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Promethee II Approach for Ranking Energy Used for Domestic Water Supply in Maiduguri, Borno State Nigeria

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Abstract: *The sources of domestic water supply in Maiduguri are the surface and underground. The energy sources used for extracting water include the energy from the national grid (PHCN), fossil fuel, and solar with each borehole having a combination energy sources. This paper focuses on the ground water source (borehole,) 175 compounds was interviewed out of which 166 compounds have boreholes as their water source from 68 boreholes in the study areas. and the for-energy source the available energy used for the extraction as ranked based on availability, efficiency and reliability using PROMETHEE (Preference Ranking Organisation Method for Enrichment Evaluation) the research found that solar energy is the most available, efficient and reliable energy source for domestic water supply in the study area. The paper will assist the provider of water supply in identifying the most sustainable energy to use.*

Key words: *Energy, Ranking, Domestic Water Supply.*

1.0 Introduction

Water is the most important substance of the world without which life is not understood by many people, perhaps could not be established on the earth (Manuel, 2017). Water is considered a purifier in most religious faith. Major faiths such as Islam, Christianity, Hinduism, and Judaism among others consider ritual washing with water as appropriate and important (Muhammed, 2015). Water is a vital component to every living organism in the world, especially the human species, more often than not clean water is not accessible to many worldwide. The importance of clean water is more often than not neglected in the developing world. Many people understand the importance of water; however, these individuals tend to not completely understand the importance of water being clean (Moustapha and Sahesh, 2018).

Apart from being seen as commodity for use, it is also viewed as an agent of socio-economic development. Water is an essential component of our economy and is at the center of economic and social development. It is vital to maintain health, grow food, manage the environment and create jobs. It is impossible to overstate our dependence on water, because it has so many different uses in every day's life and it is hard to analyze in terms of economic development (Kailash, 2017). Some 748 million people live without access to clean water, which is roughly one in ten people on the Earth. In addition, for every $1 invested in safe water and sanitation, a yield of $5-28 is refund. This increases economic activity and reduced health care cost, meaning that access to safe water stimulates the economy (Life water, 2021).

In providing this very essential element (water), energy is required both at production, treatment and distribution stages. In fact, processing of water for consumption from both underground and surface sources requires some form of energy supply which may be from the national grid or isolated sources. Energy is a major contributor to the cost of processing water and treating wastewater, it can represent over 30% of the annual operational and maintenance expenses in a typical water treatment plant (Kate *et al*, 2017). Energy and water resources are highly connected in cities' water agencies using energy to acquire, extract, pump, treat, and discharge water supply to the end user, while residents need energy to heat water in buildings (Erick *et al,* 2020).

Energy is of primary importance for water management and development. The water infrastructure solely relies on energy throughout its value chain: groundwater extraction, transportation, purification, distillation, distribution, collection and waste water management and treatment. Energy does not only play an important role in the functioning of water infrastructure, but also in the optimal cost, (UNDESA, 2019).

In the United Kingdom, water sector consumes 3% of the electricity the country produces (for pumping, water treatment and management) and generate 1% carbon dioxide emission. Not only is the water sector energy intensive, but against a backdrop of global demographic growth in the coming decades, water is set to become an even rare resource. So, the challenge is clear, how can the sector energy efficiency be improved whilst also securing a universal water supply? (Veolia, 2019). Power supply is an important aspect in the supply and distribution of water, the two are in separable. Electricity is required in the pumping of water from their source to the consumers; when the source is the ground water, power is required to pump water from the ground to the reservoir before finally released into the distribution network. This shows strong connection between energy supply and sustainable urban water supply especially for domestic use.

1.1 Aim and Objectives

The aim of this paper is assessing the various sources of energy used in providing water for domestic use in Maiduguri the Borno state capital, it has the following specific objectives:

i. Identifying the sources of water supply in Maiduguri the study area
ii. To rank the energy sources used for water supply and
iii. To identify the most sustainable energy source for water supply.

The scope of the research covers four high density residential neighborhoods in Maiduguri from the four cardinal points of north, south, east and western parts of the town refer to fig one. The criteria used for ranking of the sources are energy availability, efficiency and reliability. Several researches have been undertaken by different scholars using the PROMETHEE tool for data analysis. See table 1 for the researches' conducted.

Table 1: Application of PROMETHEE II as Tool for Analysis in Water and Energy.

