TRIBHUVAN UNIVERSITY

INSTITUTE OF ENGINEERING

PULCHOWK CAMPUS

Thesis No.: M-341-MSREE-2018-2022

Energy Consumption Analysis and Energy Saving Opportunities: A case study of Mahankalchaur Water Treatment Plant, Mahankalchaur, Kathmandu, Nepal

by

Shiva Prasad Sapkota

A THESIS

SUBMITTED TO THE DEPARTMENT OF MECHANICAL AND AEROSPACE ENGINEERING

IN PARTIAL FULFILLMENT OF THE REQUIREMENTS FOR THE DEGREE OF MASTERS OF SCIENCE IN RENEWABLE ENERGY ENGINEERING

DEPARTMENT OF MECHANICAL AND AEROSPACE ENGINEERING

LALITPUR, NEPAL

MARCH, 2022

COPYRIGHT

TRIBHUVAN UNIVERSITY

INSTITUTE OF ENGINEERING

PULCHOWK CAMPUS

DEPARTMENT OF MECHANICAL AND AEROSPACE ENGINEERING

APPROVAL PAGE

The undersigned certify that they have read, and recommended to the Institute of Engineering for acceptance, a thesis entitled **“Energy Consumption Analysis and Energy Saving Opportunities: A case study of Mahankalchaur Water Treatment Plant, Mahankalchaur Kathamndu, Nepal”** submitted by Shiva Prasad Sapkota, in partial fulfilment of the requirements for the degree of Master of Science in Renewable Energy Engineering.

____

Supervisor, Dr. Ajay Kumar Jha
Associate Professor
Department of Mechanical and Aerospace Engineering

____

External Examiner, Er. Birendra Kumar Jha
Manager
Nepal Electricity Authority

____

Committee Chairperson, Dr. Surya Prasad Adhikari
Head of Department
Department of Mechanical and Aerospace Engineering

Date: 21th, March 2022

ABSTRACT

The first systematic water supply system, known as Bir Dhara, in 1895 the first water treatment facility was built in Sundarijal with Indian assistance to treat the tail race water pouring out of the Sundarijal Hydropower Station. Actual energy consumption can be found by an energy audit, which gives the idea of energy-saving possibilities. Electrical energy consumption in water treatment plant with energy auditing find out energy consumption, energy saving area and cost-saving opportunities with simple and discounted payback period. The Mahankalchaur water treatment plant is the largest water treatment plant inside Kathmandu valley. Data collected by interview and walk though survey. There is a 500 KVA transformer with 450 KVA. Power factor varies from 0.73 to 0.93 and 75 KVAr of is present in plant need to extra 44 KVAr to maintain 0.99 power factor. From preliminary audit there is 482.39 kW connected load with transmission pump. Kapan supply pump and tanker filling pump as major electricity consuming derive. Energy bill of twenty-two month analyze, it was found that peak hour consumption and off peak hour consumption is half of normal hourly consumption. Demand varies from 91 KVA to 274 KVA. Average monthly energy consumed was found 72.56 MWh, with an average monthly bill paid for energy tariff is NRS.3, 55,309.48 and 85.75 mu with average energy cost NRS. 4, 16,857.31 per month in during 2077 and 2078 BS respectively. Specific energy consumption inside the plant is 0.1338 kWh/cubic meter.

From detail energy analysis, inefficient replaces by 20 watt led bulb save 0.12 % of total kWh and 0.16% of the total annual bill with simple payback 1.88 years and discounted payback period of 2.28 years. Two hours of Peak hour shift can, save annual 1.05% of the energy bill. Efficient pump installation on the transmission pump save, annual 21% of energy and 20.58 % of annul energy bill with simple payback 3.31 years while 19.28% annual bill could save with discounted payback period 3.25 years. For Kapan water supply system at 5% load variation, VFD saves 7.06% energy and 6.92% of annual bills while considering MARR 10% with 1% annual maintenance can save 6.7 % of annual energy bills. Overall, 10.69% energy and 27.66% energy bill with NRS 3178115.00 investment could save annually using led, efficient pump and VFD. Considering MAAR 10% and annual maintenance cost overall, 26.13% of annual energy bill could save.

ACKNOWLEDGEMENTS

It's a matter of great opportunity to forward this report on the project "Energy Consumption Analysis and Energy Saving Opportunities: A case study of Mahankalchaur Water Treatment Plant (KUKL), Mahankalchaur Kathmandu, Nepal". First of all, I would like to thank the 'Department of Mechanical and Aerospace Engineering' of Pulchwok Engineering College, Tribhuvan University for the inclusion of research as the course of study, in which we are granted an opportunity to make a choice of any project of our interest as the thesis.

I would like to express my sincere gratitude to Asst. Prof. Dr. Ajay Kumar Jha, my project supervisor for his valuable guidance, constant support, and encouragement which have been really appreciable for the persistence of my thesis project.

I would like to extend my genuine appreciation to Er.Hem Budhathoki, Er.Rupesh Gautam, Parbin Bhurtel and Ar.Pratima Panthi for providing me with his valuable suggestions and guidance for my thesis as well. I am also thankful to all the staff members of the Mahankalchaur Water Treatment Plant (KUKL) where I visited for my case studies for great support and co-operation which helped me a lot to prepare this report.

Shiva Prasad Sapkota
(074-MSREE-018)

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

LIST OF ACRONYMS

BS	Bikram Sambat
CFL	Compact Florescent Lamp
CWR	Clear Water Reservoir
DF	Discount Factor
DG	Diesel Generator
DP	Double Pole
EA	Energy Audit
GoN	Government of Nepal
HP	Horse Power
KVA	Kilo Volt Ampere
KVAr	Kilo Volt Ampere Reactive
KW	Kilo Watt
KWh	Kilo Watt Hour
KUKL	Kathmandu Upatyaka Khanepani Limited
MCB	Miniature Circuit Breaker
MCCB	Molded Case Circuit Breaker
MLD	Million Littre per Day
MS	Microsoft Office
MWTP	Mahankalchaur Water Treatment Plant
MWh	Mega Watt hour
NEA	Nepal Electricity Authority
PAC	Ploy Aluminum Chloride
PF	Power Factor
RSF	Rapid Sand Filter
SRT	Service Reservoir Tank
TOD	Time of Day
TP	Triple Pole
VFD	Variable frequency drive
WTP	Water Treatment Plant

CHAPTER ONE: INTRODUCTION

1.1 Background

History of Water treatment began early as 4000 B.C. strategies methods were recorded to progress the taste and odor of drinking water. Ancient Sanskrit uncovering to sunlight, boiling and straining. To clarify water turbidity, the Egyptians supposedly utilized the chemical alum as early as 1500 B.C. During the 1700s, filtration was a build-up to remove particles from the water, and early 1800s, slow sand filtration was starting to be utilized commonly in Europe. America started the construction of large sand filters in the 1890s. Rapid sand filtration used a jet stream to clean the filter and improve its capacity. Researchers also found that filtration worked better when treated with coagulation and sedimentation (US EPA, 2000). Prime Minister Bir Shumser built the first systematic water supply system, known as Bir Dhara, in 1895, which collected water from Shivapuri and transported it to a reservoir in Panipokhari, where it was dispersed to various areas across Kathmandu. During the reign of Chandra Shumsher, the first water treatment facility was built in Sundarijal with Indian assistance to treat the tail race water pouring out of the Sundarijal Hydropower Station. Sedimentation, coagulation, rapid sand filtration, and chlorination are all part of the treatment plant (GWP-Nepal & JVS, 2018).

