# PREFEASIBILITY STUDY FOR MINI HYDROPOWER DEVELOPMENT IN KUJE AREA COUNCIL OF ABUJA, NIGERIA.

## A CASE STUDY OF THE RIVER SHETIKO, KUJE AREA COUNCIL ABUJA, NIGERIA

**BY**

**Aguda, Richard Eniola (**B. Eng, MBA**)**

**(PG6306411)**

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**College of Engineering**

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**Certification Page**

I hereby declare that this submission is my own work towards the MSc RETs and that, to the best of my knowledge, it contains no material previously published by another person nor material which has been accepted for the award of any other degree of the University, except where due acknowledgement has been made in the text.



**Aguda, Richard Eniola** PG6306411 26th April, 2014

……………………………….…… ……………………… ……………

Student Name & ID Signature Date

Certified by:

**Dr. Takyi Gabriel**

……………………………………..… ……………………… ……………

Supervisor(s) Name Signature Date

Certified by:

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Head of Dept. Name Signature Date

# Abstract

The Nigeria government in her energy policy has empowered the private sector to implement power generation projects. A national policy which is aimed at generating widespread participation and involvement of the private sector in implementing power projects.

The development of hydroelectric power generation has been facing many issues and challenges. Despite the difficulties faced by the sector, hydroelectric power generation promises to yield a number of significant or positive benefits for the country and is an energy source indispensible for stable supply of electric power in the future.

The focus of this work is on the evaluation of the viability of harnessing small hydropower potential available from the River Shetiko for the electrification of the community. Critical parameters such as Power, Head and Flow rate as well as the unit cost of generation, and the unit cost of electricity to the consumer are determined. The results show that the 657.76 kW power obtained using 20 m head and 5 $m^3$/s flow rate would serve the 200 housing unit to a reasonable extent at an estimated 2kW/Household both power and light loads. With an assumption of construction cost per kW of 2,000.00 USD, the total capital cost is 1,315,520.00 USD. The unit energy cost is 0.11 USD (N18/kWhr). The project would give 5,761,977.60 kWh/yr energy in a year and 475,363.15 USD annual revenue; the simple payback period will be approximately three (3) years.

The results indicate that River Shetiko is situable for the production of hydroelectric power. The hydropower generated would enhance the quality of life of the people living in Kuje and similar site within the country. This will eventually lead to poverty reduction since jobs will be available as small scale industries spring up.

With the 20 meters head and a flow of 5.0$m^3$/s which was recorded at the lean period, given a power potential of 657.76kW, the site is recommended for Mini-Hydro power.

The successful completion of this project would form the basis of a “best practice guide” for future mini-hydro implementations and hence have a significant influence on many communities

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## Acknowledgment

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Finally, the author wishes to express his special thanks to all his fellow Renewable Energy Engineering students and other promoters of green energy and low carbon emission worldwide for their contribution to and promotion of renewable energy.

## Dedication

This project work is dedicated to the Glory of God, the

Source of Renewable Energy and Father of Light.

**List of Acronyms and Abbreviations**

| | |
|---|---|
| **kW** | Kilowatt |
| **MW** | Megawatt |
| **kWh** | Kilowatt Hour |
| **MWh** | Megawatt Hour |
| **GWh** | Gigawatt Hour |
| **GPS** | Global Positioning System |
| **B.C.** | British Columbia (BC) |
| **D.C.** | Direct Current |
| **A.C.** | Alternating Current |
| **CHP** | Combined Heat and Power |
| **HRSG** | Heat Recovery Steam Generators |
| **HEPP** | Hydro Electric Power Plant |
| **CCPP** | Combined Cycle Power Plants |
| **PRF** | Pressure Reducing Facility |
| **PDD** | Project Design Document |
| **PRV** | Pressure Reducing Value |
| **UV** | Utra-Violet |
| **DPR** | Detailed Project Report |
| **LCA** | Life Cycle Assessment |
| ***CRD*** | *Capital Regional District* |
| **m.a.s.l.** | meters above sea level |
| **TBM** | Tunnel Boring Machine |

**CFD** Computational Fluid Dynamics

**FDC** Flow Duration Curve

**PDC** Power Duration Curve

**SOP** *BC Hydro's* Standing Offer Program

**SHP** Small Hydro Power

**IRR** Internal Rate of Return

**USD** United States Dollars ($)

**tCO2** Tones of Carbon Dioxide

# Chapter One

# Introduction

## 1.1 Project Overview

Most states in Nigeria have one or two rivers flowing through them. Some of these rivers have great potential to generate electricity. A good number of these sites have not been harnessed for energy production. This may be due to the availability of cheaper electricity from the national grid and by the availability of portable, flexible, low cost diesel generators.

Although, diesel generators are cheap to buy, the rise in the cost of oil has made diesel generators expensive to operate. The National electric grid does not include a number of small communities, resources-based businesses, farmers, and lodge owners: people that are connected to the national grid who are paying huge amount of money for their independent way of life. To such people, who are close to a flowing river around them may consider very seriously hydropower, which offers a stable, inflation-proof source of electricity, using proven technology.

According to Canadian Small Hydropower Handbook (1989), Small hydro (one of which is mini hydro) installations have, historically, been cheap to run but expensive to build. That is changing now, with smaller, lighter and higher speed turbine equipment, lower cost electronic speed and load control systems and inexpensive plastic piping. Although capital investments are still higher than investing in diesel equipment of comparable capacity, the long life and low operating costs of small hydro make it an attractive investment for many applications.

## 1.8 Background of the project:

In recent times, there has been a growing concern over global environmental issues regarding global warming and acid rain as a result of a number of activities and processes which have to do with the usage of fossil fuel. There is a need to accomplish the targeted suppression of $CO_2$ and other greenhouse gas emissions contained in the action plan on global warming under the United Nations Framework Convention on climate change. With regards to energy supply, the aggressive promotion of the development and adoption of non-fossil energy sources has become a prominent.

Abuja, the capital city of Nigeria, located in the center of Nigeria within the Federal Capital Territory (FCT), is a planned city, and was built mainly in the 1980s, has a good number of rivers. Most of these rivers are potential sites for hydropower generation. River Shetiko in Kuje Local Government Area is one of these rivers with enormous potential for hydropower development.

**1.3 Statement of the problem:** Rampant Power epileptic, population growth, increase unemployment rate/increase poverty level, underutilization of natural resources and the problem of green house gas effect have continued to pose a serious problem to the nation and especially the Federal Capital Territory whose population growth has recorded the highest in the country in recent times. Something has to be done fast concerning the present power situation of this territory which ultimately has a direct impact on the economy of its occupants and of course on the nation as a whole.

In other to propose a solution to the above stated problems, the author of this project work took it upon himself to carry out a study on the possibility of harnessing power from river Shetiko which flows through the community.

## 1.4 Project Objectives:

The following objectives have been put together to solve the problems identified above.

**1.4.1** **T*he main objective*** is to carry out preliminary evaluation of the viability of harnessing hydropower potential available from the river Shetiko.

**1.4.2** ***The specific objectives are:-***

- To obtain flow rate and head of the river
- To calculate the estimated power potential of the river
- To determine the types and ratings of turbine that could be used in designing the scheme.
- To determine the load demand of the community

***1.5*** ***Limitations:*** The issue of getting a sponsor on time for this project has been too slow and probably the project would have reached its conclusion by the time a positive response is secured from my targeted sponsor(s). However, the researcher had no option other than to confine himself to the available financial resources within his reach including assistants from family members.

Accessing accurate secondary data was another limitation. Hence, the researcher used only the primary data obtained from the field.

## *1.6 Project Layout:*

The project starts with the introductory chapter, where the overview and background of the work are discussed followed by the statement of the problem. The objectives of the project are stated next and the limitations to the work briefly listed out. Project layout and definition of terms are the concluding aspect of this chapter.

In Chapter two, a review is carried out on small hydro power generally. The different types of hydropower available are written about from information gathered from textbooks as well as projects written on hydropower, Small, Mini and Micro hydropower inclusive.

Chapter three focuses on the case study while chapter four is on material, method and results of the project. Here, data obtained during the various visits made to the project site are accurately tabulated. From this data, the velocity of the river, the flow rate and the head of the river were calculated from which the available power of the river was obtained.

Chapter five deals with the discussions Conclusions and recommendations respectively.

***1.7 Definition of Terms:***

**Hydropower**: energy generated from the movement of masses of water, such that hydroelectric power plants transform the flowing water from river or stream into electricity. This renewable energy resource is classified based on capacity, namely pico-hydropower, micro-hydropower, mini hydropower small and large-hydropower

**Pico Hydropower:** : its capacity is between 0 to 5kW

**Micro Hydropower**: its capacity is between 5 to 100kW

**Mini Hydropower:** : its capacity is between 101kW to 1MW

**Small Hydropower:** : its capacity is between 1 to 10MW

**RETScreen:** RETScreen Clean Energy Analysis Software developed by Natural Resources Canada.

# Chapter Two

# Literature Review

## 2.1 An Introduction to Electricity

Man has been making continual efforts to improve upon his ability to convert available energy into forms that are useful to society. In 1752, Benjamin Franklin popularized the idea that electricity could be captured and used as he hooked a kite up to a key and flew it into a storm sending shocks to the touch and sparks. (National Energy Education Development, 2010).

Alessandro Volta, an Italian scientist, was the next prominent figure. He created the first electric cell by soaking paper in salt water. Once it was really wet, he placed zinc and copper slugs on opposite sides creating a chemical reaction which produced an electric current (National Energy Education Development, 2010). Volta has since been honoured by the SI unit system, with the Volt (V) being a measure of electromotive force.

In hydro power generation, the ingenious English physicist and chemist Mr. Michael Faraday must be mentioned. He is credited with discovering the magical process that happens when a magnet is passed through a copper wire, producing an electric current (National Energy Education Development, 2010). He also discovered the physical electromagnetic force and benzene, and popularized the terms Volta had worked on: anode, cathode, electrode, and ion. He has also been honoured by the SI unit system; Farad (F) is a measure of capacitance and the Faradays Constant is a known value of the charge on a mole of electrons. Almost all the hydro electricity that is harnessed today comes from a process involving magnets and coils of copper wire. These processes and principles can be commonly seen in electric generators and electric motors.

In 1879, a switch went off in Thomas Edison's brain and all his years of hard work trying to find a filament in a light bulb came to fruition as he took common cotton thread and soaked it in carbon, creating a long lasting incandescent light (National Energy Education Development, 2010). 1879 also marked the year of the first hydro electric power plants (HEPP), which occurred at Niagara Falls (National Energy Education Development, 2010). Edison then opened his own power plant in 1882, and provided limited electricity to the very local vicinity using a direct current (DC) at a steep price of $5.00 per kWh (National Energy Education Development, 2010). In 1895, George Westinghouse initiated a new HEPP at Niagara Falls and was able to transmit this electricity over 200 km to customers using an alternating current (AC) (National Energy Education Development, 2010). This was just the beginning of an avalanche of change that would occur on the electrical landscape.

The story of humans and electricity is a complex and continuously evolving one. Being that, one thing has remained relatively constant and that is the ever increasing demand for energy that humans are after. We have a growing thirst and hunger towards the availability, acquisition, storage, and use of energy, especially in the form of electricity. In fact, "in 1920, only two percent of the energy in the U. S. was used to make electricity. Today, about 41 percent of all energy is used to make electricity" (National Energy Education Development, 2010). As the global demand for technology increases, and as economically depressed countries develop, this trend will inevitably continue.

**2.2) History of Hydropower:**

The power of water has been used by humans for thousands of years. The Greeks used water in wheels where they grind wheat into flour more than 2000 years ago (U.S. Department of Energy, 2008). 19th century was the turning point for the utilization of water power. The improvements in technology and need for electricity replaced the waterwheels with modern day turbines (Korkmaz, 2007).

Hydropower also called hydraulic or water power, is essentially a way of using water's kinetic (mechanical) and/or potential energy to perform a useful task or process. The word "hydro" is Latin for "water". Water power has been used for thousands of years in various forms of irrigation (and as municipal water), and by various geographically located people on Earth. It has been used to power many different types of mills, cranes, and lifts, and has also been used as a leveling device, clock, seasonal indicator, and for many other functions. Most importantly, water is needed in the human physiological processes and is paramount for most of the life and many of the naturally occurring processes on this planet.