S/no	Name of authours	Topic	Publishers	Year of publication
1	Mukta Sapkola, Meenakshi Arora, Hector Maloa, Ashok Sharma, Maginus Moglia	Integrated evaluation of hybrid water supply systems using a Promethee-GAIA Approach	MDPI Journal water volume 10 issue 5.	2018
2	Haongju Zheo, and Wei Li	Reviewed Promethee II for improving efficiency in Emergency response	Procedia computer science vol. 17	2013
3	Martins Bertononi, Adele Boggio, Federico Dell Anna, Critian Beachio, Marta Baltero	An application of the Promethee II method for the comparison of energy requalification strategies to design post carbon cities.	http// www.awins press.com/journal energy	2022
4	Durin Bojava and Nad Lucija	Contribution to the methodology for the selection of technology most appropriate variant of the water supply system by using Promethee.	International journal of sustainable energy development. Vol. 5	2016
5	Bojan Durin and Lucija Nad	Contribution to the methodology for the selection of technologically most appropriate variant of the water supply system by using Promethee	International journal of sustainable energy development volume 5 issue 1 June 2016	2016

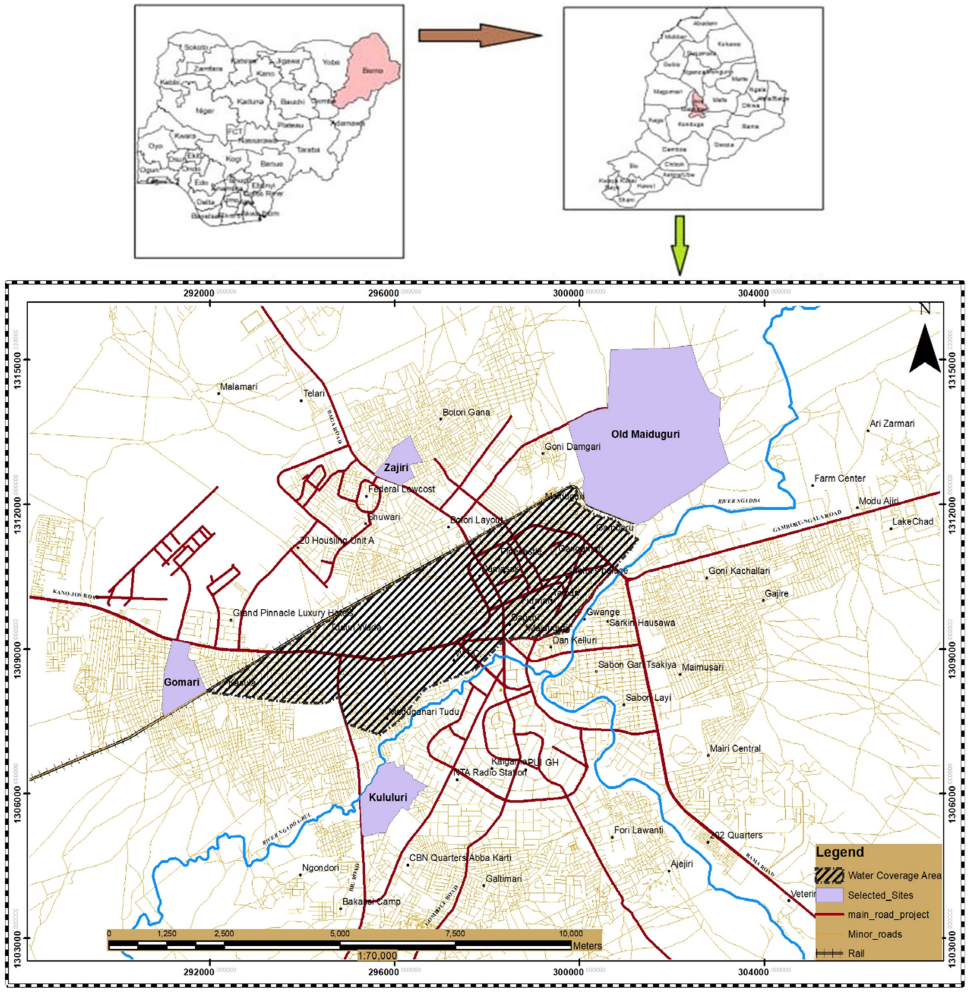
2.0 Methodology

To archive the first and second objectives, the research used questionnaire to obtain information from borehole owners/operators for the study. A total of 68 boreholes used for public water supply was identified in the four selected study locations of Maiduguri and 175 questionnaires

was administered to the inhabitants of the study area. The information collected was analyzed using SPSS version 26 and frequency distribution was used to present the data. A frequency distribution is a table that divides a set of data into a suitable of numbers, classes, showing also the number of items belonging to each class. Properties of frequency distribution relating to their shape are best exhibited through the use of tables and graphs.