Energy demand is growing in all sectors of industries annually in the world. Only finding a new alternative is not solution of energy demand fulfillment. So energy saving by effective method and technique is also important. The actual energy consumption can be found by an energy audit, which give idea of energy saving possibility. Water industry uses energy for water extraction, raw water treatment, distribution, wastewater collection, treatment, and recycling. The energy intensity of non-conventional water sources such as recovered or desalinated water is higher. When compared to surface water, groundwater requires more energy. Pumping groundwater has been known to consume up to 40% of a country's total energy (Hoff, 2011).Key features of energy audit guidelines for commercial sector include:

- Organized reduction of energy consumption and carbon emissions
- Provide instructions for benchmarking, measuring, documenting, and reporting energy usage
- Obtaining a comprehensive picture of current energy usage so that new goals and targets can be established.
- Prioritizing and assessing the use of innovative energy-saving technologies and techniques
- Provide useful information about energy-efficient devices and technology that are readily available.
- Identifying and implementing energy-saving opportunities. (Consultancy, no date)

A case study of the Lalpur water treatment plant was required in order to increase the plant's efficiency in terms of pumping power, transformer operation, and illumination. An energy audit was conducted to boost the pumping power and lighting power of the Lalpur water treatment power plant in order to improve its overall performance (Dubey *et al.*, 2012).Throughout India, most of the energy is used for water supply rather than sewage treatment. In Dehradun, most wastewater does not reach the sewage treatment plant, so the total energy consumption of the water supply system is about 16 times that wastewater treatment. It is reported that average energy intensity in India is lower than the average energy intensity in the UK (0.46 kWh / m3)(Lee *et al.*, 2017). Existing pumps and motors are being replaced with more efficient pumps and motors. The deployment of such methods saves more than 6% of the energy consumed by the water treatment plant on an annual basis (Farhaoui and Derraz, 2016).

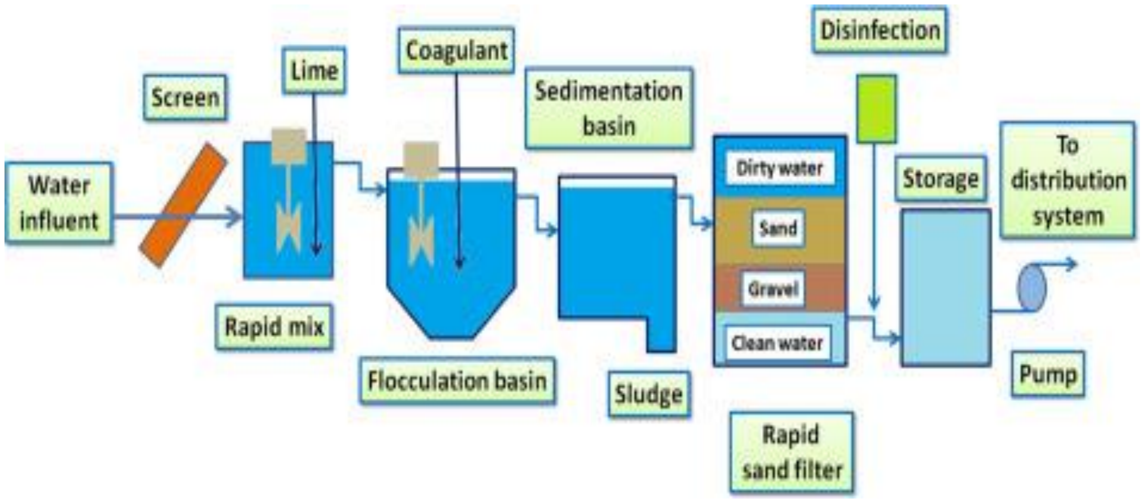


Figure 1: Water Treatment Process

Figure 1 explains that chemicals are added and disseminated fast through the water at high mixing speeds. Chemicals such as alum (aluminum sulfate) are added to the water to both neutralize the particles electrically and to bring them closer together, forming big particles known as flocs that may be sorted out more easily. Due to its weight, flocs settles to the bottom of the water supply during sedimentation. The clear water on top will flow through the filters of varied compositions (sand, gravel, and charcoal) and pore diameters to remove tiny particles that were not settled, such as dust, parasites, bacteria, viruses, and chemicals, until the flocculants has dropped to the bottom of the water supply. The addition of chemicals to the disinfection process kills or reduces the amount of pathogenic organisms (Abu Shmeis, 2018).

1.2 Problem Statement

Mahankclachour water treatment plant (MWTP) is 28 years old present in Kathmandu valley. Energy-consuming equipment's are an air blower, chemical solution pump, drainage pump, water transmitting centrifugal pump, and submersible pump. These are equipment are as old as plant and consume a monthly average of 72562.67 kWh energy. Monthly average NRS 355309.50 bill is paid to Nepal Electricity Authority (NEA). Operation and maintenance cost is increasing day by day. Sometime breakdown of equipment leads to disturbing production and distribution of water. Some units of electrical energy are wastage as the system is old, equipment's are less efficient and more power-consuming. Population and urbanization rapidly growing in Kathmandu valley, but the sources of water are certain. Groundwater level decline as excessive extraction and water treatment plant work less capacity than its design capacity due to lack of water available. Surface water, which comes from Sundarijal Bagmati River varies seasonally that why water treatment plant processes is not fully in operation plant process like PAC feeding, slaked lime feeding and disinfection partially work and consume more energy. Despite new technology and energy efficient equipment available in treatment sector, this plant still uses old pump, blower and chemical pump which consume more energy than actual need.

1.3 Objective

1.3.1 Main objective

The main objective of this research is to evaluate electrical energy consumption at the water treatment plant and find out energy cost-saving opportunities.

1.3.2 Specific Objectives:

- To find out the existing energy consuming equipment, monthly actual demand and evaluate monthly tariff of energy used in water treatment plant.
- To conduct detailed energy auditing inside water treatment plant
- To find out annual energy saving area and calculate annual energy saving
- To find out the payback period with efficient method

1.4 Limitation of the thesis

The goal of this research is to understand the energy consumption inside water treatment plants and water energy-saving opportunities. The field of water and energy management is wide, and due to time and resource constraints, it was not possible to cover all areas in this study.

Most of the analysis for the study has been carried out from primary data collection, few secondary data and interviews with plant engineers and operators. Cost related to chemical not included in the calculation. Only electrical energy-related study is considered in this project.

CHAPTER TWO: LITERATURE REVIEW

A literature review is done, though reading of various articles related to water treatment process, energy audit method, and efficient electrical energy related water treatment equipment with cost benefit analysis.