Hydropower, and life, would not exist if it was not in part for the hydrologic or water cycle (Figure 2.1). This water cycle has infinite starting points. These include the processes that water undergoes as it is heated by the sun and evaporates into the air, is transported, and then is deposited back to the surface of the Earth in the form of precipitation. It is important to acknowledge the delicateness and the complexity of the water cycle. Our understanding of the water cycle has evolved over time and it is intimately studied for many of its complexities.

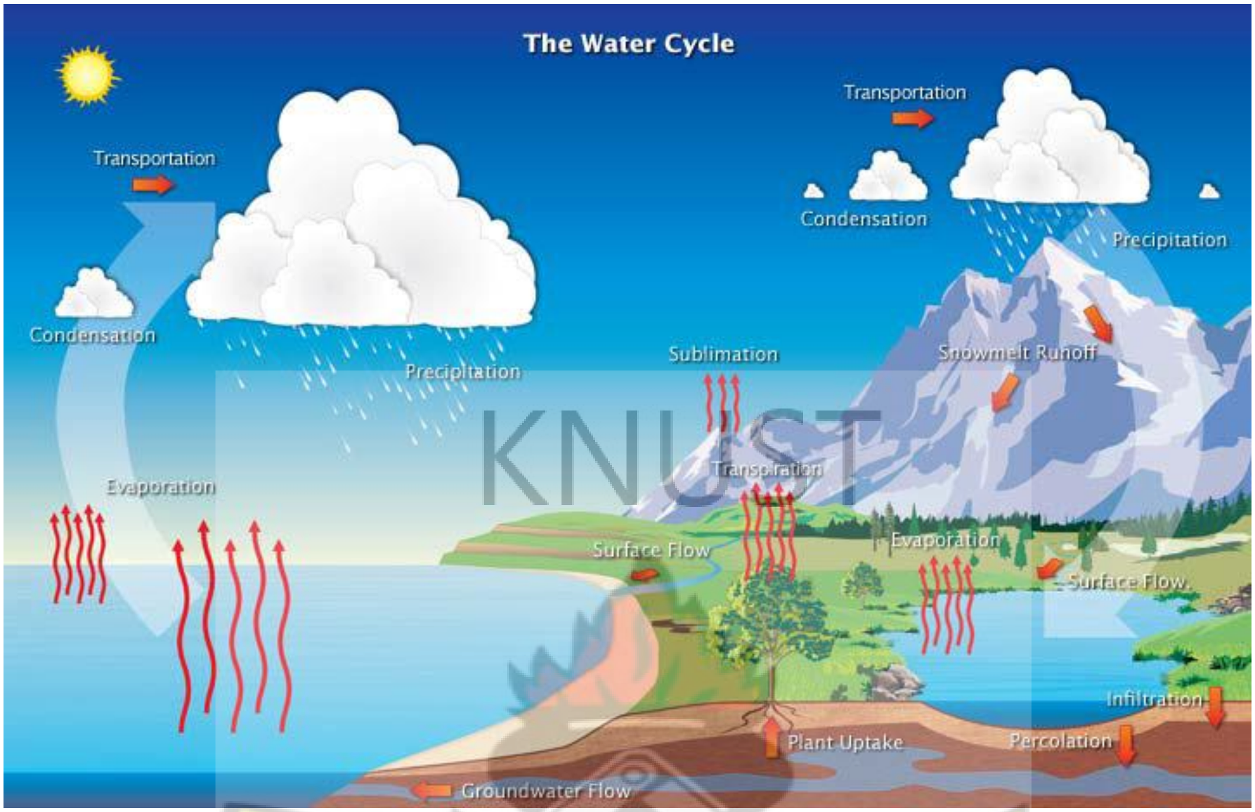



**Figure 2.1: The water cycle, as depicted by NASA (NASA, 2010)**

The current understanding of the water cycle incorporates the many paths that water travels above, below, as well as through the earth and the many varieties of water columns on this planet. This cycle also includes the paths in and out of the plant and animal cycles (photosynthesis and respiration) and through both the short and long term reservoirs. Many academic endeavors and scientific journeys have been undertaken to study water in all of its complexity. We are still unlocking many of the secrets that water holds, and are learning how it behaves in its many complex cycles. It is because of this water cycle that hydropower is considered to be a renewable energy source. Under the current conditions on planet Earth, as long as free water runs, the sun shines, precipitation falls, the tectonics cycles occur, human ingenuity exists, and gravity exerts its force, the possibility of using hydropower could be endless.

The general concept of a HEPP, Hydro Electric Power Plant, is to convert the kinetic and potential energy of the water (mass) moving with some speed (momentum) into a usable form of energy – electricity. As was mentioned earlier in the Introduction to Electricity, the first hydropower plant went into production in 1879 at Niagara Falls. Although the modern day scale of damming and power outputs are much greater than ever before, the process of generating electricity has remained relatively unchanged. Figure 2.2 shows a general case involving a dam and reservoir (energy storage device). The reservoir is connected to the powerhouse via tunnels/piping, which allows for the flow of water across a turbine. This water then exits the system as it empties into a river (via piping/trenching).

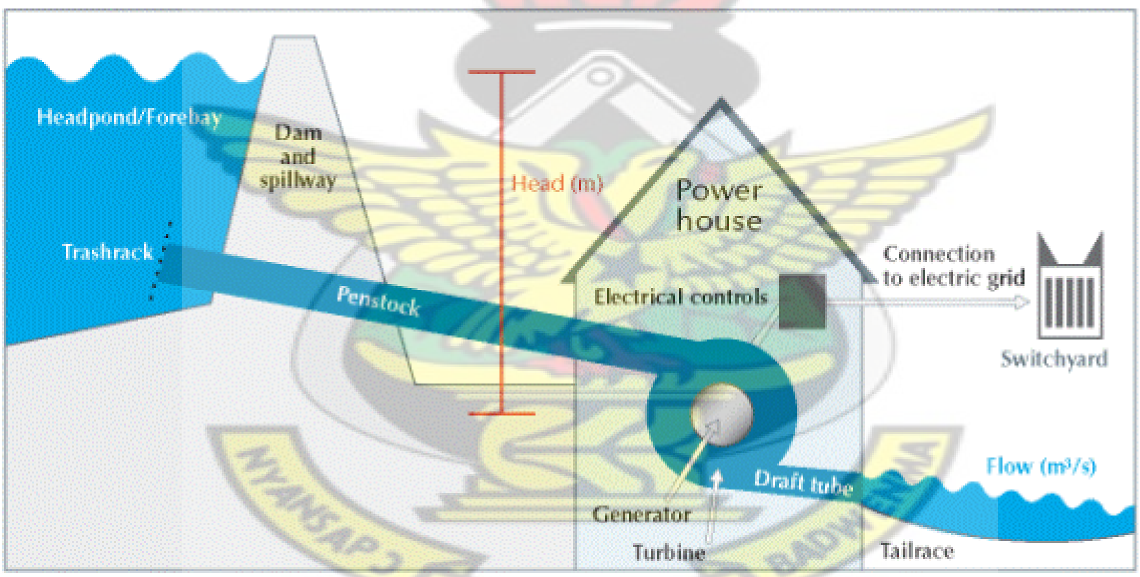



**Figure 2.2: RETScreen schematic of a generic dam, waterways, powerhouse, and switchyard/grid connect.**

An excitor or excitation unit is needed in the process of electrical generation. The main work of the excitor is to send an electrical current to the rotor as the turbine turns (Figure 2.3). This current is easily accessible to an operating plant as the locally generated electricity can be used by the excitation unit. However, at the start-up of a plant, the excitation unit is usually powered at first from electricity drawn from the transmission/distribution lines. The rotor is normally composed of a series of large electromagnets that spin inside a tightly-wound coil of copper wire, called the stator (Figure 2.4). The magnetic field between the coil and the magnets creates an electric current, just as Faraday had shown. This current is then synchronized with the system, and evacuated through the power lines via a switch yard.

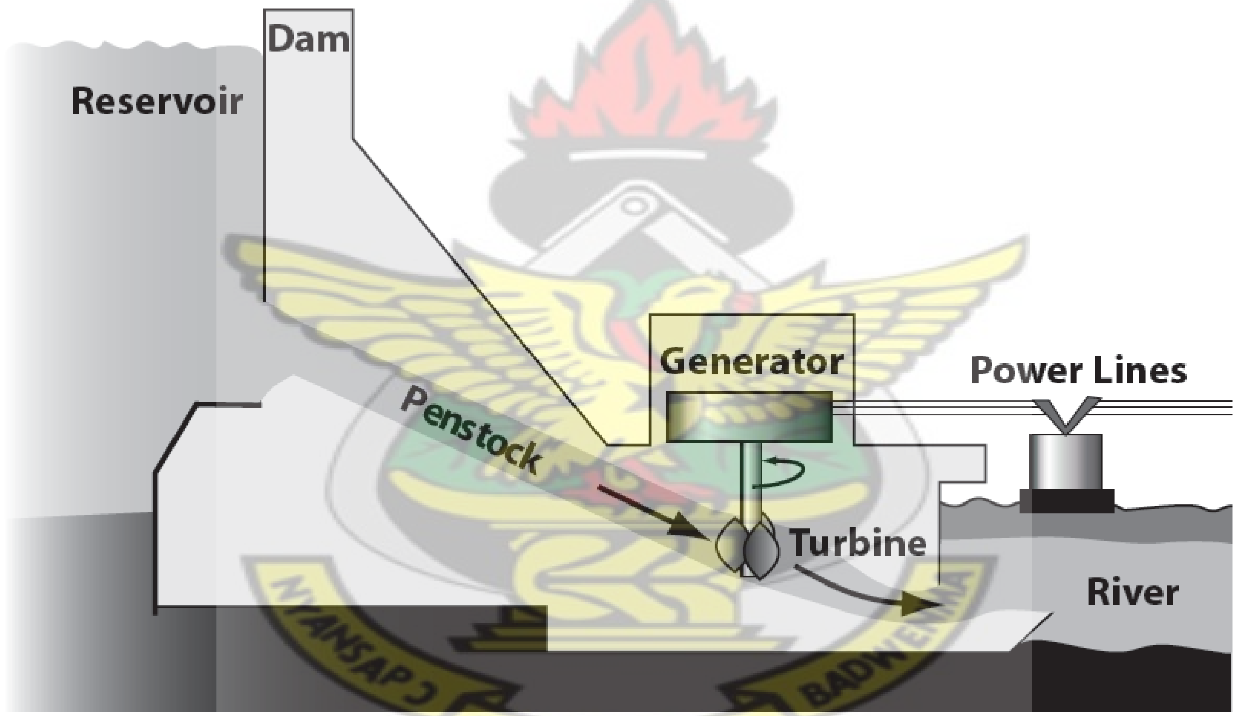



Figure 2.3: Schematic of a hydropower system. The rotor (spinning) and stator (stationary) are located within the generator. Image provided by the NEED Project, (National Energy Education Development, 2010).

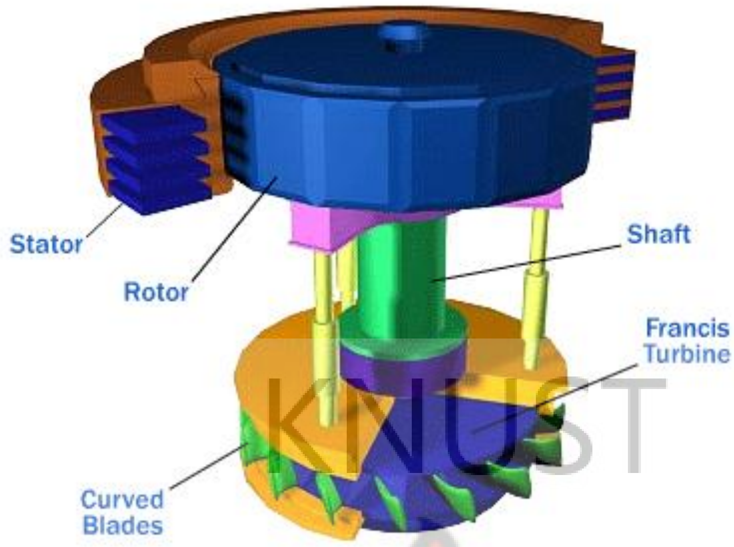



Figure 2.4: Representative drawing of a spinning Francis Turbine which is connected to a rotor by a shaft. Image provided by ENERGO-PRO, (ENERGO-PRO, 2010)

The development of these relatively simple systems and an understanding of their potential led to a hydropower land and water staking "gold rush". It was estimated by the 1940's that most of the ideal hydropower dam sites had been claimed or developed in the United Stated of America (National Energy Education Development, 2010). It was during this time that the exploitation of fossil fuels, and the intense energy density that they contain, came into popularity. From the 1940's until the 1970's oil crisis, hydrocarbon fired power plants proved to be much more economical than the conventional hydropower choice. The concepts of life cycle assessment, corporate responsibility, and environmentalism started to change public awareness in the developed world regarding the sources of electricity generation. This, as well as the recent global preoccupation with the possibility of anthropogenic climate change, has resulted in a recent revision or revisiting of the fuels or energy sources used for electricity generation. In this modern day, the ability of a country to secure long term energy deposits is at the heart of most political agendas. Over the last 70 years the energy source of choice has been an energy dense, easily transported material - crude oil and, to a lesser degree, coal. It has been speculated that whichever country is able to corner a new energy source, renewable, non-renewable, or a combination of the two, would lead the Earth (at least economically) in the 21st century. The development of hydroelectricity generation technology is shown in Table 2.1.

