs or that at the inlet of a tank. The excess energy or the pressure head representing the difference in elevation between the upper tank/Break pressure tank and the turbine located in the lower break pressure tank can be exploited for green energy production [42]. Within the sub-grid pipelines, there exists pipes and nodes with more pressure than necessary due to elevation differences and changing consumption rate. The excess pressure less the minimum required pressure is the hydro-energy potential for electricity production.

The minimum required pressure, ΔH_{min} (Fig.10) is necessary to ensure satisfactory levels of service to the water consumers downstream. The available hydropower potential, h_l, varies considerably throughout the day, depending on the consumption of water in the water supply system

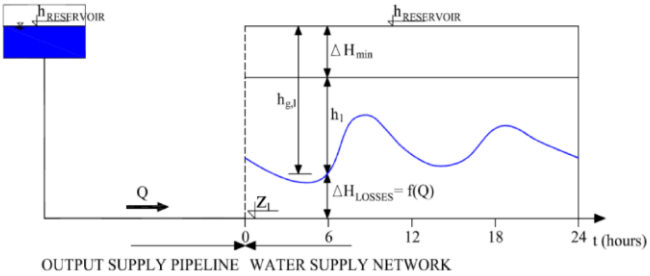

Fig. 10. Minimum required pressure and the potential energy [43].

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V. MUNICIPALITY WATER GEODATA AND COMPUTATION OF POTENTIAL ENERGY IN THE MAIN PIPELINES

The intrinsic hydropower at each potential location was determined utilizing Equation (1); that uses discharge and net head [33].

$$Power = \eta.\rho.g.Q.(h_{g,l} - \Delta H_{\min}) \qquad (1)$$

While the annual energy (in kwh/year) generated was estimated using Equation (2).

$$E = \eta.\rho.g.Q.\Delta h_1.CF.\Delta t \qquad (2)$$

Where, ρ is water density given as 1000 kg.m^{-3}, g is the acceleration due to gravity, Q is the flow rate (in m^3.s^{-1}) in the main pipelines or in the consumption node, h_l is the net head (m), $h_{g,l}$ is the gross head,

H_{min} is the minimum required head (in m), η is the efficiency of the hydropower plant, CF is the plant Capacity factor [44] and Δt is the time window.

At the initial stage of the investigation, geographical information was extracted from the geodata base which included data on the spatial location of network components such as BPTs, storage facilities, the static or pressure head, elevations, pipes, dimensions and the type of material. For each zone, information was assessed for determining the quantity of hydro potential energy for each site identified along the main water pipeline.

Fourteen sites were identified including one site upstream of each of the 11 BPTs, one at the intake of the German reservoir, one at the intake of the Mosel tank and the other at the inlet of the small Mosel treatment station.

The flow in the three zones ranged from 0.045 m3.s-1 through 0.06 m3.s-1 (Tab. 2) while the lowest average head range of 65.5 m was observed in zone 3 (Tab.3). Fig. 11, 12 and 13 depict both the available head and the eventual position of the turbine in each site.

In the main pipelines, a total average annual energy of 954 MWh (Tab. 4) was estimated using Equation (1). The net head was taken as the design head for the hydro turbine installation. We assumed a maximum supply period of 10 hours per day; hence the plant capacity factor was taken as 0.41 in the calculations; Hmin was 0 metres at BPT sites, inlets of tanks and treatment station; Δt was 365 days and efficiency, η, was 1.

Table 2: The respective flowrates of the three zones of the network

Zone	Discharge (m^3/s)	Tank providing the flow
1	0.045	German
2	0.055	Metallic
3	0.06	Mosel Spring