2.1 Drinking water treatment plant process

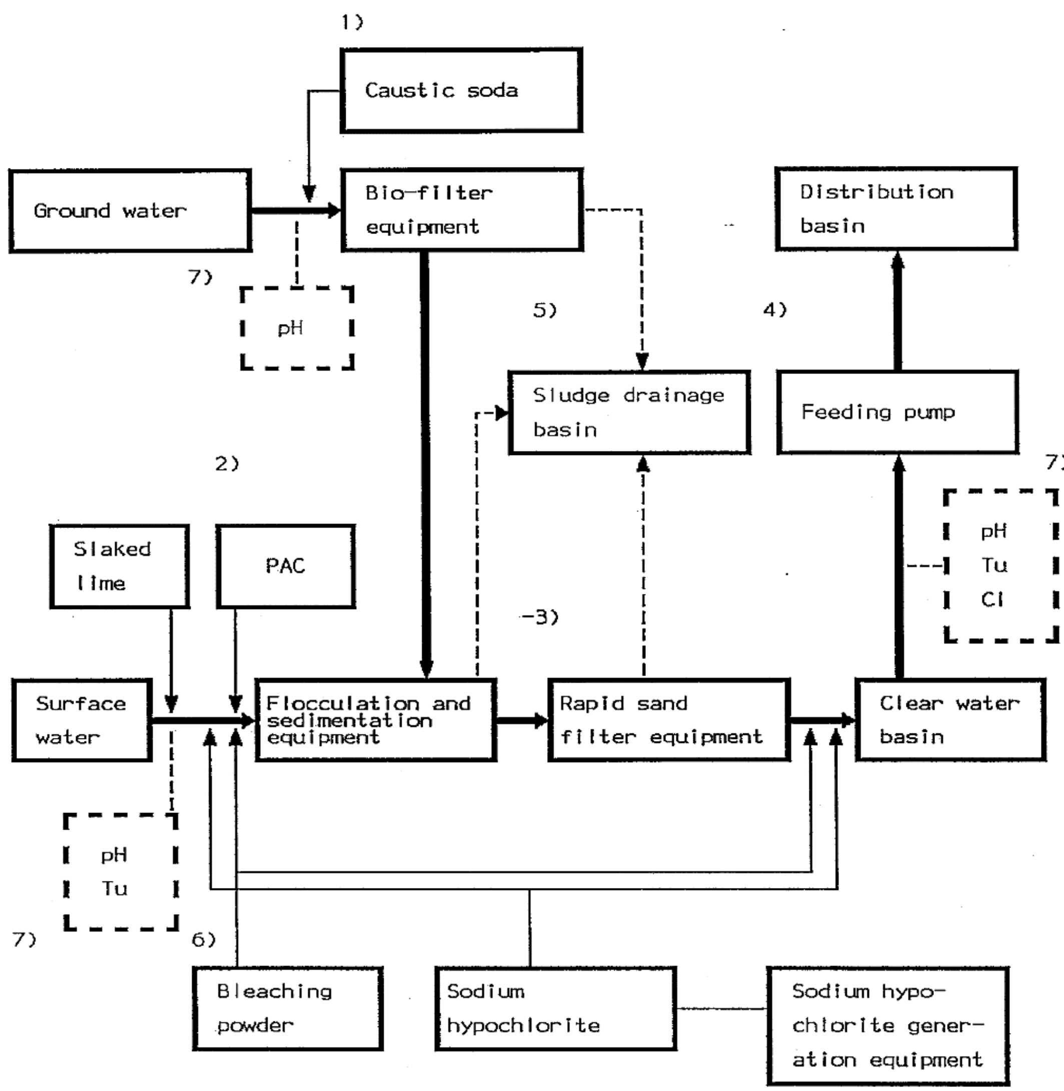
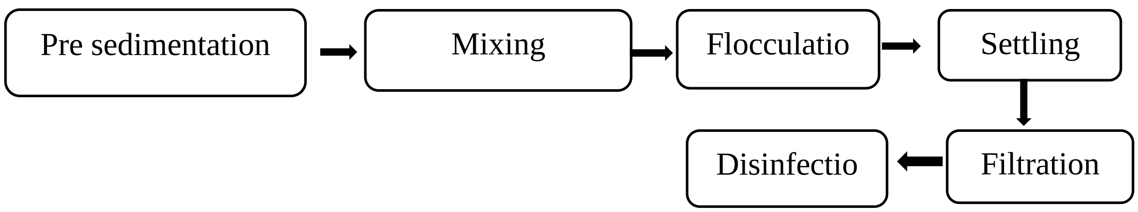


Figure 2: Mahankalchaur water treatment plant process flow diagram

Above figure 2 describes the water treatment process of Mahankclachor water treatment plant process and water. There is facility of both ground water and surface water treatment with PAC to handle turbidity, lime to handle pH value of water and bleaching powder for disinfection action. Final portable water either distributed by pump directly or from high a head tank.

Conventional surface water treatment schematic (Potable drinking water) of water as follows



- Sedimentation (flow is slowed sufficiently hence gravity will cause turbidity to settle)
- Sludge processing (mixture of solids and liquids collected from settling tank is dewatered and disposed)
- Disinfection (make sure that water is free of dangerous pathogens)
- Distribution system protection (residual disinfection) (Kumar, 2015)

2.2 NEA TOD Meter and Tariff for Public Water Supply

The Nepal Electricity Authority (NEA) was established by the Nepal Electricity Authority Act on August 16, 1985 (Bhadra 1, 2042). NEA's major goal is to generate, transmit and distribute adequate, reliable and affordable power by planning, constructing, operating and maintaining all generation, transmission and distribution services in Nepal's power system both isolated and interconnected mode.

The NEA tariff rate are different as consumer to consumer. They classified consumer from category A to category k and their other consumer tariff TOD meter base tariff.

Table 1: Nepal Electricity Authority TOD meter tariff

S.N	Consumer category	Demand charge per KVA (NRs.)	Peak hour (5 pm -11 pm) per unit(NRs.)	Off-peak hour (11 pm - 5 am) Per unit (NRs.)	Normal hour (5 am - 5 pm (12 hours) per unit (NRs.)	Remark
1	For 11 kV	0	6.3	3.4	4.7	
2	For11KV	0	6.3	4.7	4.7	Dry season

NEA tariff varies from normal day, peak and off peak hour as well as from dry season to wet season (Nepal Electricity Authority, 2021).

2.3 Energy Audit and Water Treatment Plant

One of the most significant instruments for energy conservation and energy efficiency is the energy audit. Energy audits can be used to identify areas of leakage and waste of renewable energy. Energy audits can also help you cut down on energy waste in your current systems. As a result, energy audits can help with

- Energy saving
- Cost saving

Energy audits are essential for a methodical approach to energy management decision-making. The following are the components of a basic energy audit

- Efficient energy measuring
- Recognizing and preventing losses
- Calculating our system's actual energy consumption capabilities

One of the main objectives for energy audits is to reduce current costs (Talwar, 2016).

Energy audit would allow the utilities to assess the entire system and identify areas and possibilities for energy efficiency improvements without compromising the system performance or water quality. The pumping of raw water to distribution and treatment accounts for nearly 80% of the energy used in drinking water plants, energy audits would be required to control and assess the utilities' energy consumption (Leiby and Burke, 2011).

Typically identify both capital and operational enhancements (motors, blowers, variable frequency drives, and so on).

- Time of operation, load demand contracts, unneeded equipment, and energy management systems, among other things, can result in significant cost reductions with little to no effort.
- Plant design audits can be undertaken at a very low cost.
- Possess the ability to recognize renewable energy prospects.