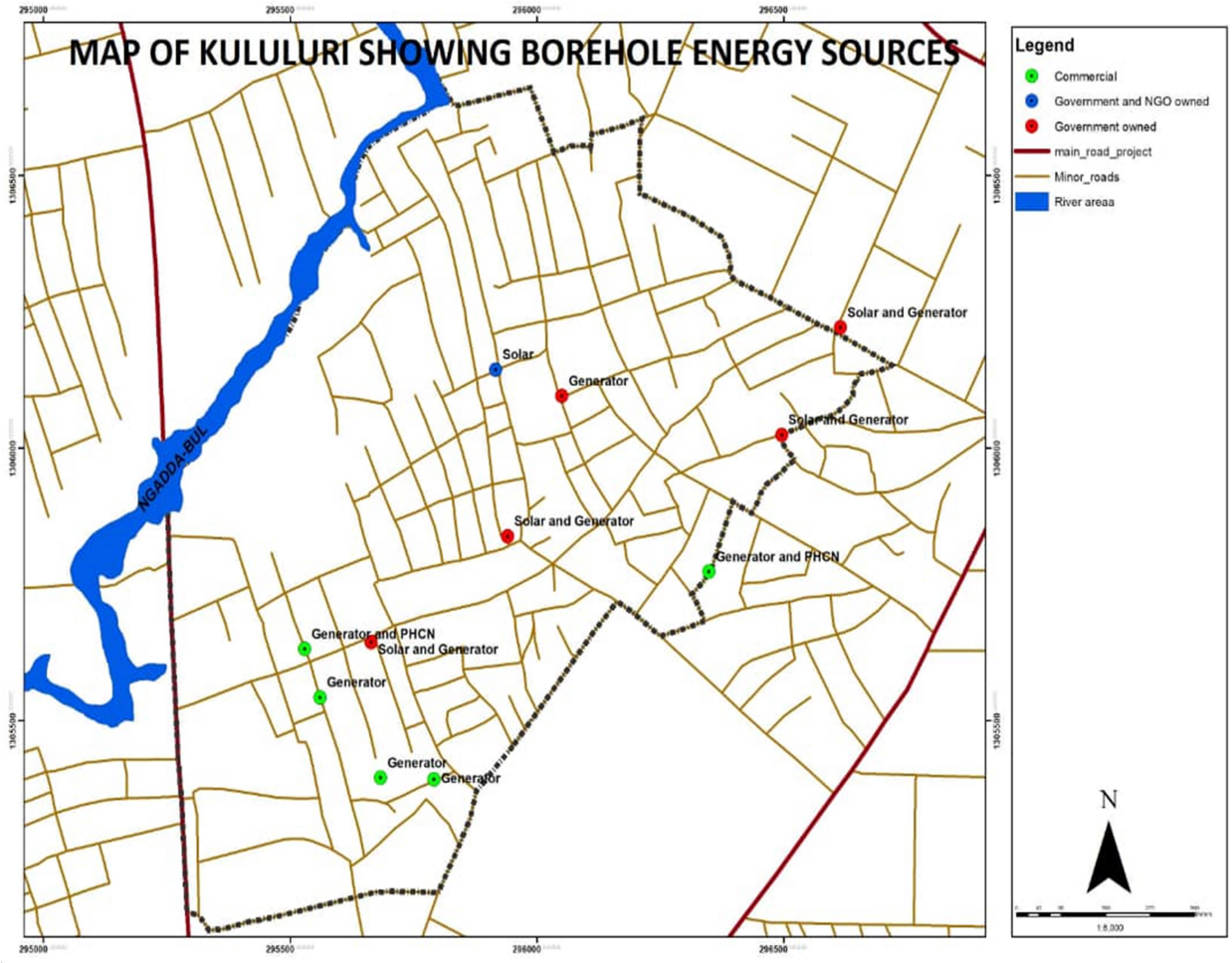
To find the location of the water sources mobile topographer application was used in the field with approximate accuracy of 0.2 meters the data collected was then transferred to Google

Earth image and processed using ArcGIS to produce maps showing the locations of boreholes in the stud area. See Figures, 2, 3,4 and 5 respectively. To achieve the third Objective PROMETHEE II was used to rank the various sources of energy used for domestic water supply in the study area.