Table 3: Geo data range

Zone	Head range(m)	Average range (m)
1	43-129	86
2	43-76	81
3	33-65	65.5

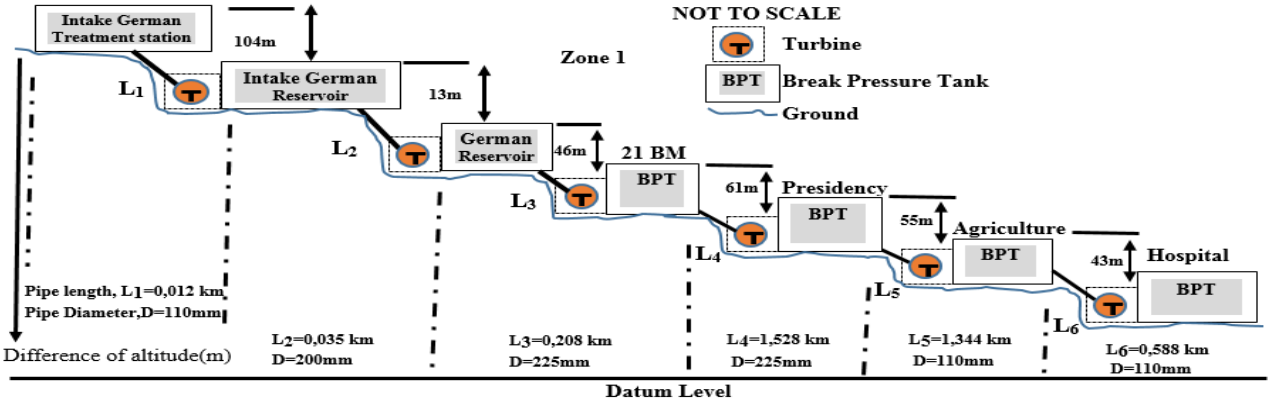

Fig. 11. Pressure heads of pressure breaking tanks in zone 1.