The following are some of the variables that influence the energy audit for a water treatment plant:

- Pumping
- Lighting
- Power factor
- Raw water quality (Dubey et al., 2012)

2.3.1 Preliminary Energy Audit

A preliminary energy audit is a quick activity that determines:

- The organization's energy consumption
- The potential for cost savings
- Estimate the scope for saving
- Determine which regions are most likely (and simplest) to receive attention.
- Identify urgent (particularly no-/low-cost) improvements/cost-cutting opportunities

- Establish a ‘reference point
- Identify areas that require additional in-depth investigation/measurement
- A preliminary energy audit makes use of data that is already available or may be easily obtained (ECBC, 2001)

2.3.2 Detailed Energy Audit

An inclusive audit provides a detailed energy project implementation plan for a facility, since it calculates all major energy using systems. Detailed audit offers the most accurate approximation energy savings and cost. This is based on a list of energy-consuming systems, assumptions about present operating circumstances, and energy-use calculations. The anticipated use is then compared to the charges on the utility bill. The detailed energy auditing process is divided into three stages:

- Pre-audit phase (Phase I)
- Audit phase (Phase II)
- Post-audit phase (Phase III)

- **Phase I –Pre Audit Phase Activities:**

A structured methodology to carry out an energy audit is necessary for efficient working. The scope develops; issues are clarified; resources are found and secured; and changes are made to the audit scope, date, and length.

- **Phase II- Detailed Energy Audit Activities**:

A comprehensive audit might take anything from a few weeks to several months to perform, depending on the scope and complexity of the site. Extensive auditing involves conducting detailed studies to create and evaluate energy and material balances for individual plant departments or pieces of process equipment

- **Post Audit Phase**

  The next phase in the energy audit process is to write a report that summarizes the findings of the energy studies and makes recommendations for energy cost savings. After completing an energy audit effectively, the energy manager/auditor should report to upper management for effective communication and implementation. A full description of the ECOs and cost-benefit evaluations is more likely in an industrial audit (Bora, 2008).

An Energy audit increases the productivity of Organization and helps to increase the output of any industry. It also reduces cost of Production without scarifying the efficiency. (Dubey et al., 2012)

2.4 Energy Consumption and Efficient Technique

Energy consumption can reduce by efficient habits or utilization and replace by efficient device.

2.4.1 Energy Efficiency

A ratio between a performance result, service, products, or energy generation and an energy input is characterized as energy efficiency. It is undeniable that increased energy efficiency allows for the same outcome to be achieved with less energy or for higher performance to be achieved with the same amount of energy. (Howley *et al.*, 2012).

On the regional, national, and international levels, energy efficiency is currently a prominent topic. Accurate monitoring of how energy is used over time can significantly improve the drinking water utility's performance and lower energy consumption. There are no benchmarks for comparing energy use among water utilities with various system characteristics (Chanpiwat and Sinha, 2014).

High Efficiency Motors (HEMs) are the most efficient of these motors, and they are categorized as EFF1 by the European Committee of Manufacturers of Electrical Machines and Power Electronics (CEMEP). According to CEMEP, motors are divided into three efficiency classes:

- EFF1 (high efficiency motors)
- EFF2 (enhanced efficiency motors)
- EFF3 (standard motors) (Elias and Jaya, 2017)

There are several energy efficiency opportunities, which typically provide high returns. Typical energy efficiency opportunities are: steam system upgrades; heat recovery; compressed air system upgrades; lighting; motor and drive system upgrades; energy efficiency in buildings; production of energy from waste; cogeneration; modernization.

Optimizing the system includes improvements such as matching the pump to requirements, optimizing the distribution piping, eliminating unnecessary valves, controlling the pump speed where appropriate, and institutionalizing improved operation and maintenance practices, replace inefficient pumps with efficient and install variable speed drives. Regular preventative inspection and maintenance, including cleaning or replacing impellers and checking lubrication of bearings. Trim impellers where pumps too large for the application otherwise suitable (Dubey et al., 2012).

2.4.2 Water Utilities and Energy Efficiency

- Lower energy consumption
- Lowering operational costs
- Lessening of climate impacts and carbon footprint
- Infrastructure for water sustainability
- Conserve water (Horne, Turgeon and Byous, 2011)

Energy efficiency studies and analyses have been carried out in Nepal since 1985, while initiatives such as energy audits of industries, energy efficiency related trainings and increased public awareness, as well as management of loans for energy efficiency in industries, were carried out between 1999 and 2005 AD. From 2009 to 2011, the Nepal

Electricity Authority implemented initiatives such as demand side management of electricity, energy audit, the study of the electricity load profile, preparation of policy suggestions for promotion of energy efficiency, and replacement of traditional bulbs with energy efficient bulbs (MoEWRI, 2019).

Nepal's Energy Efficiency Policy and Planning Initiatives Rural Energy Policy (2006)

- Electricity Crisis Resolution Action Plan (2007)
- Three Years Plan (Approach Paper-2010)

Some Regulatory Initiatives on Energy Efficiency

- Electricity Act (1992) and Regulation (1993)
- Electricity Leakage Control Act (2002)
- Electricity Tariff Fixation Rules
- National Energy Efficiency Strategy, 2075

  (Approved by the Cabinet Meeting of the GoN on November 19, 2018) (Kharal, Officer and Secretariat, 2011)

2.5 Financial Analysis Methods Used in Energy Audit

Net present value, internal rate of return, and payback are the most common economic measures used to determine cost efficiency. Payback will be used to determine feasibility because it indicates how long it will take for a measure to pay for itself through savings. It is widely used since it is simple to calculate (Bora, 2008).

The simple payback is by far the most common financial analysis tool used in the energy-auditing area, but this may not always be the most appropriate tool. For large projects a sensitivity analysis should be carried out to determine how the financial viability of a project would be affected by changes to the assumptions made, such as operating hours, forecast activity levels, energy inflation, Interdependencies and dependent projects should also be discussed.

2.5.1 Simple Payback Period

The time it takes to recoup the cost of an investment is known as the basic payback period. The payback duration is a key factor in deciding whether or not to proceed with the project; normally, longer payback periods are undesirable. Unlike other capital budgeting approaches such as net present value, internal rate of return, or discounted cash flow, the payback period ignores the time value of money. Simple payback is a well-known and regularly used method of determining a project's profitability. For example:

Project investment cost: €100,000 Projected savings per year: €40,000

Simple Payback: Investment /Savings =€100,000 / €40,000 = 2.5 years (SEAI, 2017).

2.5.2 Discounted Payback Period

Discounted payback calculated same as a simple payback period, but it considers the time value of money.

2.6 Classification of Energy Conservation Measures

A variety of possible energy-saving projects may be identified based on the energy audit and studies of the plant. These can be divided into three groups.

1. Low investment - high return
2. Medium investment - medium return
3. High investment - high return

Normally the low cost - high return projects receive priority. Other projects have to be analyzed, engineered and budgeted for implementation in a phased manner. (Bora, 2008)

CHAPTER THREE: RESEARCH METHODOLOGY

Research methodology done through data collection and energy auditing. The first step was the site visits, second one is data collection related to energy consuming device and most energy saving area, third one is efficient method and cost analysis of the most efficient method.

3.1 Overview

Energy consumption in water treatment plant finds out by detail energy audit with energy measuring instrument. Energy consumption and financial analysis have done analytically in Microsoft excel. The theoretical framework of research methodology as plotted in figure 4.