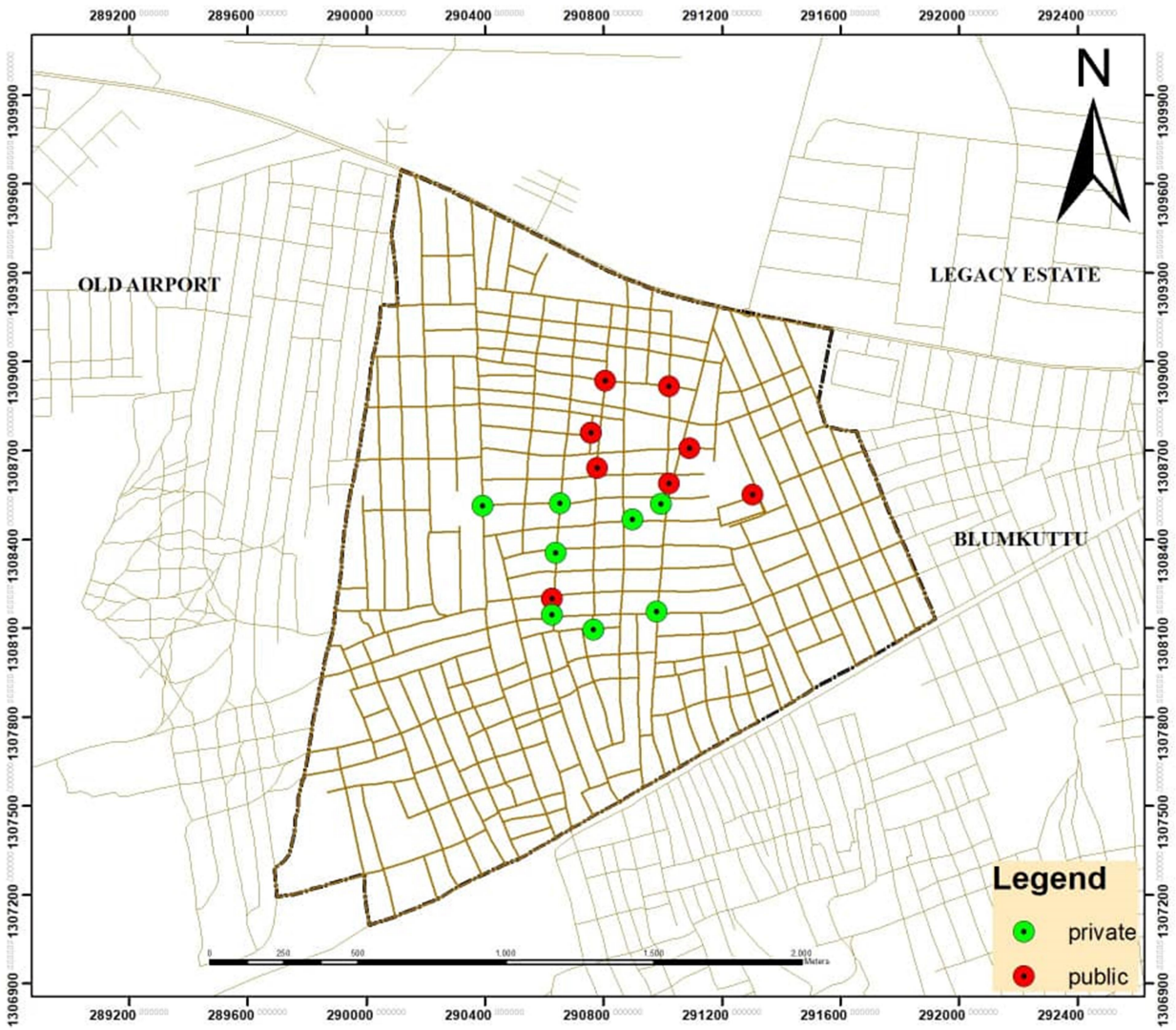
Source: GIS Lab. RAMAT Polytechnic, (2019)

Figure 1: Map of Nigeria Showing Borno state, showing Maiduguri Metropolitant showing study area