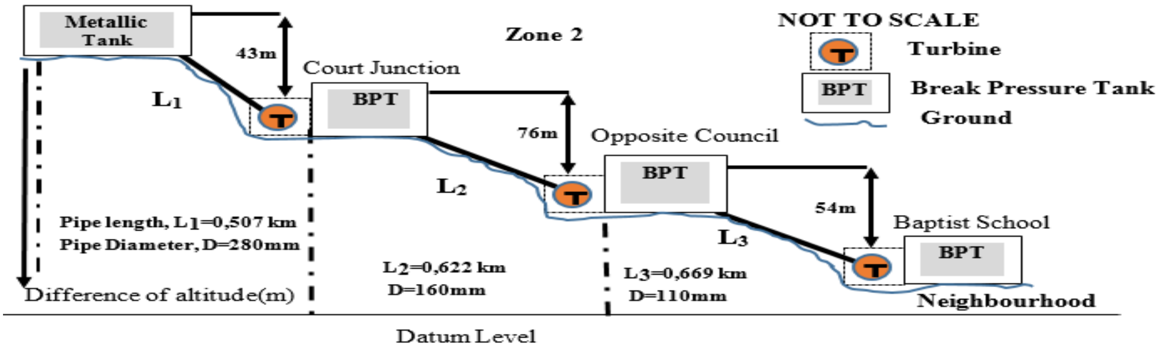

Fig. 12. Pressure heads of pressure breaking tanks in zone 2

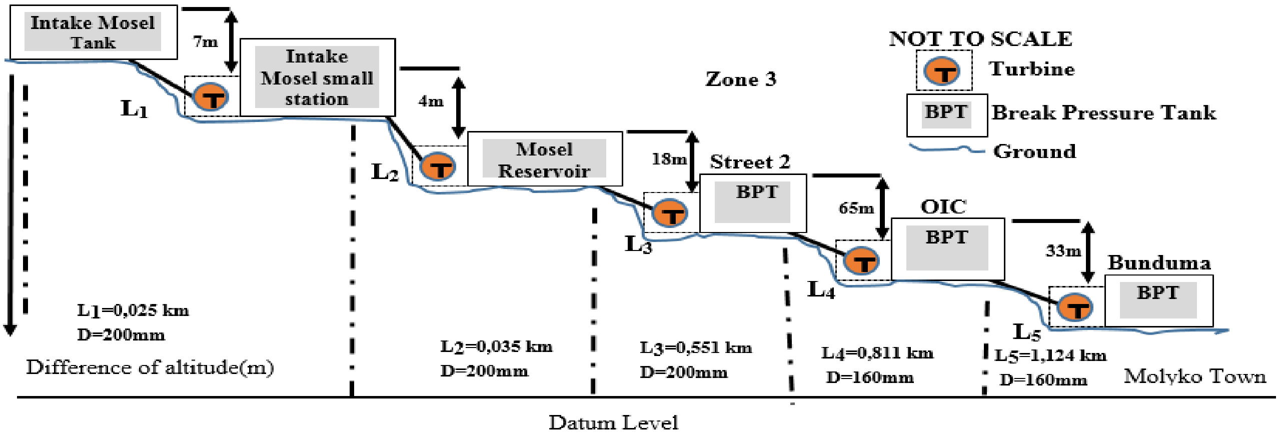

Fig. 13. Pressure heads of pressure breaking tanks in zone 3

Table 4. Average energy estimation in the main pipelines

Site	Northings	Eastings	Altitude (m)	Head (m)	Discharge (m^3/s)	Power (KW)	MWh/ Year
Intake German Treatment station	9.22784	4.15901	1080	104	0.0255	26.0	95.0
Intake German Reservoir	9.22816	4.15874	1061	13	0.0255	3.3	11.9
BPT 21 BIM	9.23002	4.1586	1015	46	0.0496	22.4	81.7
BPT Presidency	9.22866	4.14694	954	61	0.0496	29.7	108.3
BPT Opposite Agriculture	9.23503	4.1525	932	55	0.0496	26.8	97.7
BPT Brigade (Hospital)	9.2387	4.14898	889	43	0.0496	20.9	76.4
BPT Court Junction	9.2348	4.15431	952	43	0.045	19.0	69.3
BPT Opposite Council	9.24033	4.15404	876	76	0.045	33.6	122.5
BPT Opposite Baptist	9.24608	4.15234	822	54	0.045	23.8	87.0
In-take Mosel Tank	9.24609	4.15342	823	7	0.045	3.1	11.3
Intake Mosel small Station	9.24658	4.15358	821	4	0.045	1.8	6.4
Mosel Reservoir	9.25153	4.15361	805	18	0.045	7.9	29.0
BPT Street 2	9.25882	4.15441	740	65	0.045	28.7	104.7
BPT OIC	9.26832	4.15781	707	33	0.045	14.6	53.2
Total						261.6	954.4

VI. HYDROPOWER POTENTIALS IN THE SUB-GRID PIPELINES: EPANET 2.0 MODEL DEVELOPMENT

As the network operates completely with gravity, there are several nodes in the lateral lines of the network that suffer from pressures higher than minimum required pressure. The model skeleton in EPANET was done by extracting data from the GIS format shapes files to create input network files for EPANET 2.0 water model software tool. The whole network was divided into different junctions where each junction represented a definite set of houses. Each junction was also given a serial number. N_1, N_2, N_3 .The junctions, pipes and the tanks were drawn on the EPANET software and then assigning to them the required properties in the properties box of each element. Nodal demand allocation was carried out by a method called simple unit loading [45]. Using the buffer method (Fig. 14), for the case of the municipality, the number of dwelling units/housing units at a radius of 200 m for a given node was counted. This number represented the population which draws water from the node. Thus the nodal demand was obtained by multiplying the population in the service node by the unit demand. The per capita consumption per day used in the calculation was 20 liters per person per day [5]. Nodal demand (N_d) was obtained using Equation (3):

$$N_d = \sum P_n . W_c \qquad (3)$$

Where, P_n is the population in each service node and W_c is the water consumption per capita. Fig. 15 shows tables of typical input data that was used for the model.

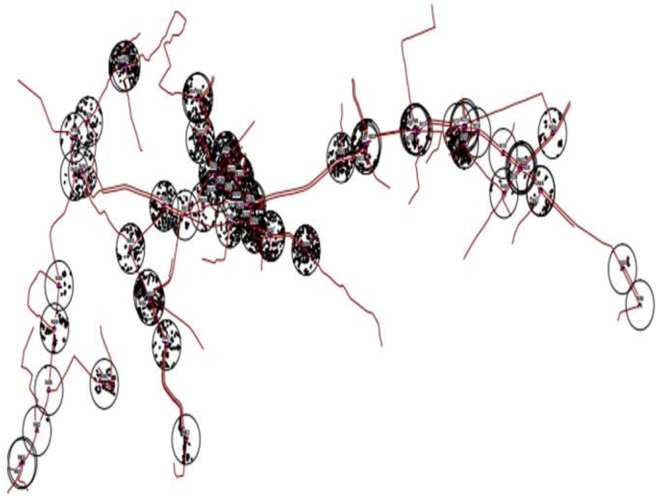

Fig. 14. Counting housing units per node (Buffer method) in the municipality.