**Table 2.1** the Development of Hydroelectricity Generation Technology (Raabe, 1985)

| Year | Developer | Development |
|---|---|---|
| | Semi-axial or Francis Turbines | |
| 1827 | Fourneyron | Centrifugal reaction-turbine |
| 1837 | Howd | Centripetal reaction-turbine |
| 1837 | Henschel | Axial reaction turbine and draft tube |
| 1848 | Boyden | Diffuser |
| 1848 | Francis | Experiments on a Howd turbine |
| 1855 | Frink | Adjustable guide-vane |
| 1869 | Swain | Reaction runner |
| 1873 | Voith | Francis turbine with adjustable gate |
| | Impulse Turbines | |
| 1863 | Girard | Axial tangential-action turbine |
| 1880 | Peiton | Bucket jet-action turbine |
| 1890 | Brener | Needle valve |
| 1900 | Abner Doble | Bucket cut-out |
| | Axial Turbines | |
| 1875 | Escher Wyss | Straflo Turbine |
| 1913 | Kaplan | Adjustable runner vane |
| 1936 | Fischer and Escher Wyss | Bulb turbine |
| 1942 | Gibrat | Tidal-pow er turbine |
| | Pumped Storage | |
| 1930 | Escher Wyss | Axial pump turbine |
| 1934 | Voith | Radial pump turbine |
| | High-Voltage transmission | |
| 1868 | Oskar von Miller and Deprez | First İnitiative for high-voltage transmission |
| 1891 | Dolivo von Dobrovolsky | Industrial —scale system with an output voltage of 15kV |

### 2.2.1 Definition of Hydropower Energy

The generation of energy from water can be explained by the law of conservation of energy. The potential energy of flowing water is converted to kinetic energy in the penstock. The kinetic energy of the flowing water turns the blades of the turbine, where is converted to mechanical energy. Finally, the turbine shaft rotates the generator and the final product, electrical energy is generated (Basnyat, 2006).

The power generated by using the potential energy of flowing water is given by the following formula:

$$P = \eta \rho g Q H \tag{2.1}$$

Where;

P is the power in Watts,

$\eta$ is the general efficiency of the plant,

$\rho$ is the density of water in $kg/m^3$,

g is the gravitational acceleration in $m/s^2$,

Q is the discharge passing through the turbine in $m^3/s$,

H is the gross head of the water in m (elevation difference between the forebay and tailwater).

The principal requirements for electricity generation from water are given in ESHA (2005) as;

- Suitable rainfall catchment area
- Hydraulic head
- Means of transporting water form intake to the turbine, such as pipe or millrace
- Turbine house containing the power generation equipment and gate valve
- Tailrace to return the water to its natural course

### 2.2.2 Important Terminology Used in Hydropower

Firm energy is the energy that a plant can generate 95 percent of the time. Firm flow required to generate the firm energy is the minimum flow that a hydroelectricity plant can operate (Linsley et al., 1992). In general, firm power is not guaranteed by a small run-of-river plant. However, a group of small hydro run-of-river plants located in different basins of the country will guarantee a firm power since the low flow seasons of each basin will occur at different times of the year (Penche, 1998).

Secondary energy is all the energy available in excess of firm power. Secondary energy is not guaranteed; therefore the price of secondary energy is lower than the firm energy.

Gross theoretical hydropower potential of a country is the amount of power that could be generated if all natural flow was turbined with 100 percent efficiency down to the sea level (DSİ, 2009).

Technically available hydropower potential of a country is the gross theoretical hydropower potential that can be changed technically into electrical power (ETH, 2009).

Economic hydropower potential of a country is the amount of technically available potential which can be technically developed and economically competitive with other energy alternatives of same size (ETH, 2009). In general, the gross theoretical hydropower potential of a country will not change by time. On the contrary, changes in the economic hydropower potential of a country will be expected due to the changes in the world's and countries' economic situation. A plant which is not economic today may become economic in the future (Öztürk et al., 2009).

### 2.2.3 Hydropower in the World

Hydropower is the most widely used renewable energy source to generate energy. Hydropower is being used by more than 150 countries in the world. 11,000 stations with 27,000 generation units have an installed capacity of 860 GW and an addition of 120-150 GW capacity is added by the pumped storage plants (IHA, 2010). Hydropower supplies at least 50 % of natural electricity production in 63 countries and at least 90 % in 23 countries (Yüksek et al., 2007). Installed capacity by continent and installed capacity under construction are given in Figure 2.5 and Figure 2.6, respectively.

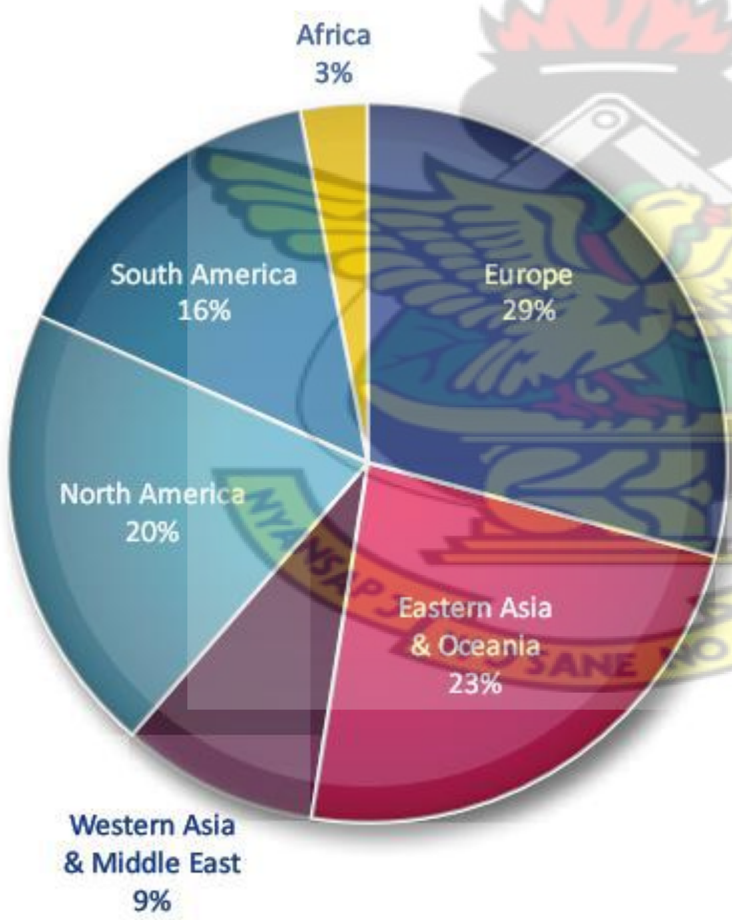



Figure 2.5. Hydropower Generation by Continent (IHA, 2010)

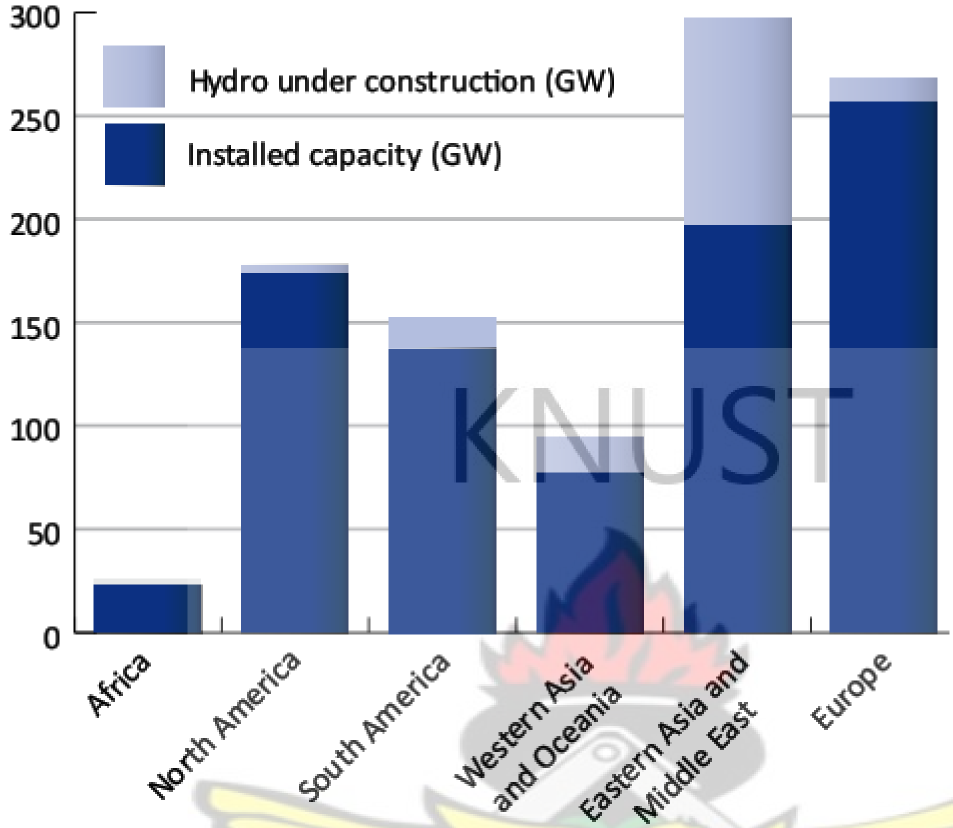



Figure 2.6 hydropower under construction (IHA, 2010)

## 2.3 Small Hydropower

### 2.3.1 Definition of Small Hydropower

There is no internationally accepted definition for small hydropower. In China, small hydropower can refer to capacities up to 25 MW, in India the limit is 15 MW; whereas the limit in Sweden is 1.5 MW. However, a general agreement of 10 MW capacity is being accepted by European Small Hydropower Association, European Commission and International Union of Producers and Distributors of Electricity (Lins et al., 2005). Moreover, within the range of small hydropower, depending on the installed capacity, the type of the plant is named as; mini, micro, and pico hydropower which have an upper limit for installed capacity as; 1 MW, 100 kW and 5 kW, respectively (Taylor et al., 2006). Table 2.2 shows the upper limits of installed capacity for small hydropower for different countries.

**Table 2.2 Upper Limits of Small Hydropower Installed Capacity for Selected Countries (TNSHP, 2004)**

| **Country** | **Upper Limit For Small Hydro (MW)** |
|---|---|
| Portugal, Spain, Greece, Ireland, Belgium | 10 |
| Italy | 3 |
| Sweeden | 1.5 |
| France | 12 |
| United Kingdom | 20 |
| Turkey | 50 |

Being used more than one hundred years, small hydropower schemes are reliable source of electricity which use a well-understood technology. By this way, they can provide energy to a central grid, an isolated grid or an off-grid load (RETScreen, 2005).

**2.3.2 Site Configuration of Small Hydropower Schemes**

The working principle of hydropower plants depends on the conversion of the potential energy of flowing water into the electricity energy in the powerhouse. The energy generated is proportional to the head and the flow.

Small Hydropower (SHP) schemes are generally classified according to their heads. Although, there are no rigid limits, the classification given in Table 2.3 can be used (TNSHP, 2004).