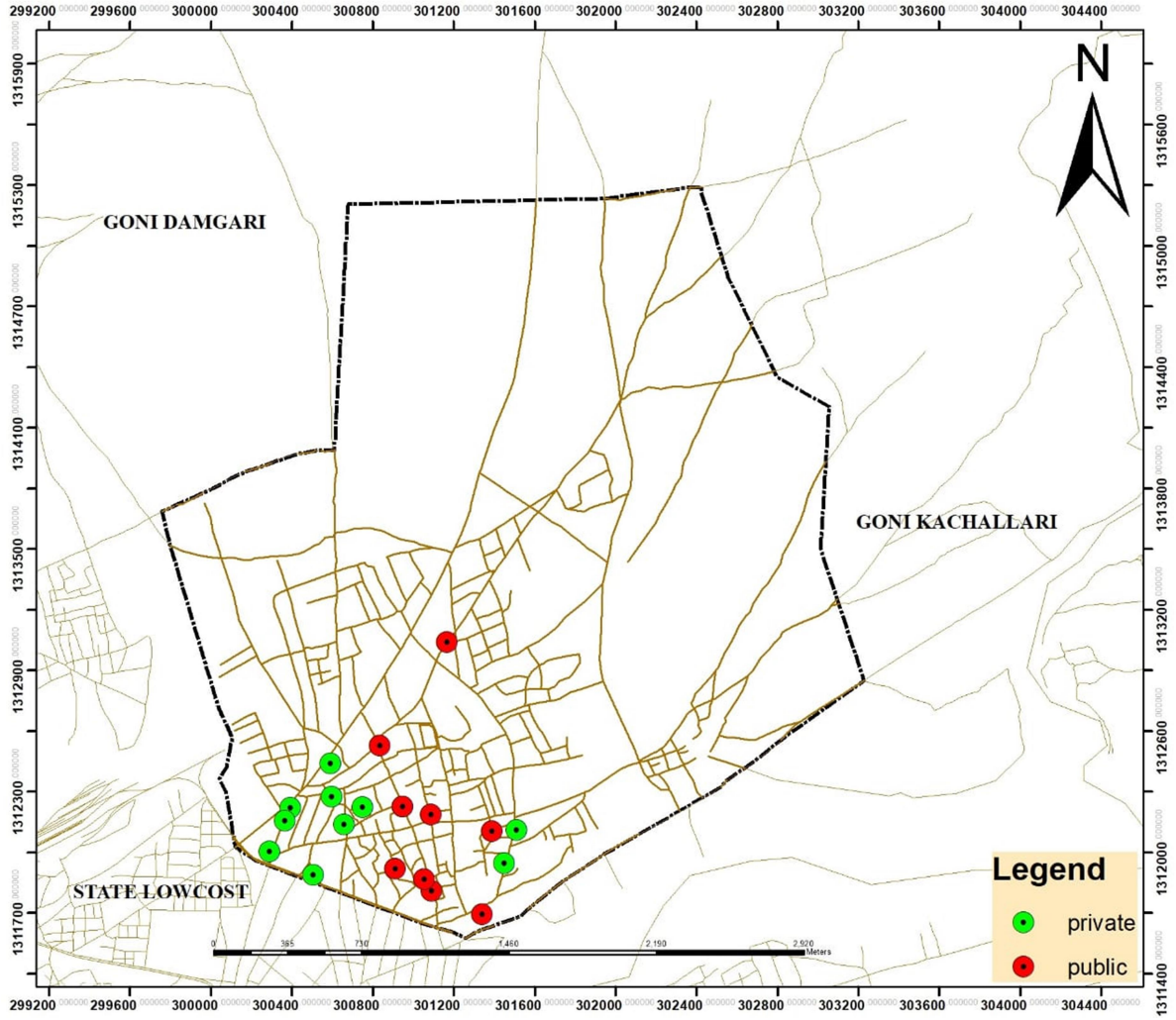
Source: GIS lab. Ramat polytechnic Maiduguri (2021)

Fig. 2 Map of Kukuluri showing boreholes location and their energy sources.