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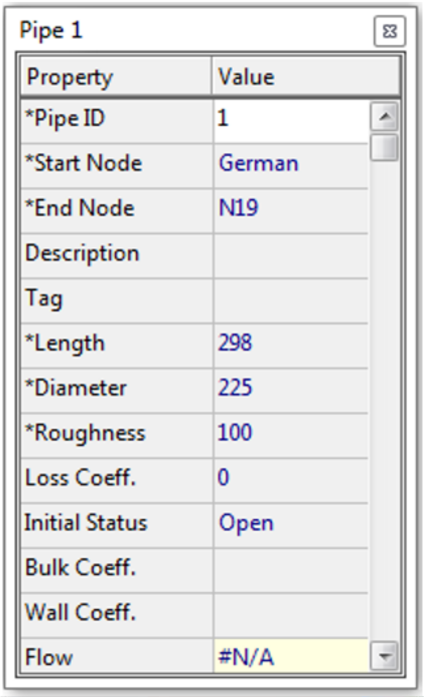
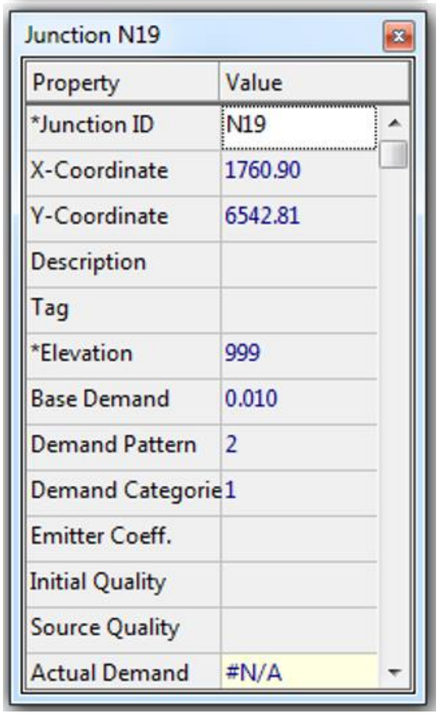


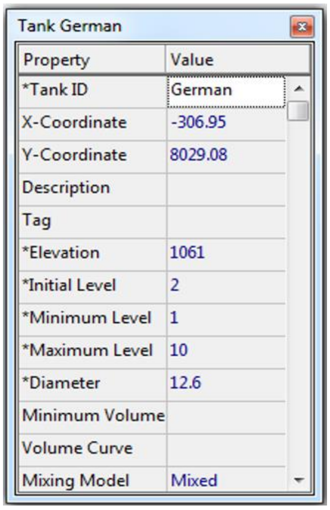
Pipe 1

Property	Value
*Pipe ID	1
*Start Node	German
*End Node	N19
Description	
Tag	
*Length	298
*Diameter	225
*Roughness	100
Loss Coeff.	0
Initial Status	Open
Bulk Coeff.	
Wall Coeff.	
Flow	#N/A



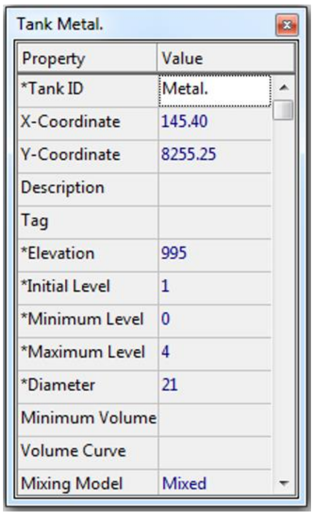
Junction N19

Property	Value
*Junction ID	N19
X-Coordinate	1760.90
Y-Coordinate	6542.81
Description	
Tag	
*Elevation	999
Base Demand	0.010
Demand Pattern	2
Demand Categorie	1
Emitter Coeff.	
Initial Quality	
Source Quality	
Actual Demand	#N/A



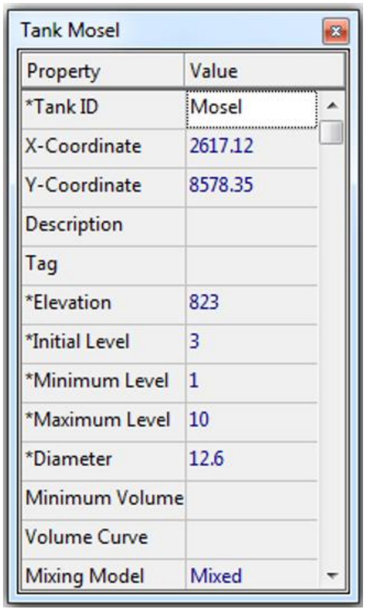
Tank German

Property	Value
*Tank ID	German
X-Coordinate	-306.95
Y-Coordinate	8029.08
Description	
Tag	
*Elevation	1061
*Initial Level	2
*Minimum Level	1
*Maximum Level	10
*Diameter	12.6
Minimum Volume	
Volume Curve	
Mixing Model	Mixed



Tank Metal.