**Table 2.3** Classification according to head

| Type | Limits |
|---|---|
| High head | 100m and above |
| Medium head | 30 – 100 m |
| Low head | 2 – 30m |

Schemes can also be classified with respect to the type as; Run-of river schemes, schemes with the powerhouse located at the base of a dam and schemes integrated on a canal or in a water supply pipe.

### 2.3.3 Run-of River Schemes

Run-of river schemes use the flowing water of the river to generate electricity. If the flow drops below the minimum design discharge, the generation will stop (TNSHP, 2004). Run-of river type small hydropower plants generate power without flow regulation. Most of the run-of river schemes has no water storage, thus the energy generated will fluctuate with river flow. Jiandong et al., (1996) states that most of the small hydropower plants are run-of river type plants in the world. Some of the run-of river type plants have a head pond or a forebay which adds a little storage capacity to the scheme. This little storage capacity is used to regulate the peak loads. A weir is used to divert the water from river bed. The diverted water is carried by a combination of channels and tunnels into the forebay (Figure 2.7).

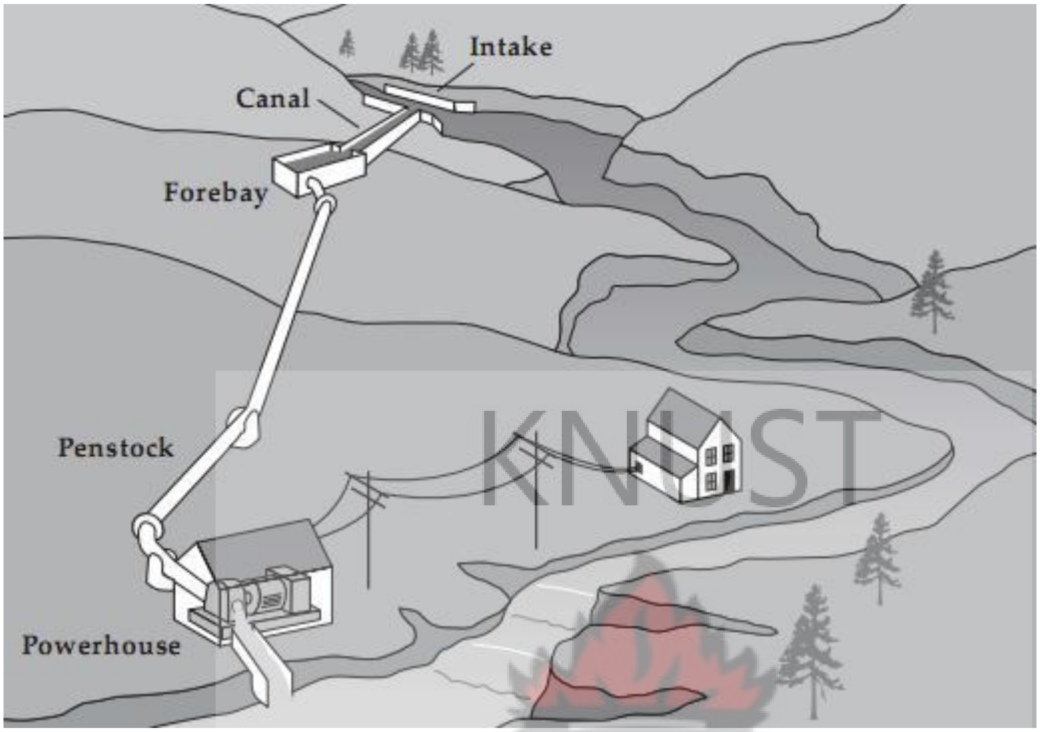



Figure 2.7 A run-of-scheme (National Renewable Energy Laboratory, 2001)

### 2.3.4 Other Types

In some cases, reservoirs are built for other purposes, such as; flood control, supply water for irrigation, municipal or industrial purposes, or recreational use. Some of these reservoirs can also be used for energy generation (TNSHP, 2004). The main problem with this scheme is how to connect the head water with the tail water and where to fit the turbine (TNSHP, 2004). One solution if the dam already has a bottom outlet is construction of a powerhouse at the outlet to generate electricity (Figure 2.8).

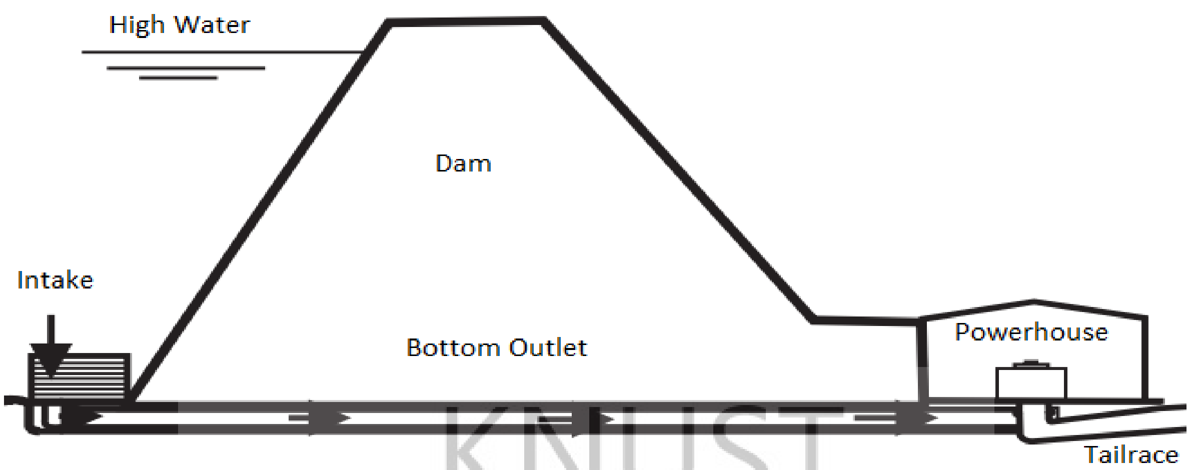



**Figure 2.8, Low head scheme using an existing dam (Penche, 1998)**

Some of the small hydropower schemes are integrated within the irrigation canals. In these kinds of schemes, the canal is enlarged to accommodate the intake, the power station, the tailrace and the lateral bypass. In case of shutdown of the turbine, to be able to supply the water for irrigation a lateral bypass must be included into this type of scheme (TNSHP, 2004). Figure 2.9 shows a scheme of this kind with a submerged powerhouse.

Schemes integrated into the water abstraction system of a city are another type of SHP scheme (Figure 2.10). Pressured pipes are used to convey the clean water to the city. Normally, special valves are used at the entrance of water treatment plant to dissipate the energy in these pipes. In these types of schemes a turbine is installed at the entrance of the treatment plant to convert the otherwise lost energy to electricity, instead of the valves. Similar to the schemes integrated into the irrigation canal, a bypass valve must be installed to ensure water supply all the time (TNSHP, 2004).

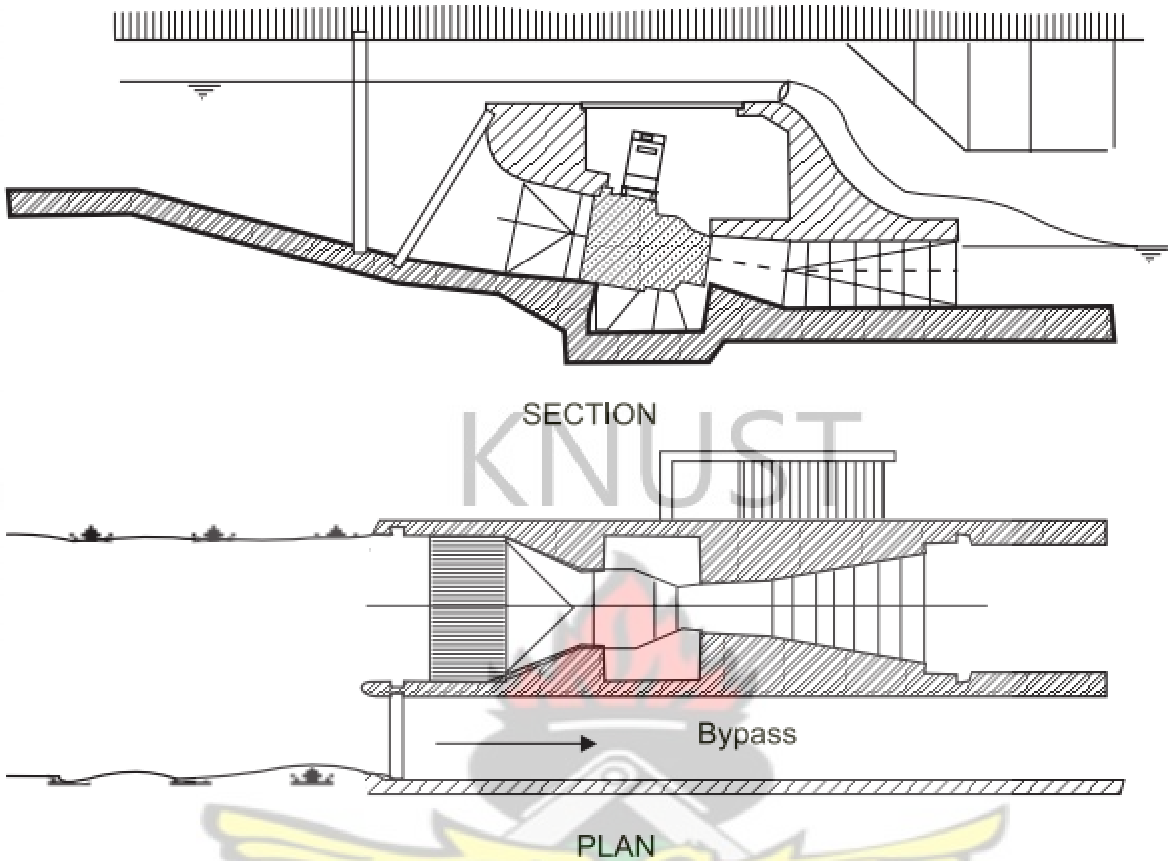



**Figure 2.9**: A Typical Canal Scheme (Source: TNSHP, 2004)

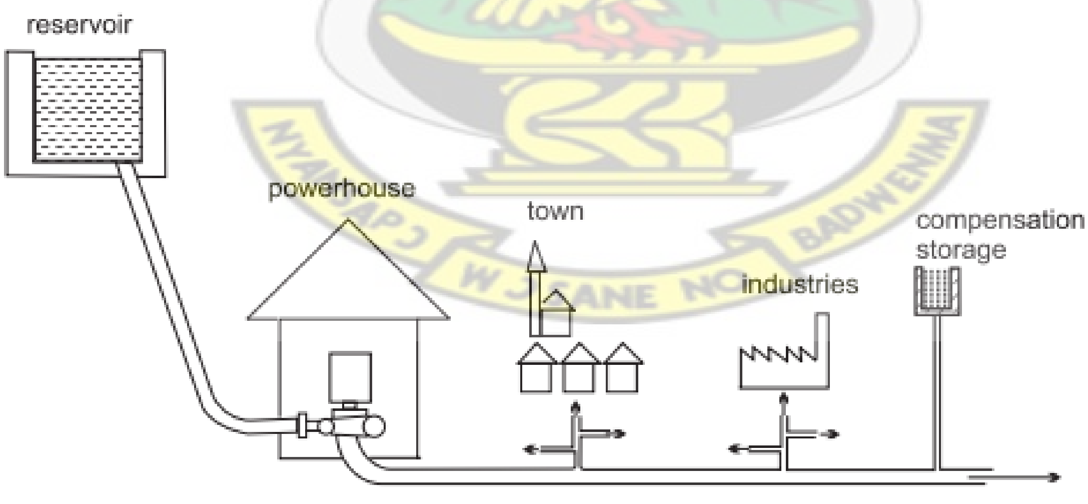



**Figure 2.10:** Scheme integrated into a water supply system (Penche, 1998)

### 2.3.5. Components of Small Hydropower Schemes

The main components of run-of river schemes can be divided into two headings; civil works and electromechanical works.

The civil works of a run-of river SHP scheme include water conveyance structures, head pond or forebay, penstock, powerhouse and tailrace structures. Turbine, generator, governor, and regulator are the electromechanical components of a run-of river scheme.