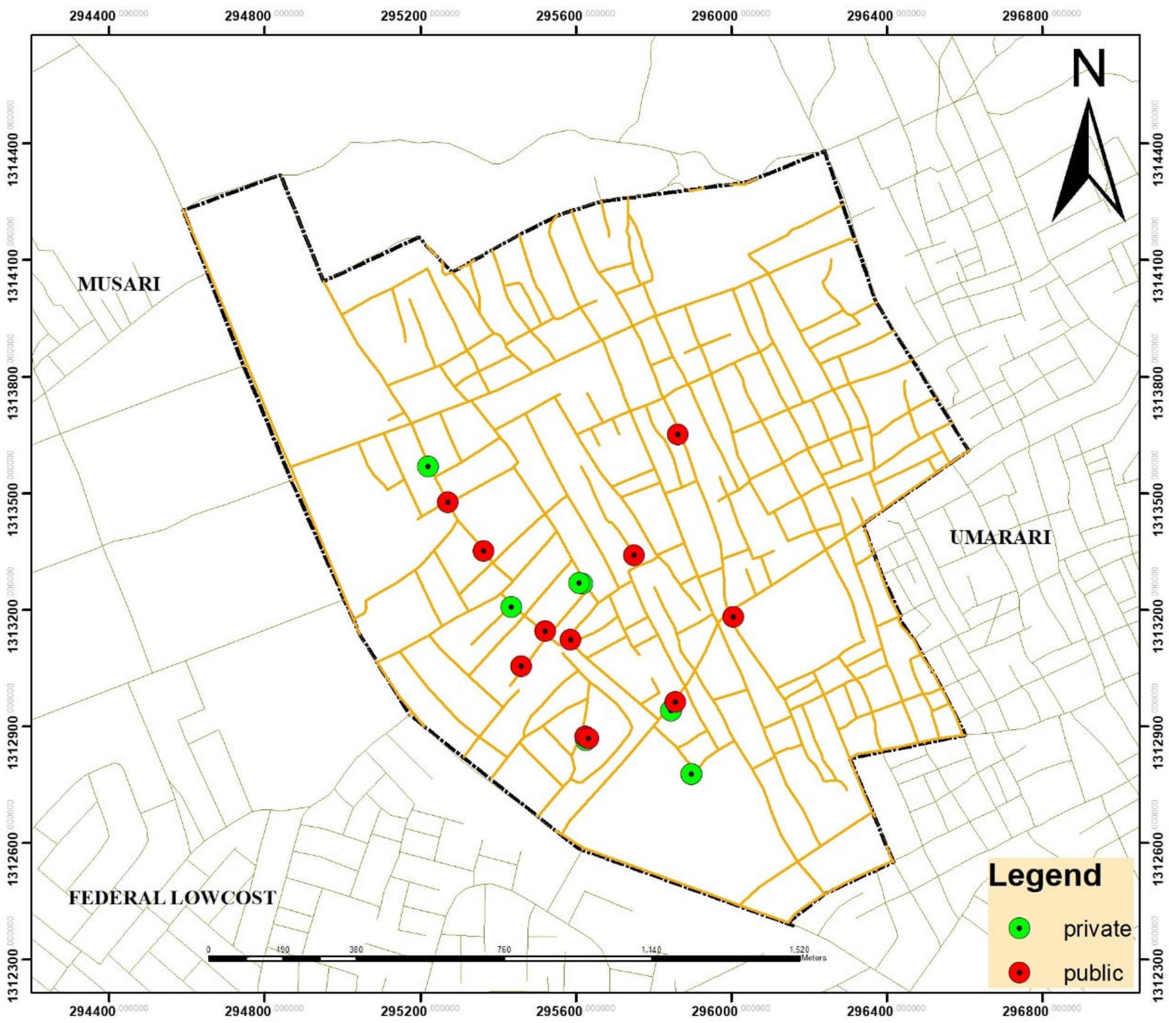
Source: GIS lab. Ramat polytechnic Maiduguri (2021)

Figure 3 Map of Gomari showing boreholes the four-study location



Source: GIS lab. Ramat polytechnic Maiduguri (2021)

Figure 4 Map of old Maiduguri showing boreholes the four-study location



Source: GIS lab. Ramat polytechnic Maiduguri (2021)

Figure 5. Zajeri showing boreholes the four-study location

3.0 Result and Discussion

Water an essential element in the survival of human is source in many ways, this include the following: Ground water, Surface water, Rain water

Ground water is the water present beneath earth surface in soil pore spaces and in the fracture of rocks formation. A unit of rock or an unconsolidated deposit is called an aquifer when it can yield a useable quantity of water. Ground water makes up about twenty percent of the world fresh water supply, for example ground water supplies drinking water for 51% of the total United State population and 99% of rural population. Arun (2010). Ground water is usually good quality water as it often buried at significant depth. The major ways through which ground water exploited for domestic use is either the well or bore hole.

A well (shallow well) is an excavation or structure created in the ground by digging, driving or drilling to access liquid resources usually water these are usually less than 30m

depth. The oldest and most common kind of well is water well, to access ground water in underground aquifer. The well water is drawn up by human, animals or pumps using container such as the bucket. Hand dogged wells are excavation with diameter large enough to accommodate one or more people with shovels digging down to below the water table. There are inexpensive and low techs as they use mostly manual labour to access ground water especially in rural location of developing countries. They may be built with a high degree of community population or by local entrepreneurs who are specialized. Wells where first constructed at least eight thousand years ago as historically, varying in construction from simple scoop in the sediment of a dry water course to the gnats of Iran and step wells and sulkies of India. Placing a lining in the well shaft helps create stability and lining of woods or wicker woods date back at least as far as the Iron ages.

A borehole (deep well) is a narrow shaft bored in the ground vertically for the purpose of extracting water and other liquid. A bore hole used as water well is completed by installing a vertical pipe (casing) and well screen to keep the borehole from caving, this also helps prevent any installed pump from drawn on sand and sediments. It can be drill using rig or a hand operated rig. Bore holes are operated either with the submersible pumps which uses electric power or hand pumps which are operated manually.