Property	Value
*Tank ID	Metal.
X-Coordinate	145.40
Y-Coordinate	8255.25
Description	
Tag	
*Elevation	995
*Initial Level	1
*Minimum Level	0
*Maximum Level	4
*Diameter	21
Minimum Volume	
Volume Curve	
Mixing Model	Mixed



Tank Mosel

Property	Value
*Tank ID	Mosel
X-Coordinate	2617.12
Y-Coordinate	8578.35
Description	
Tag	
*Elevation	823
*Initial Level	3
*Minimum Level	1
*Maximum Level	10
*Diameter	12.6
Minimum Volume	
Volume Curve	
Mixing Model	Mixed

Fig. 15. Tables of typical input data of the model

Once the hydraulic model of the WDN was developed, an extended hydraulic analysis was run and the best locations of excess pressure to install hydropower plants were assessed. From the results, four nodes, N_3, N_{32}, N_{33} and N_{45} were identified as potential energy recovery sites, with an available excess pressures of 89.58 m, 31.94 m, 38.9 m and 43.89 m respectively. It was ensured that the service pressure reaching the users located downstream was always greater than or equal to the minimal pressure required, 20 m in this case, which can supply a G+4 building from the distribution system. The location of these points can be seen in Fig. 16 and Fig. 17. Flows presenting an exceedance probability of 60 % and pressure head values (Table 5) of the simulation were used to compute the potential energy. An annual energy of 21.81 Mwh of hydropower energy potential was estimated in the nodes of the sub-grid pipelines using Equations (1) and (2). The flow discharge in each pipe was determined using the continuity Equation (4).

$$Flow \quad (m^3.s^{-1}) = A.V \tag{4}$$

Where A is the cross-sectional area of the pipeline and V is the velocity of water in the pipeline.

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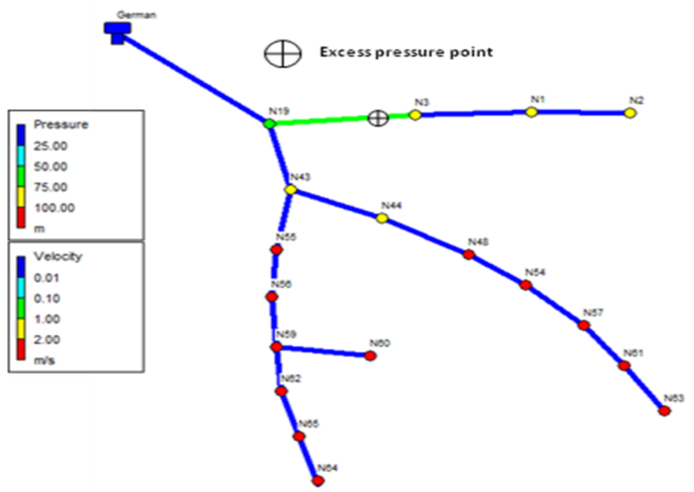