#### 2.3.5.1 Civil Works

An intake structure is required at the entrance to a conduit through which water is withdrawn from a river (Linsley et al., 1992). To prevent the entrance of debris to the system, trash racks are built. The diverted water is carried by the water conveyance structures. Water conveyance structures are either canal or a tunnel. Depending on the topography and the soil conditions of the construction area, the best alternative to carry water is selected.

**Forebay** is a small reservoir located at the end of the canal or tunnel which diverts water into the penstock. Forebay always have to store enough water to ensure that the penstock is fully submerged (Yanmaz, 2006). **Penstock** is a pressurized water pipe that carries the water to the powerhouse. Steel is the most commonly used material to build penstocks; however, reinforced-concrete and wood-stave pipes are also used (Linsley et al., 1992).

**Powerhouse** is a building built by conventional building materials. Most of the electromechanical equipment of the hydropower plant is located in the powerhouse that the electricity is generated in the powerhouse.

**Tailwater canal** connects the turbine with the natural stream bed. The water used in the turbines is diverted into its natural bed by using the tail water canal.

### 2.3.5.2 Electromechanical Works

**Turbine** transforms the potential energy of flowing water into rotational energy. The selection of turbine type is dependent on the head and the design discharge of the plant. Table 2.4 shows the turbine classification according to head. Figure 2.11 provides application ranges of different types of turbines depending on the head and the discharge.

**Table 2.4** Turbine type According to the Head (Küçükbeycan, 2008; Paish, 2002)

| Turbine Type | Head Classification | | |
|---|---|---|---|
| | **High Head** | **Medium Head** | **Low Head** |
| Impulse | Pelton<br>Turgo<br>Multi-jet Pelton | Cross Flow<br>Turgo<br>Multi-jet Pelton | Cross Flow |
| Reaction | | Francis | Francis<br>Propeller<br>Kaplan |

**Governors** are used to control the rotational speed of the turbine within the limits by adjusting the water flow. The range of correct frequency is between 50 to 60 MHz (Paish, 2002).

**Generator of the plant** transforms the rotational energy of the turbine shaft into electrical energy.

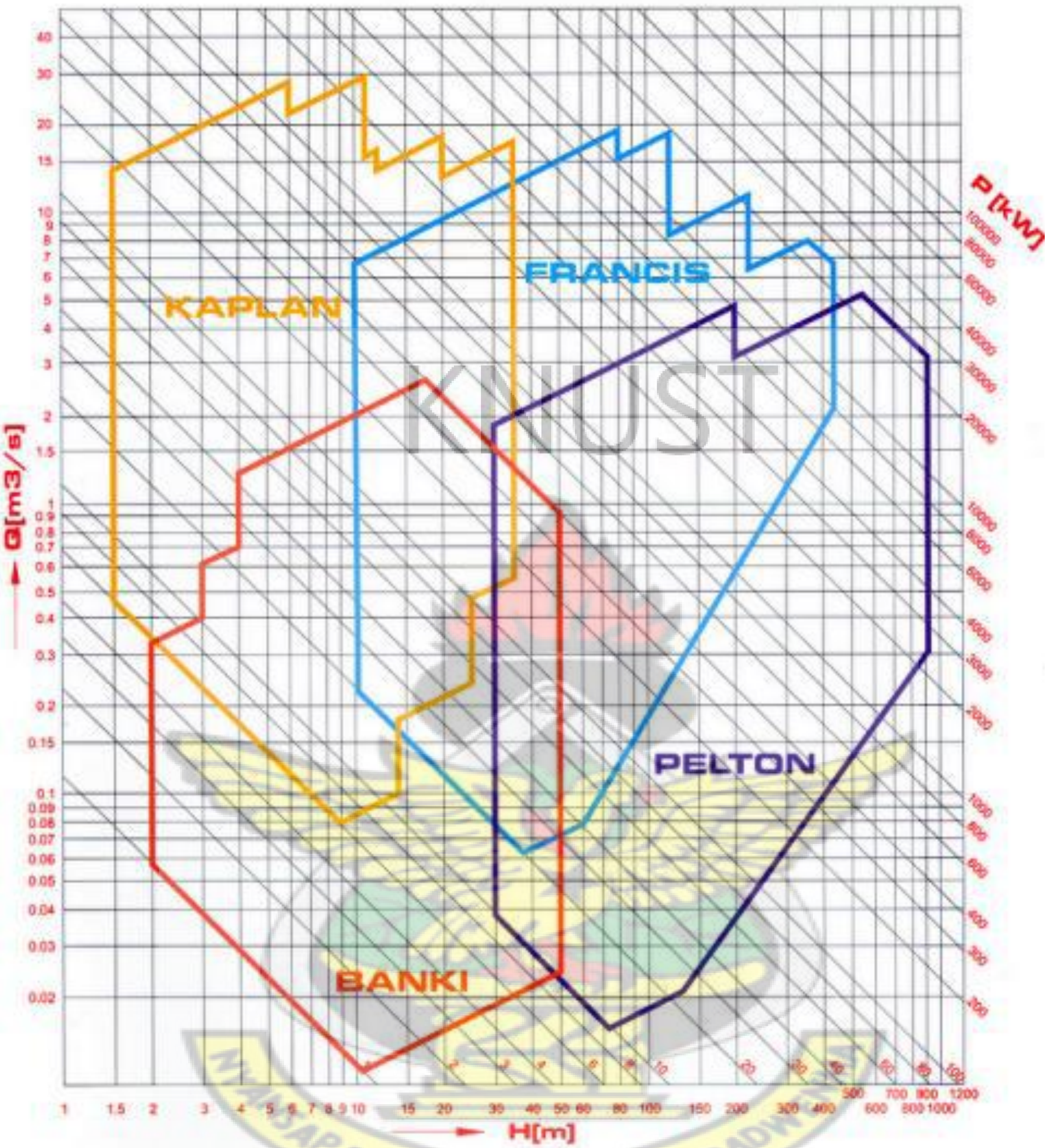



**Figure 2.11** Turbine application range (MAVEL, 2009)

### 2.3.6 Advantages and Disadvantages of Small Hydropower

Small hydropower is a sustainable resource. Lins et al. (2004) states that "SHP meets the needs of the present without compromising the ability of future generations to meet their own needs."

Small hydropower plants are among the cheapest systems to generate electricity. It is a well known technology open to new technological developments. SHP has a high untapped potential especially in developing countries (ESHA, 2005). The main characteristics of small hydropower plants are their flexibility and reliable operation. Moreover, depending on the rapid demand changes, its fast start up and shutdown response is an important advantage (Dragu et al., 2001). Small hydropower plants use water to generate electricity therefore the electricity generation is independent of the changes in fuel costs (Dragu et al., 2001). Without any harm or decrease to its resource it can satisfy the energy demand (Lins et al., 2004). Moreover, SHP schemes recovers the waste that flows with the river flow with its trash racks, thus it helps the maintenance of river basins (Pelikan et al., 2006).

Small hydropower is a clean energy source, thus it is environmentally friendly. It does not pollute the environment and does not generate greenhouse gases. Pelikan et al. (2006) states that "one GWh of electricity produced by small hydropower means a reduction of 480 tonnes of emitted carbon dioxide". Moreover, small hydropower schemes have long life span and very limited maintenance is required (Paish, 2002).

Another advantage given by Lins et al. (2004) is that SHP schemes are located within the borders of one country, thus, there will be no disruption by international political events.

On the other hand, there are some disadvantages of small hydropower plants. For example, seasonal variations of the river flow results in variations in energy generation. These low flow seasons limits the firm power of the plant (Paish, 2002). Dragu et al. (2001) states some adverse effects of small hydropower schemes on fish life. First of all, weir of the plant acts like a barrier which affect the fish movement. Secondly, especially young fish swimming downstream can be killed by the blades of the turbine. Thirdly, the spilled water will be supersaturated with the gas in the air. The gas bubbles in the water will kill the fish if they absorb it. Lastly, warm water will be collected at the surface of the reservoir, while cold water will be present at the bottom. This will result in a decrease in the oxygen level in the cold water in which most species of fish cannot survive.

Another disadvantage is the size and the flow of the river will limit the future site expansions as the demand for power increases (Alternative Energy, 2006).

One problem associated with SHPs in Turkey is public opposition. The critics of SHP in Turkey claim that diversion of most of the water from its natural bed into channels and tunnels causes the water quality and quantity to decrease at the downstream of the diversion. This causes the fish species and various microorganisms living in the river to decrease, and in some cases endangered species to become extinct. Moreover, the critics claim that since the water is carried by canals or tunnels to a downstream location, the groundwater is not fed; therefore, the groundwater table gets lower. They claim that in the long run this may result in drought (Karadeniz İsyandadır,2010).

A summary of advantages and disadvantages are given in Table 2.5

**Table 2.5** Summary of Advantages and Disadvantages of SHP (Hydro Tasmania, 2006).

| **ECONOMIC ASPECTS** | |
|---|---|
| **ADVANTAGES** | **DISADVANTAGES** |
| Provides low operating and maintenance costs | Precipitation dependent |
| Provides long life span (50 to 100 years and more) | Requires long-term planning |
| Includes proven technology | Requires long-term agreements |
| Creates employment opportunities | Requires multidisciplinary involvement |
| Saves fuel | |
| Can provide energy independence by exploiting national resources | |
| Optimizes power supply of other generating options (thermal and intermittent renewables) | |
| SOCIAL ASPECTS | |
| ADVANTAGES | DISADVANTAGES |
| Leaves water available for other uses | Local land use patterns will be modified |
| Provides opportunities for construction with a high Percentage of local manpower | Waterborne disease may occur |
| **ENVIRONMENTAL ASPECTS** | |
| **ADVANTAGES** | **DISADVANTAGES** |
| Produces no atmospheric pollutants | Barriers for fish migration, fish entrainment |
| Neither consumes nor pollutes the water it uses for electricity generation purposes | Modification of hydrological regimes |
| Produces no waste | Modification of aquatic habitats |
| Avoids depleting non-renewable fuel resources (i.e., coal, gas, oil) | Water quality needs to be monitored/managed |
| Can result in increased attention to existing environmental issues in the affected area. | Species activities and populations need to be monitored/managed. |

## 2.4 Small Hydropower in the World

Among the other renewable energy sources, small hydropower being a cheap and clean energy source has a key role in development. Small hydropower has an important share in worlds' renewable energy budget. Table 2.6 shows global electricity generation by each renewable energy source.

**Table 2.6** Global Electricity Generation by Each Renewable Energy Source (Dragu et al., 2001)

| | |
|---|---|
| Large hydro (> 10MW) | 86% |
| Small hydro (< 10MW) | 8.3% |
| Wind and Solar | 0.6% |
| Geothermal | 1.6% |
| Biomass | 3.5% |

In 2004, the total installed capacity of small hydropower (<10 MW) was about 48 GW worldwide as shown in Table 2.7. In 2005, China has reached a SHP capacity of 31,200 MW which is more than half of the worlds SHP capacity (Taylor et al., 2006). Canada uses small hydropower to replace expensive diesel generation in remote off-grid regions. Moreover, countries in South America, Africa and former Soviet Union also have great untapped potentials (Lins et al., 2005).

**Table 2.7** Installed SHP (<10 MW) Capacity by World Region in 2004 (Taylor et al., 2006)

| Region | Capacity (MW) | Percentage (%) |
|---|---|---|
| Asia | 32,641 | 68.0 |
| Europe | 10,723 | 22.3 |
| North America | 2,929 | 6.1 |
| South America | 1,280 | 2.7 |
| Africa | 228 | 0.5 |
| Australia | 198 | 0.4 |

10,723 MW capacity of SHP are in operation in 25 European Union Countries in 2004. The number of plants in the candidate countries is only 400. Concerning the total hydropower generation, the share of SHP is about 11-13 % in EU25 countries (Marketing Working Group of TNSHP, 2004).

According to Laguna (2006), more than 82 % of the economical potential is developed in the former 15 European Union countries. The development of economical potential in EU10 and candidate countries is less than 40- % and 6- %, respectively. The remaining potential is 20TWh/year in EU15, 4 TWh/year in EU10 and 22 TWh/year in the candidate countries. More than 19,500 GWh/year of the latter is located in Turkey.

### 2.5 Small Hydropower Development in Nigeria

Hydropower sector witnessed about 360% growth between 1971 and 2005 and yet only 5% of the vast small hydropower potential is tapped by the few plants built between 1923 and 1964. (Ohunakin et al, 2011).