Surface water is water that collect in the ground or in stream, rivers, lakes, reservoirs or oceans. Surface water is constantly replenished through precipitation and lost through evaporation and seepage into the ground water supply, the quality and quantity of surface water varies from one place to another and over time due to factors as geology, climate and surrounding land use. According to the United State Environmental Protection Agency (2019), 68% of community water supply system user received their supply from surface water source such as lake and rivers. This source of water supply is capital intensive as huge dams and treatment plants are constructed and connecting pipes are laid from the dams to the treatment plants and finally to the communities. It also requires large amount of energy to operate in some cases a mini energy generating plant attached to them.

Rain water collection in regions where rainfall is abundant and frequent, rain water can be a good source of water supply for families and small communities. The storage of rainwater is particularly important in areas with good long dry season or where ground water or surface water is difficult to be polluted. This is one of the oldest means of collecting water for domestic purpose. Rain water has several advantages such a s being free and relatively clean, usually reliable, even if it rains only twice in a year, it can easily be constructed and maintain at low cost. For example, in India simple stone rubbles structure for impounding rain water date back to the third millennium BC.

Rain water can be collected in several ways some of which include the roof catchment; water can be collected from roofs made of corrugated metal or equivalent, concrete etc. pipes feed water from the roof and gutters into a collection tank where it can be stored until needed. However, to prevent contamination from dust, birth dropping and other pollutant, measure such as covering of the containers and cleaning of the mesh screen gutters and pipes used regularly.

Table 2: Source of water supply

Water source	Frequency	Percentage (%)
Borehole	166	93.3
(Surface water) Pipe from public mains	9	5.1
Total	**175**	**98.3**

Source: Field survey, 2021)

A total of 175 questionnaires was administered to the inhabitant of the four selected settlements of old Maiduguri, Zajeri, Gomari and Kukuluri. Finding from data collected shows that 93.3 % of the house get their source of water from the bore holes, while only 5.1 % from the pipe from the Maiduguri surface water supply.

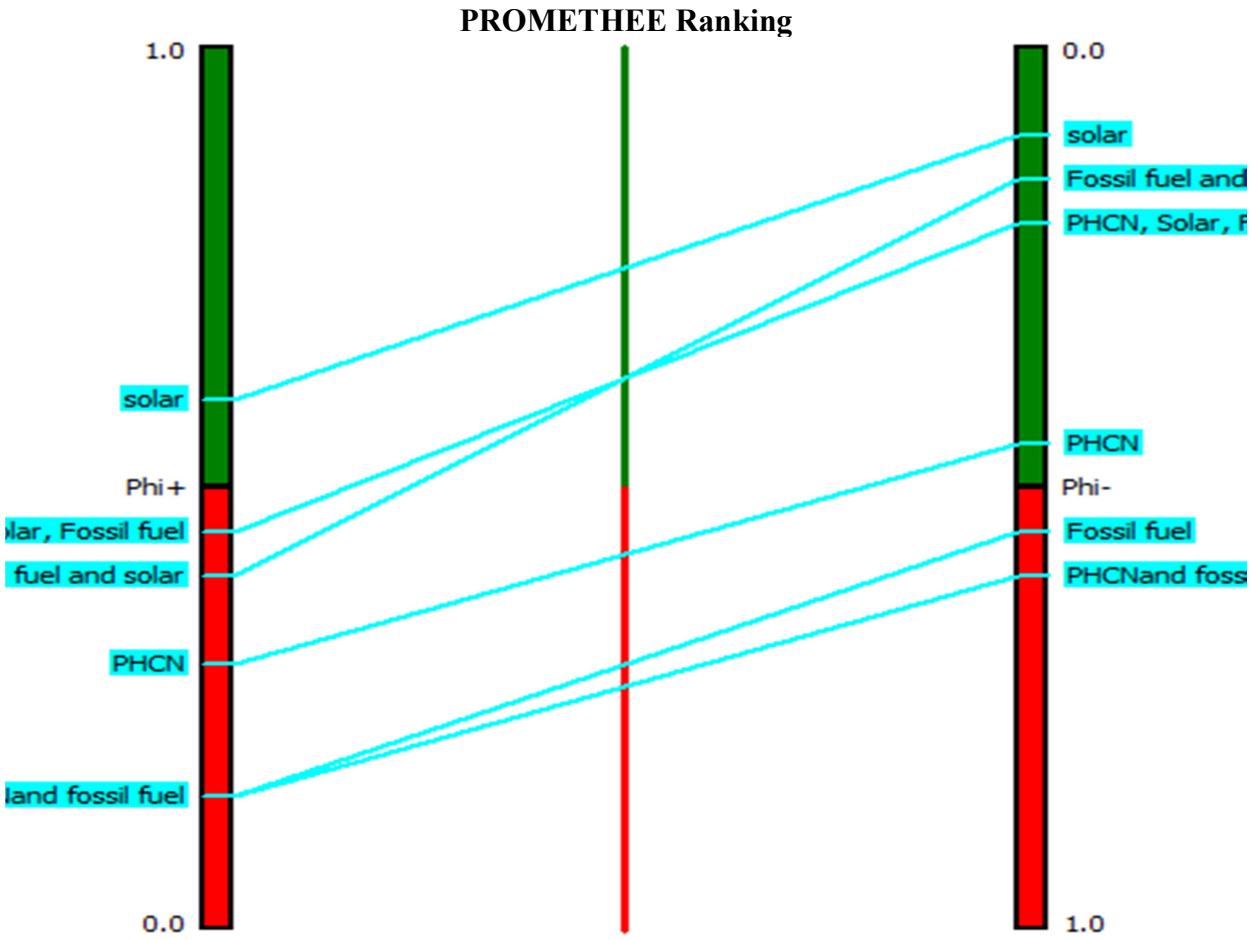
Table 3: Source of energy for the bore hole