Fig. 16. One potential site for hydropower recovery in zone 1

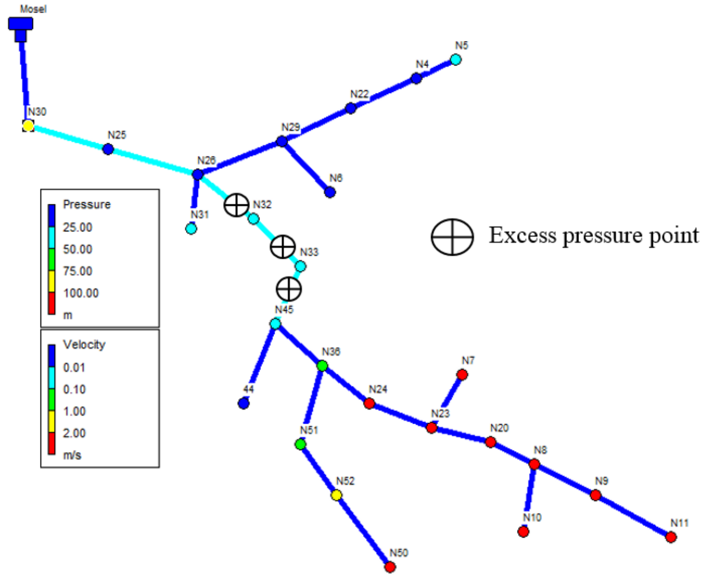

Fig. 17. Three potential sites for hydropower recovery in zone 3

Table 5: Energy potentials in the sub-grids

Node I.D	Velocity (m/s)	Pressure (m)	Service Pressure (m)	Net Pressure (m)	Pipe diameter (m)	Discharge (m3/s)	Potential power(kw)	Annual Energy (Mwh)
N_3	0.21	89.58	20	69.58	0.225	0.00835	5.695	20.79
N_{32}	0.09	31.94	20	11.94	0.09	0.000572	0.0670	0.24
N_{33}	0.08	38.9	20	18.9	0.09	0.000509	0.0943	0.34
N_{45} Total	0.08	43.89	20	23.89	0.09	0.000509	0.1192	0.44 21.81

VII. PRODUCTION OF THE HYDROPOWER POTENTIAL MAP, GEO-REFERENCING AND ASSESSMENT OF EMISSIONS REDUCTIONS

ArcGIS was used to produce a hydro-potential energy map with selected map scale along with the Map legend key for all symbols identification existing in map and labels adjusted in order to view sites easily and read, thus creating a paper map that contains all valuable data needed to be used to characterize the energy potential site. The map was projected to the WGS84 UTM, Zone 32 N northern hemisphere projection. The RETScreen Clean Energy Project Analysis software was used to estimate the amount of greenhouse gases, which could be avoided as a result of harvesting the renewable energy.

VIII. RESULTS AND DISCUSSION

The resulting map (Fig.18) presents a total of 18 sites as suitable locations for the installation of energy recovery devices. Of which, there was approximately 954.4 MWh.year^{-1} in the mains pipelines of the network.

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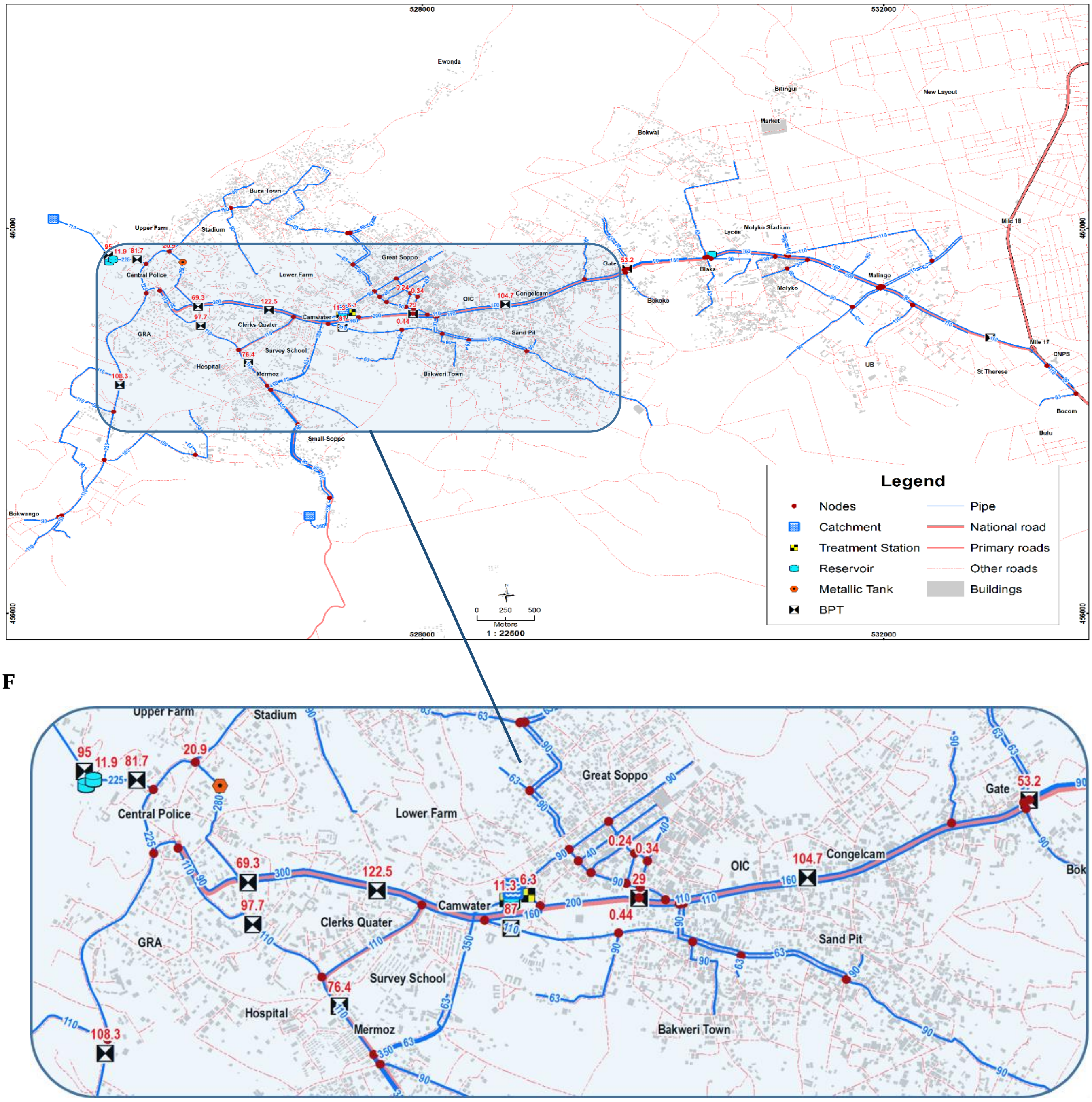