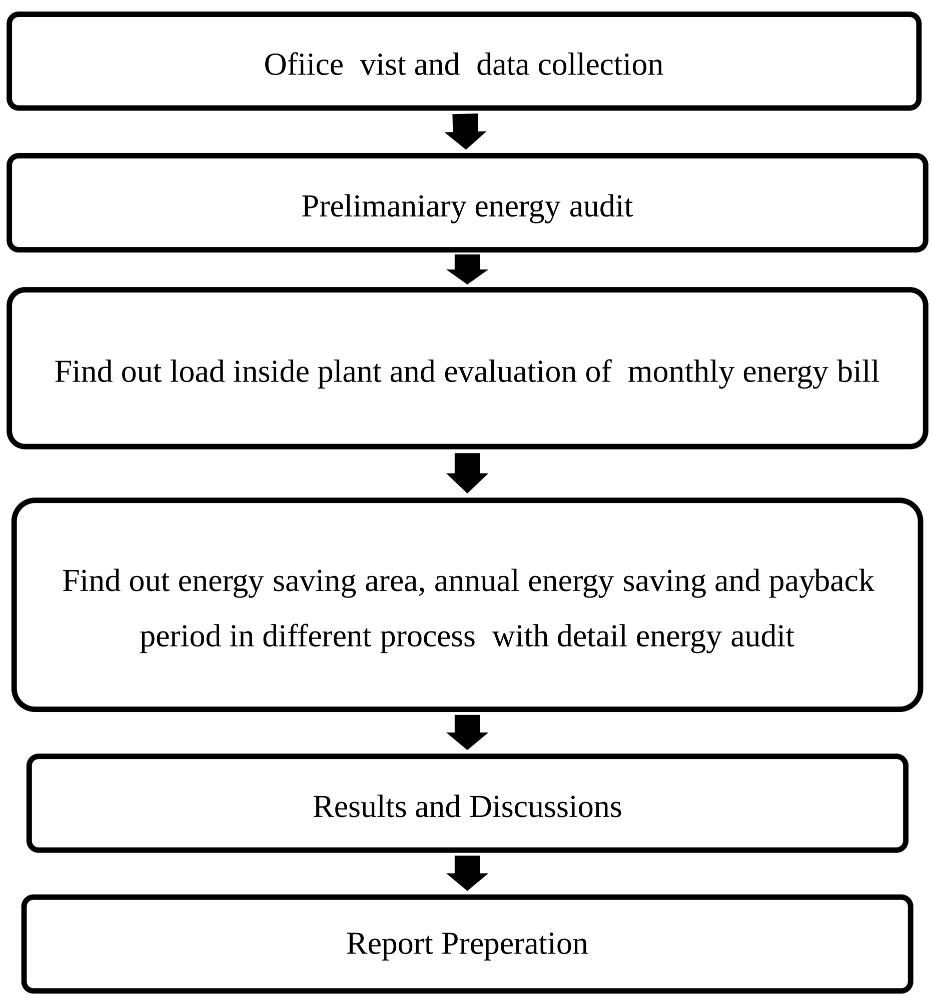


Figure 4: Theoretical Framework of Research Methodology

3.2 Energy audit and Energy Consumption Calculation

Energy auditing is details are verified, monitoring, and analyzing energy usage, as well as submitting a technical report with recommendations for improving energy efficiency, as well as a cost-benefit analysis and an action plan to reduce energy consumption. (Ministry of Power, 2001)

There are two types of energy audits.

1. Preliminary Audit
2. Detail energy Audit

3.2.1 Preliminary Audit

It is called also known as walk through survey. Energy consumption pattern, major energy consuming device and most energy conservation area figure out after preliminary audit.

3.2.2 Detail Energy Audit Methodology

Detail auditing have a ten-step methodology and three audit phase.

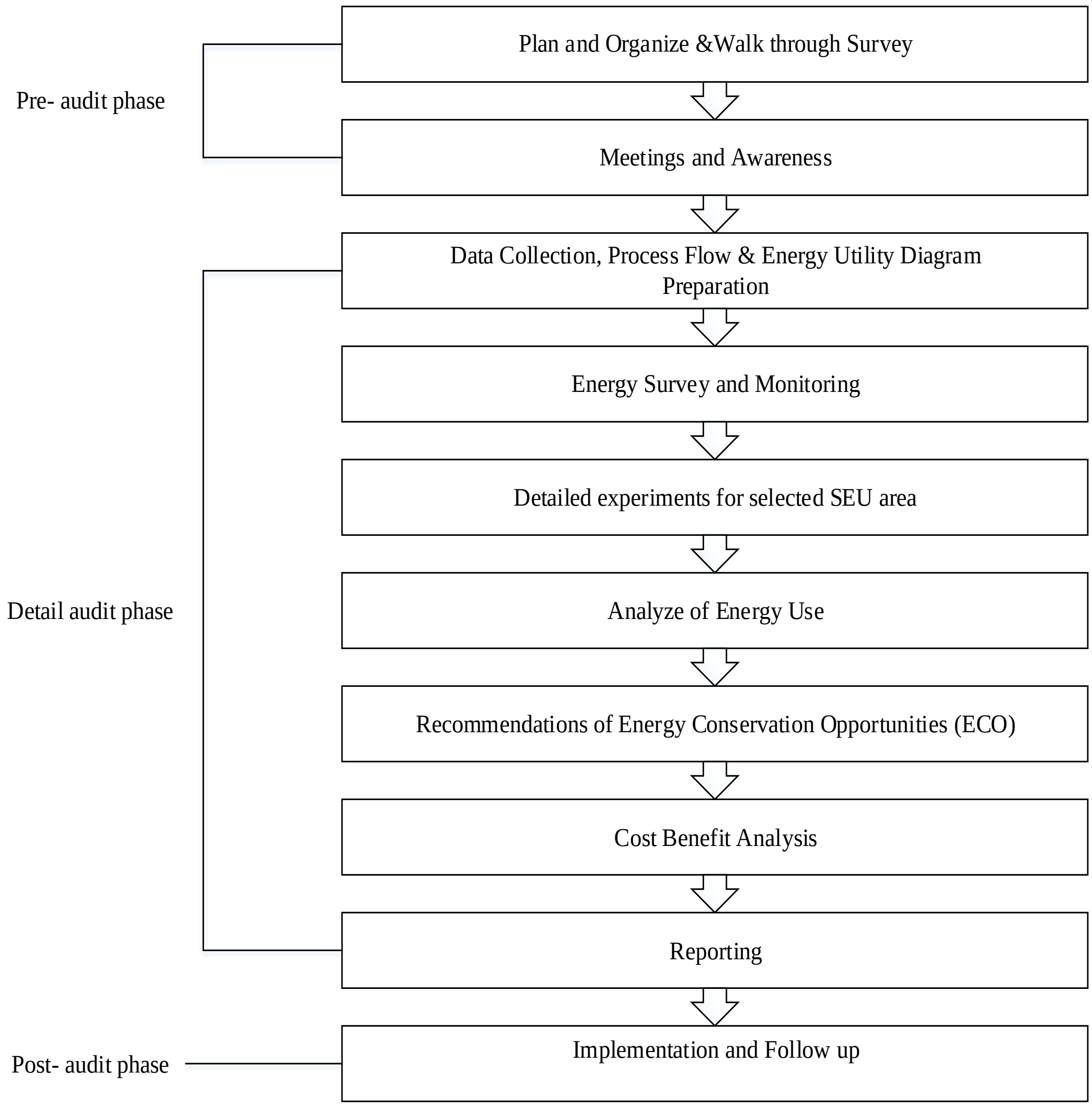


Figure 5: Detail auditing flow diagram

3.2.3 Electrical energy consumption, energy saving and economic analysis

A simple way to calculate energy consumption is to use the operating time and rated power of the load.