Source of energy	Frequency	Percentage (%)
Fossil fuel	9	13.2
PHCN	1	1.5
PHCN AND Fossil fuel	40	58.8
Solar	10	14.7
Fossil fuel, PHCN and Solar	6	8.8
Fossil fuel and Solar	2	2.9
Total	68	100.0

Source: Field survey, 2021

A total 68 bore holes was identified in the four selected study locations which are old Maiduguri, Zajeri, Gomari and Kukuluri settlements. The data energy source from the combination of the National grid (PHCN) and fossil fuel (generators) take the highest percentage of 58.8% followed by solar and fossil fuel (generator) with 14.7% and 13.2% respectively and the lowest source of energy are from National grid (PHCN) and fossil fuel / solar with 2.9% and 1.5% respectively. See Fig. 2,3,4 and 5.

In comparing the energy sources used for water supply in the study area, a specialized software which has been used by several researchers in similar studies to this research was used; it is the PROMETHEE approach. The academic version was used to compare the available energy used for water supply in the study area, the criteria property was modified to serve the purpose of this research. The first stage involves the assigning a name to the first criteria which is Energy Availability an acronym EA, then a unit as assigned as 5 point and then the scale is declared as qualitative. The same steps were done for all the four criteria. The data obtained from the government agency charged with water supply was inputted in the software. PROMETHEE II diamond was used to show the Ranking of the energy sources.



The PROMETHEE partial ranking shows the ranking of the energy sources in lines of Ph+ and Ph-. The result indicate that solar energy source is at the top in both the Phi+ 1.0 and Phi-.0.0 while, PHCN (National grid), solar and fossil fuel is second in Ph+ and fossil and solar is second in Ph-. The result confirm that Solar source of energy is most sustainable based on the criteria set.

Similar studies were conducted by Gessica and Marcele, (2018) on a multi criteria decision making approach to balance water supply- demand strategies in water supply system in semi-arid regions of northeast Brazil the study was able to balance water supply-demand strategy through selecting alternatives for both supply and demand which is reducing the demand and increasing the supply. Julia *et al.,* (2010) evaluated heat and power supply alternatives for a municipal area in Germany the result of the study based on multimulti-criteria cycle shows that, renewable energy technologies are more competitive with convectional alternatives for supplying heat and power. In another research Martina *et al.,* (2022) conducted research using applied PROMETHEE II to compare energy requalification strategy to design post carbon cities a case study of Turin,(Piedont Region Italy) the comprehensive assessment of performance on energy based on economic nature with the intention of guiding local government in the study area . Mukta et *al.*, (2018) conducted research on Integrated Evaluation OF Hybrid water supply system using a PROMETHEE-GAIA Approach in northern growth area of Melbourne, Australia

the studies propose a model to aid a groudecision-makersakers to establish a portfolio of feasible action (alternative) that are able to balance water supply – demand strategies.

Conclusion

The paper has identified the most sustainable energy sources to supply water for domestic use in the study area, based on energy availability, reliability, and affordability. using PROMETHEE II. Because of the combination of multiple energy sources on single bore, the package has given a clear result of the finding in a graphical form. This study can be applied to places where energy for the supply of domestic is scares and solar radiation is available for usage.

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