Fig. 18. Hydro-energy potential map of the municipality.

Taking into consideration the 21.81 MWh.year^{-1} in the nodes of the lateral lines, there exists a total of approximately 976.21 MWh.year^{-1} (i.e. 33.5 % of the total energy supplied to the network if 65 % of the hydro energy were converted into electrical power). The most interesting sites included BPT Presidency, BPT Opposite Council and BPT OIC where each could generate energy greater than 100 Mwh per year. A maximum power of 33.6 kW was achieved in BPT Opposite Council, with an annual energy production of 122.5 MWh. The annual potential energy ranged from 0.24 kWh to 97.7 kWh in the residual sites. The nodes energy contribution represented 2.2 % of the total. The maximum energy potential in the lateral lines was produced in node 3 with 20.79 MWh.year^{-1}. Meanwhile the average annual energy potential per site in the network was 54.21 MWh.

IX. CONCLUSIONS AND PERSPECTIVES

This research highlighted the investigation of the potential for hydro energy generation in pressurized water system network in one of the most mountainous cities of Cameroon**.** The methodology proposed proved to be robust for hydropower potential evaluation. The application of the methodology to the WDN of Buea-Cameroon allowed an energy potential map for renewable energy recovery to be created and leveraging the map, locations of potential energy for recovery can easily be identified in the network.

The network was surveyed, the GIS technology was used to organize the data of the network and a geodatabase was developed. Additionally, a comprehensive analysis of the distribution system was carried out using EPANET, a computer aided tool. The results of the assessment show that there is substantial hydropower potential in the main and sub-grid pipelines of the network for electrical energy harvesting**.** This energy potential increases the added value of the water distribution network of the municipality. And if recovered, it could be used to reduce the energy footprint of the water supply network: reduction of energy unit cost needed to satisfy each stage of the water cycle (catchment, pumping, treatment and distribution).The recovered energy could be a power source for both water monitoring sensors and street lighting in the municipality. The recovery of renewable energy will also reduce the environmental pressure to reduce the greenhouse gases emissions. The estimated potential recoverable energy savings constitute a significant portion of the net gain showing the capability of this technology to improve the sustainability of the network. BPTs are generally have a high capital cost and are a potential contamination risk. Thus, replacing them with energy harvesters is vital for the interest of the utility company and the water consumers.

Following the aforementioned benefits, local energy recovery in water distribution networks is an alternative for the development of these systems towards more sustainable and efficient solutions. Hydraulic recovery in water networks is thus a necessary alternative to improve the energy efficiency of the whole system.

However, water demand in the city of Buea is expected to grow. Changes in water demand affects the energy potentials and impacts output capacity at the micro-turbines. Hence, long term flow variation and its effect on the output of the harvesters require further research. We also recommend that in order to achieve technical feasibility assessment of the hydropower plant at the identified sites, the diurnal discharges should be monitored to obtain flow duration curves and the most suitable types of harvesters for each site location. An economic analysis is also needed to estimate water cost savings due to reductions in leakage which may improve the economic feasibility of the installation of the energy harvesters.

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