The calculations are done according to:

$$E = P_r * t \quad (3.1)$$

Where E is the consumed energy (KWH), p_r is rated power of equipment and *t* is operating time

Monthly energy bill calculated as

$$E_{eb} = E_m * e_{kwh} + E_{max} * e_{kva} \quad (3.2)$$

Where E_{eb} is total monthly bill, E_m is the total no. of unit consumed, e_{kwh} is per unit energy consumption charge and E_{max} is maximum demand and e_{kva} is per unit demand charge

TOD meter bill for no. unit consumption only

$$E_{mb} = E_{pkwh} * e_p + E_{nkwh} * e_n + E_{n-pkwh} * e_{n-p} \quad (3.3)$$

Where E_{mb} monthly energy bill, E_{pkwh} is monthly peak hour unit, e_p is per unit peak hour rate, $E_{nkwh}$is monthly normal hour unit, e_n is normal hour unit rate, E_{n-pkwh} is monthly non peak hour unit and $e_{n-p}$is non peak hour unit rate

Annual energy saving

$$EE_{save} = (E_{old} - E_{new}) * 12 \quad (3.4)$$

Where EE_{save} is total annual energy saving, E_{old} is total no. of unit consumed before efficient method and E_{new} $is\ the$ total no of unit energy consume after efficient method

Annual money saving

$$EE_{save} = (E_{old} - E_{new}) * 12 \quad (3.5)$$

Where E_{moneys} is total annual energy bill saving, e_{unit} is per unit cost energy

Payback period of efficient equipment or system

$$\text{Payback period} = \frac{Capitalinvestment}{Annaul\ saving} \quad (3.6)$$

Pump power and efficiency calculation

Pump efficiency obtained from head and discharge

$$P_{eff} = \frac{P_h}{P_{shaft}} \quad (3.7)$$

Where Hydraulic power,

$$P_h(\text{kW}) = \text{Q x}(h_{net}) * \text{d x g / 1000} \quad (3.8)$$

Q = Volume flow rate (m^3/s), d = density of the fluid (kg/m^3), g = acceleration due to gravity (m/s^2), h_{net} = Total head in meters and P_{shaft} is shaft power input to pump

3.2.4 Water Volume and Water Consumption Bill

Water volume stored in rectangular tank or reservoir

$$V = L * B * H \quad (3.9)$$

Where V is water storing capacity of tank L is length of tank, B is breath of tank and H height of tank

1 m^3= 1000 liter = one unit consumption of water

Water utility bill

$$W_{bill} = W_{cons} * U_{wr} \quad (3.10)$$

Where W_{bill} means monthly bill of water, W_{cons} is total consumed unit and U_{wr} is unit price of water

Load Factor of Water treatment plant

$$(\text{LF}) = \text{Actual load / Approved load} \quad (3.11)$$

Energy save by variable frequency drive

For variable load

Affinity Laws: power $\propto$ pressure $*$ flow

Pressure$\propto$ speed^2

Flow$\propto$ speed

Power$\propto$ speed^3

$$P_2 = p_1 * (N2/N1)^3 \quad (3.12)$$

Where P_2 is power consume after VFD installation and P_1 is before VFD installation power consumption. N1 and N2 are speed before and after VFD installation.

$$\text{Power save} = P2 - P1 \quad (3.13)$$

Power factor improvement

$$KW = KVA * \cos\beta \quad (3.14)$$

Where Cosβ is power factor of equipment

$$KVAr = P*(\tan\beta1 - \tan\beta2) \quad (3.15)$$

P is the active power, β1 is initial power factor angle and β2 is improved power factor angle and KVAr is reactive power required for power factor correction.

3.3 Site Selection

This treatment plant 1.87 km from Chabahil ring road near to Hyatt Regency Kathmandu. It is located at co-ordinates of 27.43 N, 85 .21 E in Bagmati province. The geographical map of Mahankalchaur water treatment plant is shown in Figure 3.2.

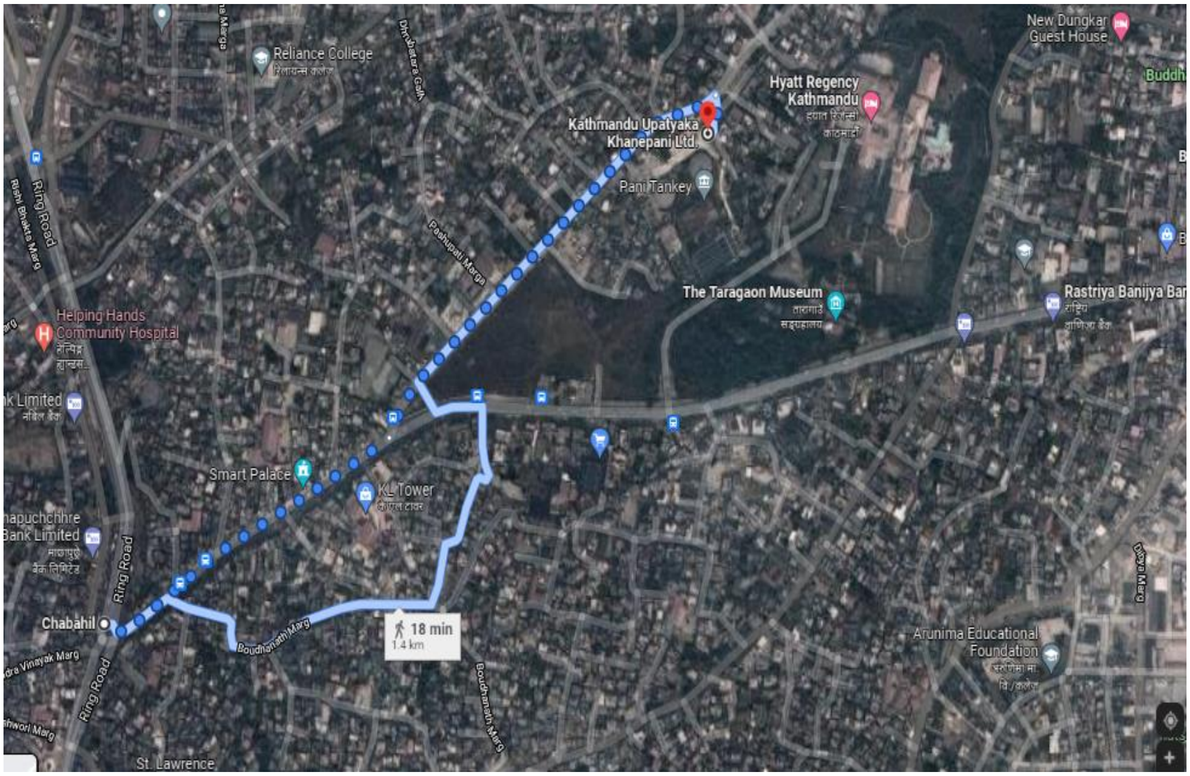


Figure 6: Mahankalchaur water treatment plant location

3.3.1 Mahankalchaur Water Treatment Plant

Kathmandu Upatyaka Khanepani limited is water supply and sanitation operator inside Kathmandu valley. Kathmandu Upatyaka Khanepani Limited (KUKL) founded in 2007 as the Kathmandu Valley's water utility operator, with responsibility for the management of water supply and wastewater services. Under the Company Act, KUKL was established as a public company with a majority share owned by municipalities (50%) and the government (30%), and the remaining shares owned by private sector representative bodies (15%) and the employees' trust (5 percent). It has major three water treatment plant Mahankalchaur kathamndu, Basbari kathamndu and Bode Bhaktapur water treatment plant. There are also medium and small size water treatment plant like sundarijal old plant,Saibu panipokhari ,Takhel ,Bhatapur Basbari water treatment plant.