Operating and maintenance costs are in favour of SHP development in the country, being the lowest when compared with the situation in European countries. The Nigerian Government has taken steps to diversify energy sources in order to promote renewable energy development by encouraging private investments in the energy sector through reforms, but this may not be adequate as there remain barriers against SHP development in the country. It was concluded that government must incorporate subsidies, feed-in-tariffs, and framework for Price Purchase Agreements (PPA) into the policies in order to further promote renewable energy and attract both indigenous and foreign investments for quick adoption and rapid expansion of SHP technologies.

### 2.6 Potentials of Small Hydro Power in Nigeria

In this section the small hydro power potentials in Nigeria, its present status and investment opportunities are discussed. Nigeria is endowed with so many resources both human and natural; the need to harness these resources in serving the human needs is paramount. Renewable energy remains the cleanest, most reliable and inexhaustible energy type and Nigeria is blessed with almost all types of renewable energy resources. One of the most readily available renewable energy resources is small hydro. Nigeria has the potentials of over 277 dispersed small hydro sites capable of generating electric power of about 734.2 MW out of which only 30 MW has been harnessed in 2005, and the potential as at today is estimated to reach 3,500 MW. (Roseline et al 2012). This of course is good enough to attract any serious investors considering the overwhelming population of the country as well as the high demands of electricity in all the surrounding villages of the said potential small hydro sites.

Although there are few challenges in the sector, one important assertion is that, the profit margin in SHP in Nigeria cannot be overemphasized and investment in this sector will be highly rewarding.

According to Bala (2010), Energy consumption in Nigeria by type and by total vindicates hydro power as covering up to 23.9% in 2007. It was 14.2% in 2003 and the sudden growth from 14.2% to 23.9% between 2003 and 2007 shows that, there is improvement close to 100% within four years. Details as shown in figure 2.12.

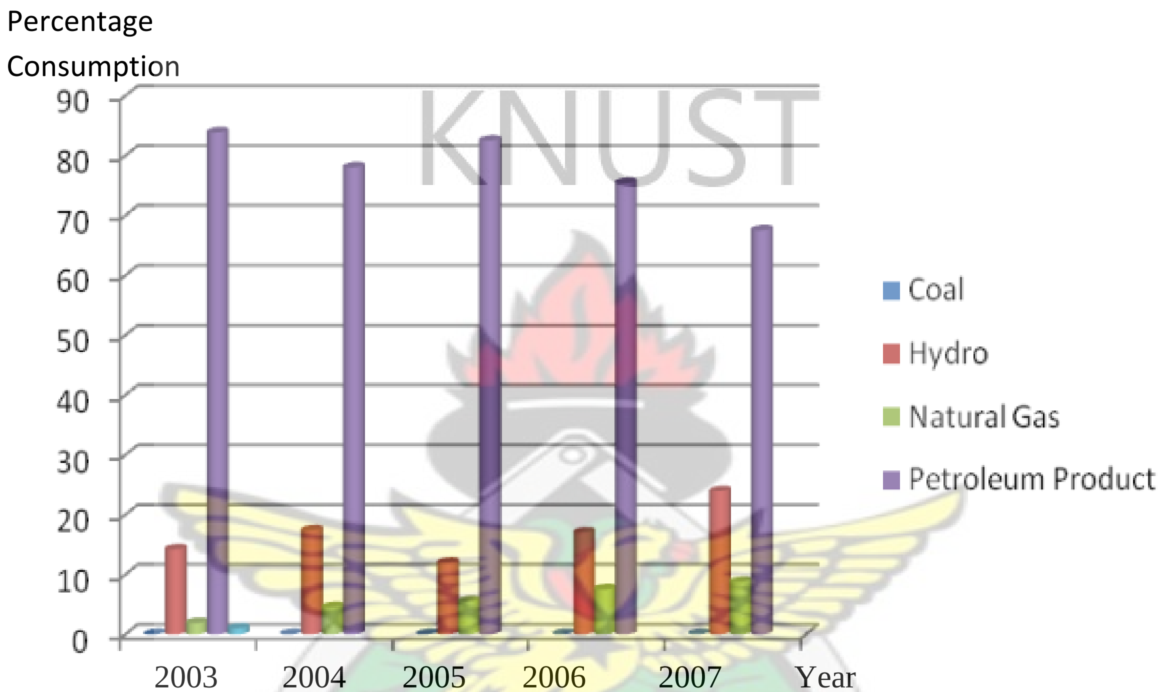



**Figure 2.12:** Energy Consumption by Type from 2003 to 2007

The major rivers in Nigeria, such as the Niger, Benue, Cross River, Kano and their tributaries along with some smaller rivers, provide a desirable potential for the exploitation of hydro energy in Nigeria. In the same way, mountains and hilly terrains with high river slopes, predominantly in the Jos/Bauchi and Mambilla Plateau regions proliferate, and have very good sites for construction of reservoirs and diverting flows for electricity generation. This technically exploitable hydropower potential is put at 20,000 MW, though the hypothetically approximated potential is about 30,000 MW.

The large - scale development of hydro potential is mainly restricted by the fluctuating characteristics of the Nigerian river flows.

Usually, the rivers are characterized with high water discharges in rainy season and with very low discharges in the dry season. Currently, the main hydro sites are at Kainji and Jebba on the river Niger and Shiroro on the Kaduna River, with generating capacity of 760, 640 and 600 MW respectively. In addition to these, there are numerous small-scale hydro schemes around Jos Plateau, generating and supplying about 19 MW by a private sector operator, National Electricity Supply Company (NESCO). Viability studies have since been completed for 3 hydro stations at Makurdi, Lokoja and Ikom. In addition to these sites, there are a good number of identified sites with potentials for supporting micro hydro (less than 100 kW), mini hydro (between 500 kW and 5,000 kW) systems, in over 248 small rivers in the country. A network of small decentralized plants may be well favoured as small rivers and waterfalls are widespread and usually more disseminated than large waterfalls and consequently they prospects for the development of isolated and remote areas. As of today, of all the renewable energy resources, only hydro energy is being meaningfully exploited. (UNIDO, 2006)

Furthermore, for any small hydro power station, the potential power can be calculated as follows (Saket, 2010):

Theoretical power (P) = Flow rate (Q) x Head (H) x Gravity (g)

When Q is in cubic metres per second, H in metres and g = 9.81 m/s$^2$ then,

P = 9.81 x Q x H (kW)

Small water turbines rarely have efficiencies above 80%.

Power will also be lost in the pipe conveying the water to the turbine, due to frictional losses.

By cautious design, this loss can be abridged to only a little percentage.

Tables 2.8 and 2.9 show the identified small hydro power potentials in Nigeria.

**Table 2.8: Summary of Small Hydro Potential Sites in Nigeria**

| S/No | STATE | POTENTIAL SITES | CUMMULATIVE POWER ESTIMATE (MW) |
|---|---|---|---|
| 1 | Adamawa | 3 | 28.600 |
| 2 | Akwa Ibom | 13 | |
| 3 | Bauchi | 1 | 0.150 |
| 4 | Benue | 10 | 1.306 (1 Site) |
| 5 | Cross River | 5 | 3.000 |
| 6 | Delta | 1 | 1.000 |
| 7 | Ebonyi | 5 | 1.399 |
| 8 | Edo | 5 | 3.828 |
| 9 | Ekiti | 6 | 1.2472 |
| 10 | Enugu | 1 | |
| 11 | FCT | 6 | |
| 12 | Gombe | 2 | 35.099 |
| 13 | Imo | 71 | |
| 14 | Kaduna | 15 | 25.000 |
| 15 | Kano | 2 | 14.000 |
| 16 | Katsina | 11 | 234.34 |
| 17 | Kebbi | 1 | |
| 18 | Kogi | 2 | 1.050 |
| 19 | Kwara | 4 | 5.200 |
| 20 | Nassarawa | 3 | 0.454 |
| 21 | Niger | 11 | 110.580 |
| 22 | Ogun | 13 | 15.610 |
| 23 | Ondo | 1 | 1.300 |
| 24 | Osun | 8 | 2.622 |
| 25 | Oyo | 3 | 1.062 |
| 26 | Plateau | 14 | 89.100 |
| 27 | Sokoto | 1 | |
| 28 | Taraba | 9 | 134.720 |
| 29 | Yobe | 5 | |
| 30 | Zamfara | 16 | |

Source: UNIDO-RC-SHP in Africa, Abuja, 2009

**Table 2.9: Small Hydro Potentials in Surveyed States in Nigeria**

| S/No | State | River Basin | Sites | Total MW |
|---|---|---|---|---|
| 1 | Sokoto | Sokoto-Rima | 22 | 30.6 |
| 2 | Katsina | Sokoto-Rima | 11 | 8 |
| 3 | Niger | Niger | 30 | 117.6 |
| 4 | Katsina | Niger | 19 | 59.2 |
| 5 | Kwara | Niger | 12 | 38.8 |
| 6 | Kano | Hadejia-Jamaare | 28 | 46.2 |
| 7 | Borno | Chad | 28 | 20.8 |
| 8 | Bauchi | Upper Benue | 20 | 42.6 |
| 9 | Gongola | Upper Benue | 38 | 162.7 |
| 10 | Plateau | Lower Benue | 32 | 110.4 |
| 11 | Benue | Lower Benue | 19 | 69.2 |
| 12 | Rivers | Cross River | 18 | 258.1 |
| Total | | | 277 | 734.2 |

Source: ECN-UNDP Renewable Energy Master Plan

In terms of the current Status of SHP in Nigeria as at 2005, the recognized SHP prospective was about 734.2 MW of which only 30 MW had been developed (ECN- UNDP RE Master Plan, 2005). A study of SHP potential in Nigeria had also being considered for support by African Development Bank, (UNIDO, 2006). According to (Brianand Emma, 2009), UNIDO has concluded two of four designed pilot projects planned to build awareness and generate capacity for micro. hydro power development in Nigeria. The project in Enugu State (30KW capacity) and Bauchi State (150 kW) were undertaken through a partnership, with UNIDO providing the equipment and proficiency, and states and local government providing erstwhile logistics and labour in-kind. Power generated from the projects will supply electricity for lighting, agricultural processing and information and communications technology (ICT) for local communities. The projects also provide technical training and energy efficiency responsiveness to ensure the technology is maintained locally and sustainably.

Furthermore, the National Agency for Science and Engineering Infrastructure, NASENI is developing capacity in the manufacture of SHP Equipments (NASENI, 2011).

According to the Agency, it has been approximated that the entire Small Hydro Power (SHP) Potential in the nation might reach 3,500 MW, signifying 23% of the country's entire hydropower potential. With this prospective in SHP, there will be a rising demand for local capacities in the expansion of this technology in the country. In the late 2007, UNIDO brought in NASENI to a Stakeholders summit on the Local Manufacturing of Small Hydro Power Equipment in the African constituency. NASENI has been identified as the Host Agency and the delegate of the Nigerian Government on the mission. Whereas UNIDO awaits Nigeria's complementary subsidy, Cross flow turbine has been chosen for the first manufacture involving Nigerian engineers and using domestic technology. The Cross Flow turbine was chosen based on the head and flow rate available from the river besides the domestic technology on ground.

## 2.7 Computer Software for Small Hydropower Development

Development of a small hydropower scheme is a challenging process which needs great amount of time and money in addition to expertise in various disciplines. The first stages of the development require quick estimations of the energy output of the project. Several computer software programs such as RETScreen, HES, Hydra are employed to make initial economical analysis for a new SHP project. Utilization of such software shortens the time and money spent for conducting the initial economical assessments for the projects. Table 2.10 summarizes some of the software programs and their main features. Due to some features of these softwares, some of them are applicable only in limited countries or regions. However; as can be seen from Table 2.10 IMP and RETScreen can be used internationally. Both IMP and RETScreen can evaluate energy output of the projects, but RETScreen is one step forward since it is capable of making cost analysis and it can be downloaded free-of charge from the internet. Moreover, its user friendly manual helps the user to learn and use the program easily.