There are 26 existing water treatment plants in kathmandu valley water supply system. Twenty numbers of WTP's in operating condition with a total treatment capacity of about 117 MLD. Six numbers of WTPs are comparatively larger size (greater than10 MLD treatment capacity) which treat water from surface or ground source only or both surface and groundwater source and the rest are mostly smaller size facilities. The most small WTPs are for treatment of groundwater and are attached to individual tube wells located at various places in Kathmandu valley (Kumar Tamrakar and Sharma, 2016). Among them Mahankalchaur treatment plant is the largest water treatment plants inside Kathmandu valley which collectors of raw water, processer and distributor branch office of KUKL which is located in Mahankalchaur, Kathmandu. The plant supplies water that draws from Sundarijal source and from different ground water (tube well) source near to WTP. These water processes in the Mahanlakchaur WTP and distributes to the city around Kathmandu valley (Bartaula, 2016).

3.3.2 General Information

(1) Facility Name:	Water Treatment Plant of the Mahankalchaur Branch
(2) Facility type:	Surface and Groundwater treatment plant
(3) Establishment:	1994
(4) Water Source:	Surface water from Sundarijal river and ground water from several Wells in the vicinity of the treatment plant area.
(5) Capacity:	25 MLD (Design) 20.1 MLD (Actual)
(6) Access:	1.8 km (3 minutes' drive) from Chabahil, Ring Road
(7) Objective:	Removal of turbidity, organic matter, bacteria and other harmful Matter from raw in order to provide portable water

CHAPER FOUR: RESULTS AND DISCUSSION

Data collected by interview and walk though survey. Energy consumption finds out using power logger, clamp meter and water discharge is measured by ultrasonic flow meter. After data collection, analyze in MS excel with required formulation.

4.1 Electrical Single Line Diagram and Overall Power Factor Correction

4.1.1 Electrical Single Line Diagram

From single line diagram, NEA 11 KV line comes to plant having 500KVA main transformer and 450 KVA backup diesel generator. Their operation controlled by a changeover switch at 400 V system. Kapan supply fed by 225 A MCCB and other 225 A MCCB fed to transmission pump house panel board. There is a 75 KVA capacitor bank for a power factor of plant. Electricity is distributed from the main distribution panel to other sub distribution board. 300A MCCB from the distribution panel board goes to the MM1 hypo panel board. Now’s day hypo not in operation as it replaced by the bleaching power system. Distribution board of hypo fed to tanker feeling pump and one of Kapan supply pump. 32A TP MCB All motors use star delta starter as induction motor starting current is high. All detail power distribution diagrams as shown in figure 12 below.

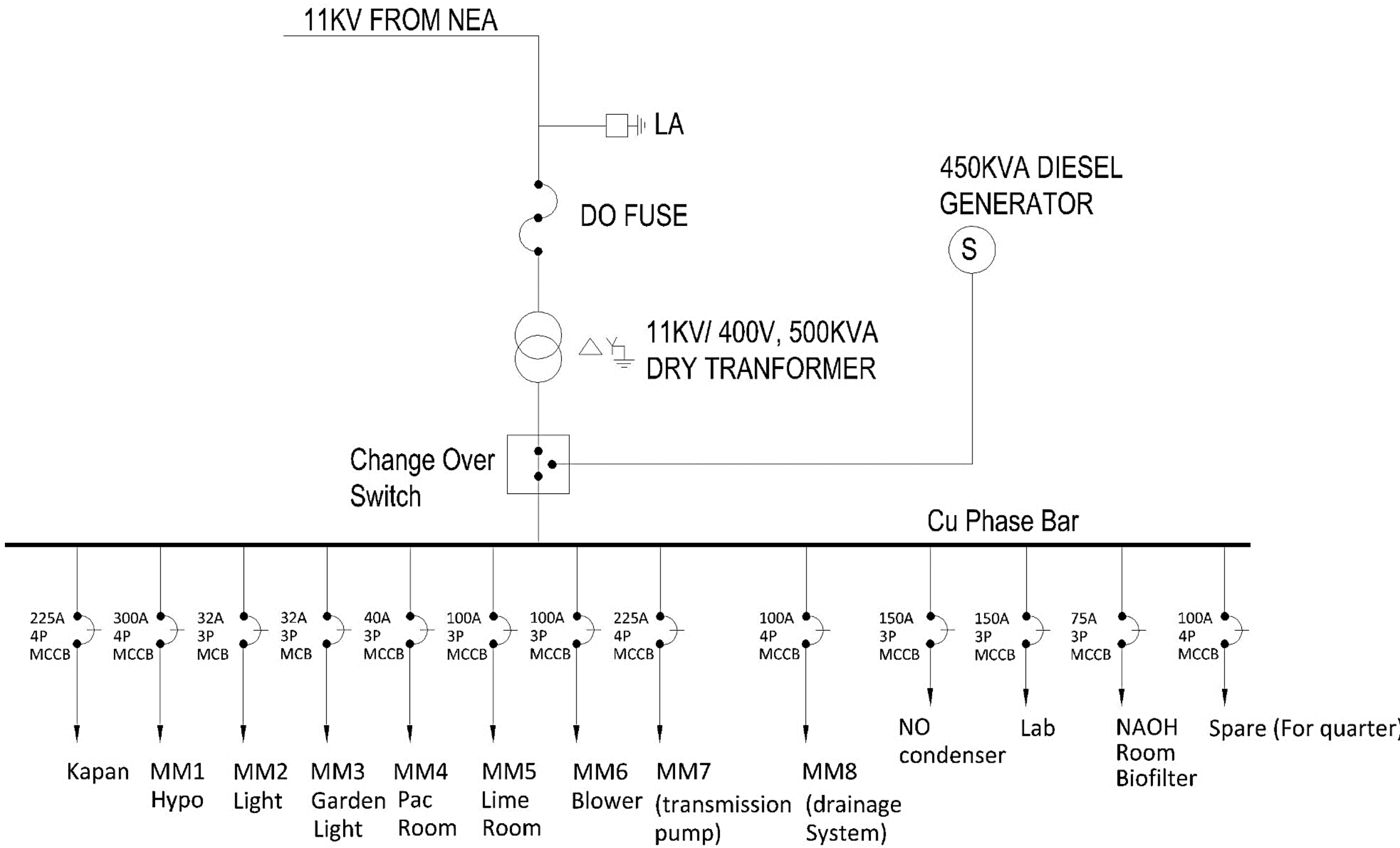


Figure 7: Single Line Diagram of Plant

4.1.2 Power Factor of Plant

Power factor is cosine angle between voltage and current. Power facto inside plant measure by data logger during detail energy auditing. The power factor of plant is 0.7 to 0.93 during Seventeen hour. Suppose power factor improve from 0.7 to o.99 addition of capacitor bank

KVAr=138 *(tan45.45 - tan 8.10) = 138(1-0.14) =118.68KVAr

There has been already installed 75KVAR static capacitor bank installed at LV side of main distribution panel board so there is 44 KVAr capacity of static capacitor bank should add for need of extra power factor improving. The cost of capacitor bank per KVA from NEA store rate is 1,389.90/ KVAr. Total cost of 44KVR capacitor bank installation is NRS. 61155.6