**Table 2.10** Small Hydropower Assessment Tools (Wilson, 2000)

| **Assessment Tool** | | **Features** | | | | |
|---|---|---|---|---|---|---|
| Software | Applicable Countries | Hydrology | Power/Energy | Costing | Economic Evaluation | Preliminary Design |
| ASCE Small Hydro | USA | X | | | | |
| HES | USA | X | | | | |
| Hydra | Europe | X | X | | | |
| IMP | International | X | X | | X | |
| PEACH | France | X | | X | | X |
| PROPHETE | Fraance | X | X | | X | |
| REMOTE SMALL HYDRO | Canada | X | X | | X | |
| RETScreen | International | X | X | X | X | |

## 2.8 RETScreen Clean Energy Analysis Software

RETScreen International Clean Energy Decision Support Centre is managed under the leadership and ongoing financial support of Canmet_ENERGY which is a research centre of Natural Resources Canada (Natural Resources Canada, 2010). The RETScreen Clean Energy Decision Support Centre seeks the capacity of planners, decision makers and industry to implement renewable energy and energy efficient projects (Leng et al., 2004). This objective is achieved by:



- developing decision-making tools that reduce the cost of pre-feasibility studies (RETScreen Clean Energy Analysis Software);
- disseminating knowledge to help people make better decisions;
- training people to better analyze the technical and financial viability of possible projects.

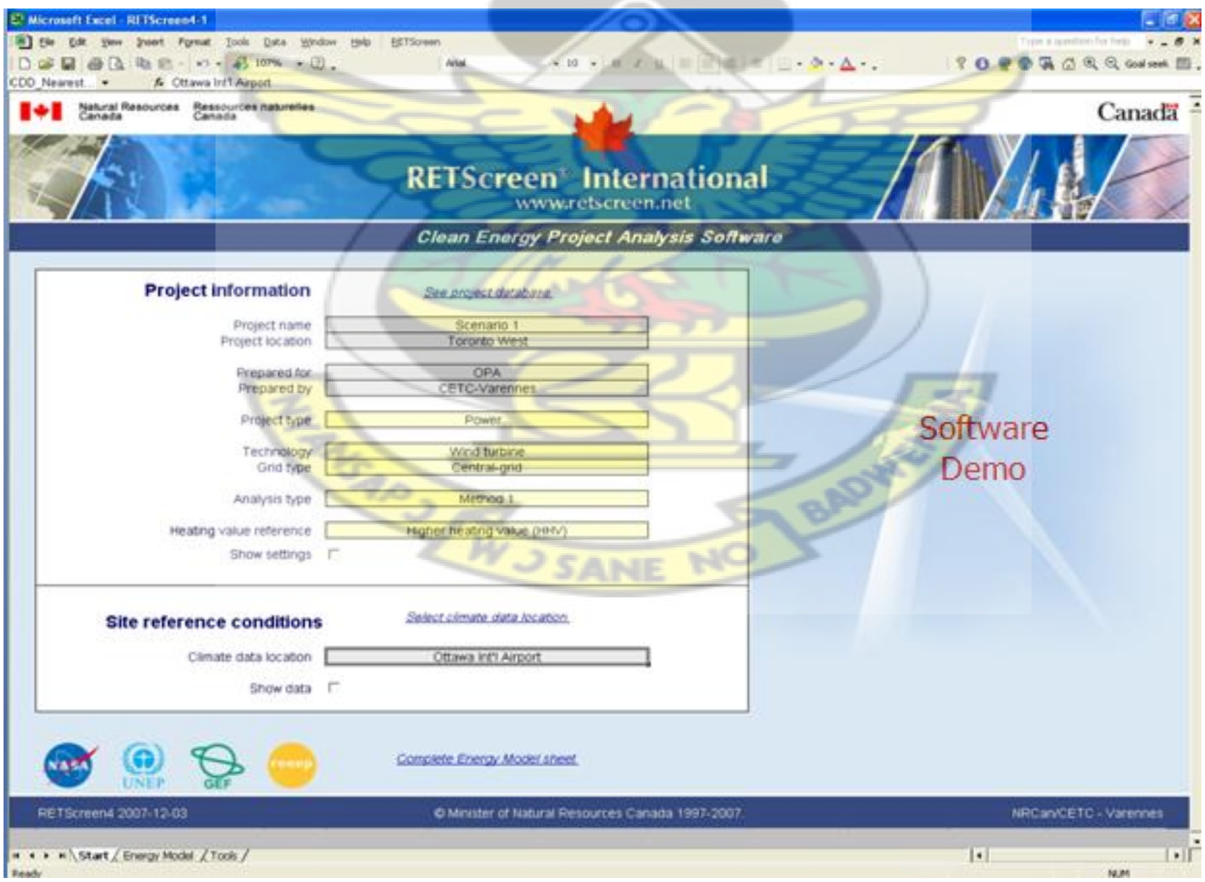



Figure 2.13: Retscreen Introductory page

RETScreen can be used worldwide to evaluate the energy production and savings, costs, emission reductions, financial viability and risk for various types of Renewable-energy and Energy-efficient Technologies (RETs). (Natural Resources Canada, 2010). The usage of RETScreen worldwide has resulted in considerable achievements in different areas. Table 2.11 shows predictions about some of the achievements of RETScreen.

**Table 2.11** Predictions for some of the achievements (Leng et al., 2004)

| Performance Indicators | Future Impact (1998 to 2012) | |
|---|---|---|
| | Canada | World |
| User Savings | \$1.8 billion | \$7.9 billion |
| Installed Capacity | 4.9 GW | 24 GW |
| Installed Value | \$10 billion | \$ 41 billion |
| GHG Reduction | 3.6 million tonnes $CO_2$/yr | 20 million tonnes $CO_2$/yr |

As can be seen from Table 2.11, by the end of the 2012, it is estimated that the users will save \$7.9 billion due to the use of RETScreen. RETScreen does not compute any environmental or social costs. The emission analysis sheet allows the user to compare the greenhouse gas emissions of the project with that of a conventional power plant. Moreover, RETScreen does not provide any tool to calculate the costs associated with possible problems such as erosion, sedimentation and earthquake. RETScreen can be used to evaluate different type of clean energy models. Some of them are; power, heating, cooling, combined heating and power, combined cooling and power and energy efficiency measures. Each model on RETScreen has a common look and follows a standard path to help the decision maker. Moreover, each model has integrated product, cost and weather databases (Leng et al., 2004).

## Chapter 3

# Case Study Project

## 3.1 Project Area

The project area is located in Hydraform Estate in kuje Area Council in Abuja, Federal Capital Territory, Nigeria. The hydropower project is situated on River Shetiko. Baltacı Stream located in Hydraform Estate. The project area is a mountainous region mostly covered with forests. There is no private estate in the project area. The local people use some parts of the area as farmland.

### 3.1.1 Earthquake Conditions

The project site is considered to be relatively safe in terms of earthquakes.

### 3.1.2 Climate Conditions

The project area receives rain during the rainy season. The raining season starts in April and runoff water starts almost immediately while the peak flow is experienced in September/October every year.

## 3.2 PLANNING / DESIGNING OF HYDRO POWER SCHEMES

Planning of small hydro project requires many stages of technical and financial studies to determine if a site is technically and economically feasible. The viability of each potential project is very site specific. Power output depends on flow of water and the height of the drop of the available water. The amount of energy that can be generated depends on the quantity of water available and the variability of flow throughout the year. Although most small-hydro projects are different, the following steps provide a good outline of the main stages in the development and operation of a project:

### 3.2.1 Reconnaissance Surveys and Hydraulic Studies

This first phase of work frequently covers numerous sites and includes: map studies; delineation of the drainage basins; preliminary estimates of flow and floods; and a one day site visit to each site (by a design engineer and geologist or geotechnical engineer); preliminary layout; cost estimates (based on formulae or computer data); a final ranking of sites based on power potential; and an index of cost.

### 3.2.2 Hydrology and Site Survey

This stage, which involves collation of hydrological data within and around the sites visited, is the core of the project. Outcome is the assessment of flow rate of available resources in combination with available head within the project area and therefore the potential capacity of the scheme, taking cognizance of various uses of water.

### 3.2.3 Other Stages

The Other stages are Prefeasibility Study, Feasibility Study, System Design/Project Engineering, Financing, Ownership and Maintenance. These are discussed briefly in section 3.3 – 3.5.

## 3.3 Pre-feasibility Study

Work on the selected site or sites would include: site mapping and geological investigations (with drilling confined to areas where foundation uncertainty would have a major effect on costs); a reconnaissance for suitable borrowed areas (e.g. for sand and gravel); a preliminary layout based on materials known to be available; preliminary selection of the main project characteristics (installed capacity, type of development, etc.); a cost estimate based on major quantities; the identification of possible environmental impacts; and production of a single volume report on each site.

### 3.4 **Feasibility Study**

Work would continue on the selected site with a major foundation investigation programme; delineation and testing of all borrow areas; estimation of diversion, design and probable maximum floods; determination of power potential for a range of dam heights and installed capacities for project optimization; determination of the project design earthquake and the maximum credible earthquake; design of all structures in sufficient detail to obtain quantities for all items contributing more than about 10 per cent to the cost of individual structures; determination of the dewatering sequence and project schedule; optimization of the project layout, water levels and components; production of a detailed cost estimate; and finally, an economic and financial evaluation of the project including an assessment of the impact on the existing electrical grid along with a multi-volume comprehensive feasibility report.

### 3.5 **System Planning and Project Engineering (Detailed Project Report) DPR**

This work would include detail studies and final design of the transmission system; integration of the transmission system; integration of the project into the power network to determine precise operating mode; production of tender drawings; analysis of bids and detailed design of the project; production of detailed construction drawings and review of manufacturer's equipment drawings. However, the scope of this phase would not include site supervision or project management, since this work would form part of the project execution costs.

### 3.6 **Financing**

The process of arranging financing for small-hydro projects is often difficult. The developer has to complete two steps to realize their development plans. The first is to obtain a contract with a utility or organization which will purchase the produced electricity. With this contract in place the next step is to negotiate a bank loan or other source of financing. However, many banks lack knowledge of small-hydro projects and have no experience with this type of loan. In recent years some banks have acquired the necessary experience and now routinely provide loans for small-hydro projects.

### 3.7 River Shetiko



River Shetiko flows in a meandering manner along Kuje Area Council in natural channels with sandy banks through the project site of Hydraform Estate in the area. The raining season starts in April and runoff water starts almost immediately while the peak flow is experienced in September/October every year. Fig 3.1 is a photograph of river Shetiko shown in the next page..

Figure 3.1: Photograph of River Shetiko

### 3.8 Kuje

Kuje is a Local Government Area of the Federal Capital Territory (Nigeria) and the town is the headquarters of the LGA. It is about 40 km south west of Abuja, the Capital of Nigeria. It has an area of 1,644 $km^2$ and a population of over 97,367 at the 2006 census. Fig 3.2 shows the map of Abuja indicating the location of Kuje.


Figure 3.2: Map of Abuja showing Kuje

# Chapter Four

# Material, Method and Result

This chapter presents the methodology and the result obtained from study.

## 4.1 Flow Determination

The flow of River Shetiko was determined insitu using the Velocity - Area method. Figure 4.1: (The determination of River Shetiko's Flow rate). The average velocities with respect to depth across the river were determined.

The flow rate, Q, was obtained using the formula in equation 4.1

$$Q = \Sigma_i^n A_i V_i \qquad \text{.....................................................} 4.1$$

Where Q = Average flow rate ($m^3/s$)

$A_i$ = Elemental cross section at point (i) across the channel ($m^2$)

$V_i$ = Average velocity I across the channel ($m^3/s$)

Detailed calculation is shown in section 4.3

Figure 4.1: Photograph showing the determination of River Shetiko's Flow rate.

## 4.2 Head Measurement

Elevations were taken at Lat N8.9016$^o$, E7.2078$^o$ of about 400 m upstream and Lat N8.9037$^o$. Long E7.0266$^o$ of the River Shetiko course using hand held GPS as the terrain is walked-through. A tentative location for SHP infrastructure is yet to be identified. The elevation of this position relative to downstream elevation is about 20 m head.

## 4.3 Data Analysis for Mini-Hydro Power Investigation on River Shetiko

In this section, the followings parameters are to be calculated in order to find the flow rate.

Velocity, V m/s

Cross sectional area of the river, A $m^2$ and

The Flow rate, Q $m^3/s$ is obtained as the product of the velocity and the cross sectional area

### 4.3.1 Velocity determination

For this site, the Float Method was used to estimate the velocity of the flowing River. Data collected on site is shown in table 4.1:

**Table 4.1:** Tabulated Result of the determination of Velocity of River Shetiko

<table>
<tr><th>D (m)<br>length across river</th><th>Time(s)</th><th>d (m)<br>travel distance</th><th>Depth (m)</th></tr>
<tr><td rowspan="5">27.8</td><td>41</td><td rowspan="5">15</td><td>0.69</td></tr>
<tr><td>54</td><td>0.55</td></tr>
<tr><td>59</td><td>0.42</td></tr>
<tr><td>54</td><td>0.71</td></tr>
<tr><td>52</td><td>0.24</td></tr>
</table>

Finding average time, $T_{av} = \frac{41 + 54 + 59 + 54 + 52}{5}$

$= \underline{52 \text{ seconds}}$

Knowing that velocity; m/s     (m/s , meter per second)

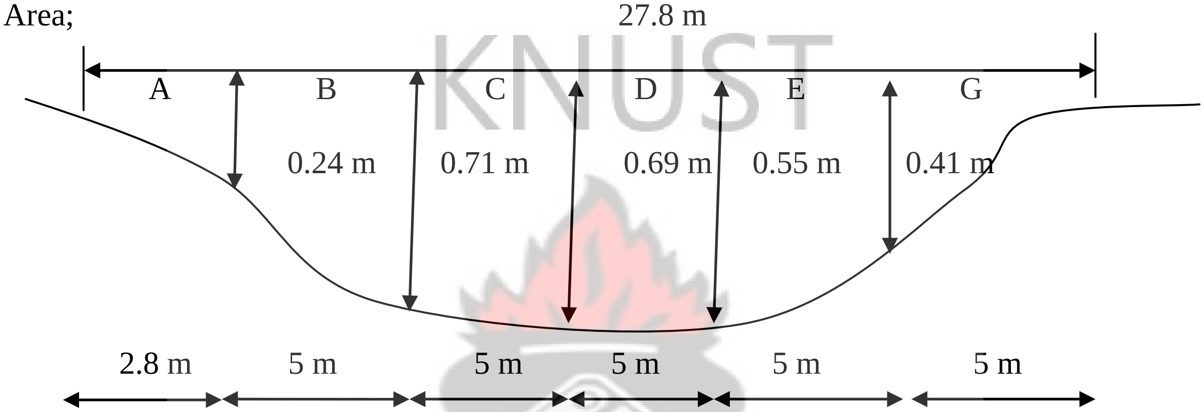
We have 27.8/52 = **0.53 m/s**

But Velocity, V = Vs x 0.75 (taking 75% of the velocity)

V = 0.53 x 0.75 = **0.397 m/s**

**4.3.2 Calculation of the Cross sectional Area, A of the River**

For Area;




A = $\frac{1}{2}bh$ (formula for finding the area of a triangle)

Where b = base

. h = height

$= \frac{1}{2} \times 2.8 \times 0.24$

$= \mathbf{0.336\ m^2}$

B = $\left(\frac{a+b}{2}\right)h$ (formula for finding the area of a trapezium)

Where a and b are opposite sides of the trapezium

. h is the distance between the parallel sides

$= \left(\frac{0.24+0.71}{2}\right)5$

$= \mathbf{0.2.375\ m^2}$

C = $\left(\frac{a+b}{2}\right)h$

C = $\left(\frac{0.71+0.69}{2}\right) 5$

= ***0.3.5 m***$^{2}$

D = $\left(\frac{a+b}{2}\right) h$

= $\left(\frac{0.69+0.55}{2}\right) 5$

= ***3.1 m***$^{2}$

E = $\left(\frac{a+b}{2}\right) h$

= $\left(\frac{0.55+0.41}{2}\right) 5$

= ***2.4 m***$^{2}$

F = $\frac{1}{2} \times 5 \times 0.41$

= ***1.025 m***$^{2}$

Area Total = (0.336 + 2.375 + 3.5 + 3.1 + 2.4 + 1.025)m$^{2}$ = **12.736 m**$^{2}$

**4.3.3 Calculation of the flow rate**

Q = AV (formula for finding the flow rate or discharge)

Where A is the Cross Sectional Area

V is the velocity of flow of River Shetiko

= 12.736 m$^{2}$ X 0.397 m/s

= 5.06 m$^{3}$/s

≈ **5.0 m**$^{3}$**/s**

**4.3.4 Power Potential**

The power potential of the site is calculated from the formula given below

Power potential, P = KQH

Where K = Constant; 7 (a factor which lies between 5 and 7 whose main function is to take care of the various losses incurred as water flows right from the water intake conveyed through the canals and through the penstock before it finally gets to the turbine in the power house)

Q = Discharge; 5.0 $m^3/s$

H = Head; 20 m

P = 7 X 5.0 X 20

= **657.76 kW**

With power potential of 657.76 kW obtained using the base flow rate of 5.0 $m^3/s$ and a head of 20 m which an elevation difference from the water intake to Turbine position in the power house , the energy demand of the community would be met throughout the raining period and one or two months after the raining period. That is from April up to November. However, with storage of water it could last for another two months.

## 4.4 LOAD SURVEY DEMAND

The immediate Housing Estate in Kuje Council Area is expected to have about 200 housing units with an estimate of 2 kW/Household both power and light loads. Equaling an estimate of 400 kW. This estimate is quite rough, when a Detailed Project Report, DPR, is commissioned, this data will be well fine tuned in the Project Design Document. PDD.

### 4.4.1 Load Management Strategy

The amount of energy generated from the SHP power station needs to be efficiently and strategically managed. This warrants the use of energy efficient devices/systems as well as optimal use. This is because the SHP plant can run for 24 hrs of the day and many months, depending on the available water.

## 4.5 Proposed Scheme

As a result of extensive walk-through survey of the terrain, a diversion scheme is being proposed which entails constructing a weir to hold back the water and raise elevation. A power house will also be constructed to house the turbines and control panels. The electricity generated from the SHP plant will be evacuated through the existing PHCN transmission lines.

### 4.6 Equipment Selection E/M

The basic data for selecting the E/M equipment are head, flow and the power capacity. The head and flow as determined are 20 m and 5 $m^3/s$ respectively. The head and flow determination have been earlier explained in sections 4.2 and 4.3 respectively. A 2 x 250 kW Cross flow turbine (CFT) is tentatively proposed for the project. Using Manufacturer's catalogue, the Cross Flow Turbine is selected for ruggedness, ease of manufacture and installation and above all, for reduced cost, as well as the demand of operation and maintenance. The two (2) units will run at a speed of 250 - 300 rpm.

Note that the above are tentative as further study (feasibility study and Detailed Project Report) are expected to bring up more issues that must be taken into consideration as this study is not inclusive of the wet flow (Rain Season) of River Shetiko.

### 4.7 ESTIMATED COST

Assuming a system cost of 2,000 USD per kW.

Power potential of the site is 657.76 kW

Therefore, 2000 x 657.76 = 1,315,520 USD.

### 4.8 TECHNO-ECONOMIC ANALYSIS

#### 4.8.1 Economic Analysis

The project is expected to have an installation period of less than two (2) years since the proposed scheme is diversion scheme.

### 4.8.2 Expected Revenue

No of household in the community = 200

Power Consumption per household = 2 kW

Total power consumption for the entire community = 2 X 200 kW = 400 kW

Power consumption for one year = 400 x 24 hr x 365 days x 0.11 USD

= 385.440.00 USD

Assuming a 20% increase = 385,440 x 1.2 = 462,528.00 USD

We have 462,528.00 USD.

### 4.8.3 Payback Period

The simple payback period is calculated by dividing the investment cost by the Expected Revenue.

Thus;

Payback Period = Total Investment Cost / Expected Revenue

= 1,315,520 ( see section 4.7)

462,528 ( sede section 4.8.2)

= 2.84 yrs (Approximately 3 years)

Meaning, with the total investment cost of 1,315,520.00 USD and with the annual expected revenue of 462,528 USD the simple payback period is approximately 3 years. That means the investor will have all the money he invested in the project with the first 3 years after which profit follows. Considering the fact the active life expectancy of the project is between 30- 50 years, the investor stands to make good profit and once again the project is worthwhile.

## 4.9 Analysis of Results

The outcome of this work is discussed under the following sub headings:

Technical, Financial and Socio-economic.

### (a) *Technical Results*

Power potential calculation was made using the flow rate, net head and efficiency values (i.e constant k for losses on the power equation given in section 4.3.4 of this project. A suitable turbine was selected based on the head and discharge parameters. The following results were obtained from the study:

Head = 20 m (using hand held GPS)

Flow rate = 5 $m^3/s$ (using flow method)

Power = 657.76 kW (using hydropower equation)

Turbine type = Crossflow (using manufacturer's guide)

**(b) Financial Results**

The total capital cost is (1,315,520.00 USD). The specific construction cost per kW is (US 2000 USD) and unit energy cost was found to be (0.11 USD). The quantity of energy to be delivered by the project is calculated thus;

| | | |
|---|---|---|
| Capacity | = | 657.7 6kW |
| Operating Time | = | 24 hours |
| Energy produced | = | 657.76 kW x 24 hrs x 365 days |
| | = 5,761,977.60 kWh/year. | |

**(c) *Socio-economic benefits***

Small hydropower has been found to have positive impact on the quality of life of rural dwellers in numerous ways. It provides a wide range of services such as small cottage industries, schools computer service centres, clinics, improved lighting, more entertainment, communication options and operations of a range of appliances.

More so, small hydropower reduces environmental pollution through replacement of paraffin lamps and other cooking fuels. Hence, Small Hydropower is said to be environmentally friendly.

# Chapter Five

## Conclusions and Recommendations

### 5.1 Conclusions

Though the initial cost of installation is huge compared to any other form of power production, the operating and maintenance cost is very low, and in the long run the investment pays off especially when carbon emission and other environmental degradation is taking into consideration. Within the context of the objective of the proposed project, which is partly financial and partly social, this project could be considered as a worthwhile investment bearing in mind the numerous socio economic benefits to be derived by the community.

The major conclusions are summarized under the following headings:

- Technical
- Financial and
- Socio-economic

**(a) *Technical***

Power potential calculation was made using the flow rate, net head and efficiency values on the power equation given in section 4.3 of this project. 2 Cross Flow turbines were selected based on the 20 m head and 5 $m^3/s$ discharge parameters. The following results were obtained from the study:

Head = 20m

Flow rate = 5 $m^3/s$

Power = 657.76kW

Turbine type = Crossflow 2 nos

**(b) Financial Results**

The total capital cost is (1,315,520.00 USD). The specific construction cost per kW is (US 2,000USD) and unit energy cost was found to be (0.11 USD). The project would deliver 5,761,977.60 kWh/year.

**(c) *Socio-economic benefits***

Small hydropower has been found to have positive impact on the quality of life of rural dwellers in numerous ways. It provides a wide range of services such as small cottage industries, schools computer service centres, clinics, improved lighting, more entertainment, communication options and operations of a range of appliances.

More so, small hydropower reduces environmental pollution through replacement of paraffin lamps and other cooking fuels.

The people of Kuje specifically have a lot to benefit among which are small scale industries like barbing salon, pepper grinding machine, ice cream and ice water business, computer training skill acquisition centres could spring up and lots more. The water at the tail race is still available for irrigation purposes.

Finally, small hydropower is environmentally friendly, even to Kuje community.

### 5.2 Recommendations

The next step after prefeasibility studies would be the preparation of a detailed feasibility study. By further refining the energy price forecast and construction costs, a more accurate result can be determined.

The detailed feasibility study would include the following tasks:

- Develop a detailed energy price forecast based on projected avoided cost energy prices and renewable energy credit values applied to the estimated energy output associated with the project.
- Prepare an interconnection study to determine whether the existing transmission system can accommodate the power generated by the hydro facility.
- Have a structural engineer visit the site to conduct a visual inspection of the intake tower and to obtain information to assist in developing conceptual design plans.
- Prepare a detailed headloss analysis.
- Have an electrical engineer prepare a one-line diagram, conceptual layout of the electric control booth, transmission line and transformer, and cost estimate.
- Further review of renewable power generation incentives.

I will like the authority of KNUST particularly the mechanical department to encourage any other Nigerian who might have interest in hydropower to pick up this project and carry other detailed study on it. This study should include the secondary data and carryout Flow Duration Curve (FDC), Power Duration Curve (PDC) and come out with a more detailed result.

With the above accomplished during the, this project is on its way to implementation.

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