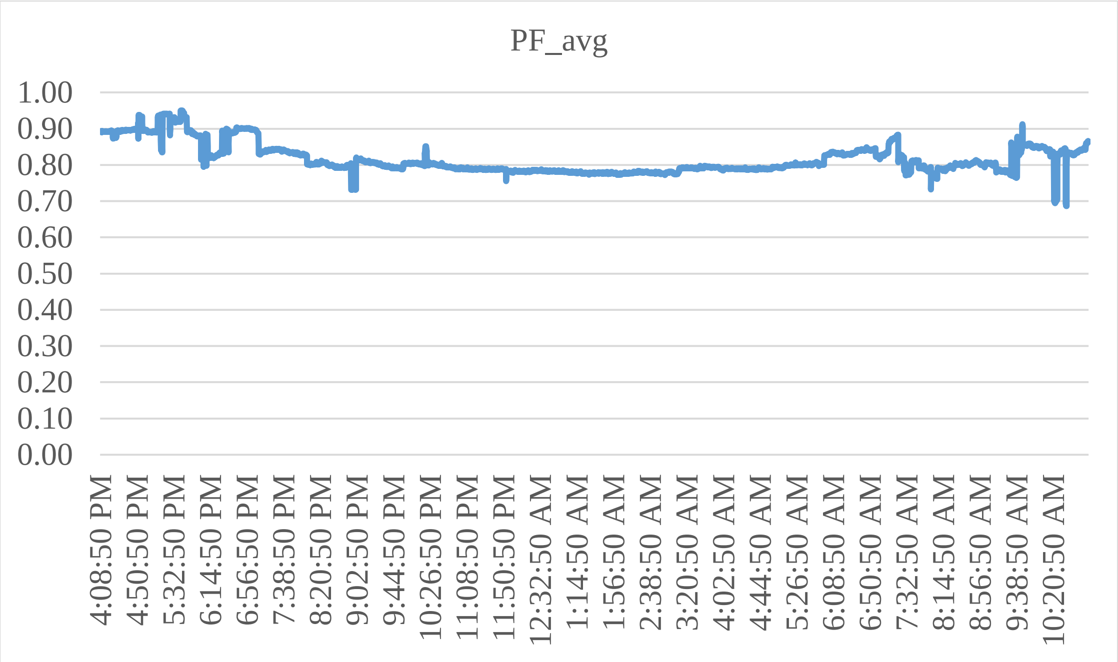


Figure 8: Overall power factor of plant

Currently demand charge for public water supply system is free from NEA. So energy cost cannot reduce by reducing KVA demand. Capacitor bank can only improve system reliability.

4.2 Load Analysis of Water Treatment Plant

4.2.1 Total Connected Load at Water Treatment Plant

Total connected load inside plant found as below during field survey.

Table 2: Total connected load

S.N	Process equipment	Total load (KW)
1	Bio filter Blower, make up and lime feeding	144.9
2	PAC and slaked lime equipment	6.2
3	RSF backwash and make up pump	64.4
4	CWR transmission and pressure pump	67.8
5	Kapan and tanker supply pump	143
6	Drainage pump	37.5
7	Chlorine feeding equipment	11.25
8	Lighting and building load	7.34
	Total	482.39

Although connected load on bio filter is high, it operates only few months with few hours. This is due to groundwater directly distributed to local area and the bio filter out of proper operation. Make up pump and NAOH equipment is not in operation at present. It was found that daily one-hour operation of air blower just for keeping in good condition.

Poly aluminum chloride (PAC) operates daily fifteen minutes' dissolution, fifteen minutes sifting and 15 minutes dosing. Single unit operates at one time. Slaked lime equipment out of operation because water have a nearly accurate level of pH and no need of PH correction. The chlorine feeding equipment operate half hour dissolution, 15 minutes shifting of chemical solution and 15 minutes dosing.

RSF should wash to clear filter dirt. Surface wash and make up pump operate unit set simultaneously. Drain water during backwash collected in the drainage basin and collected water again shifting to a sewerage system by pump.

Main and continuous load in the plant is clear water transmission pump kapan supply pump and tanker filling pump. They have almost been operating 16to 18 hours in dry and 22 to 24 hours in the wet season. All connected load as follows:

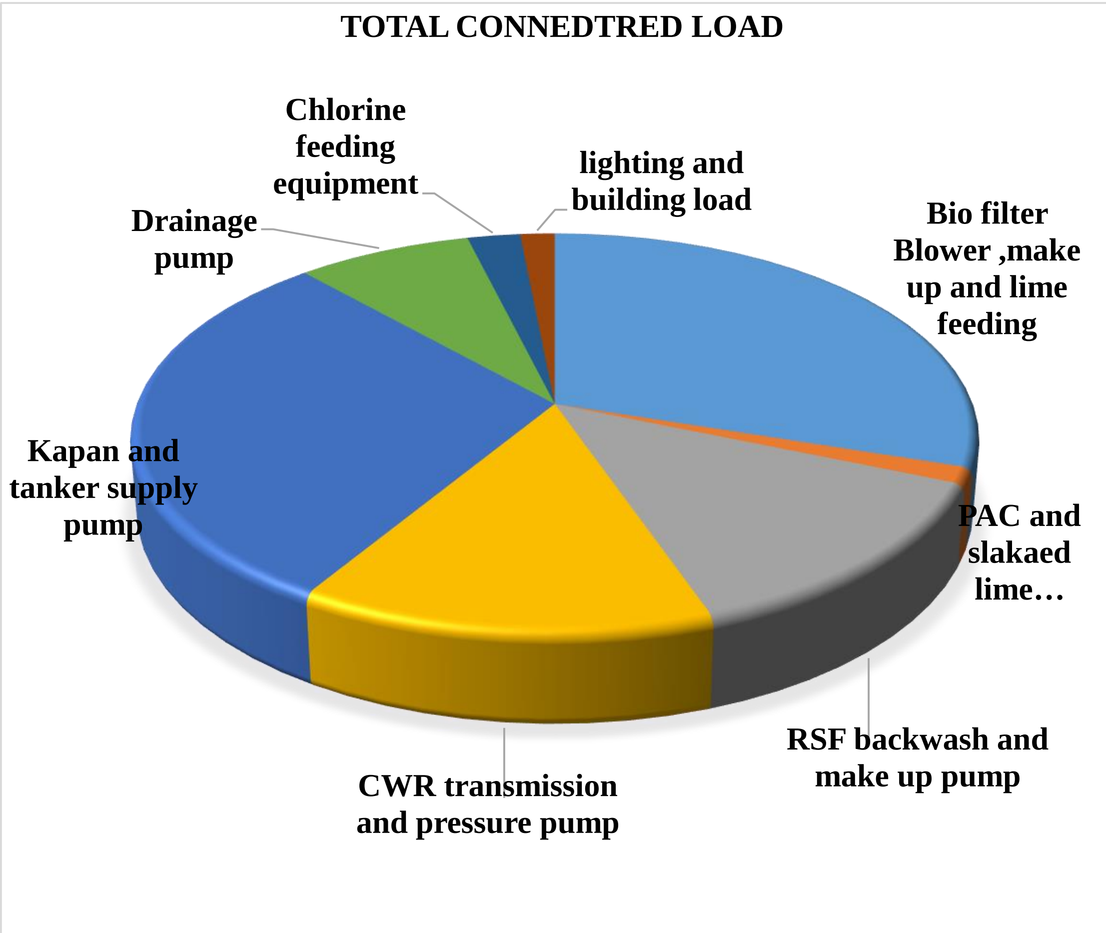


Figure 9: Total Connected load inside Plant

4.2.2 Energy Consumption Pattern of Each System

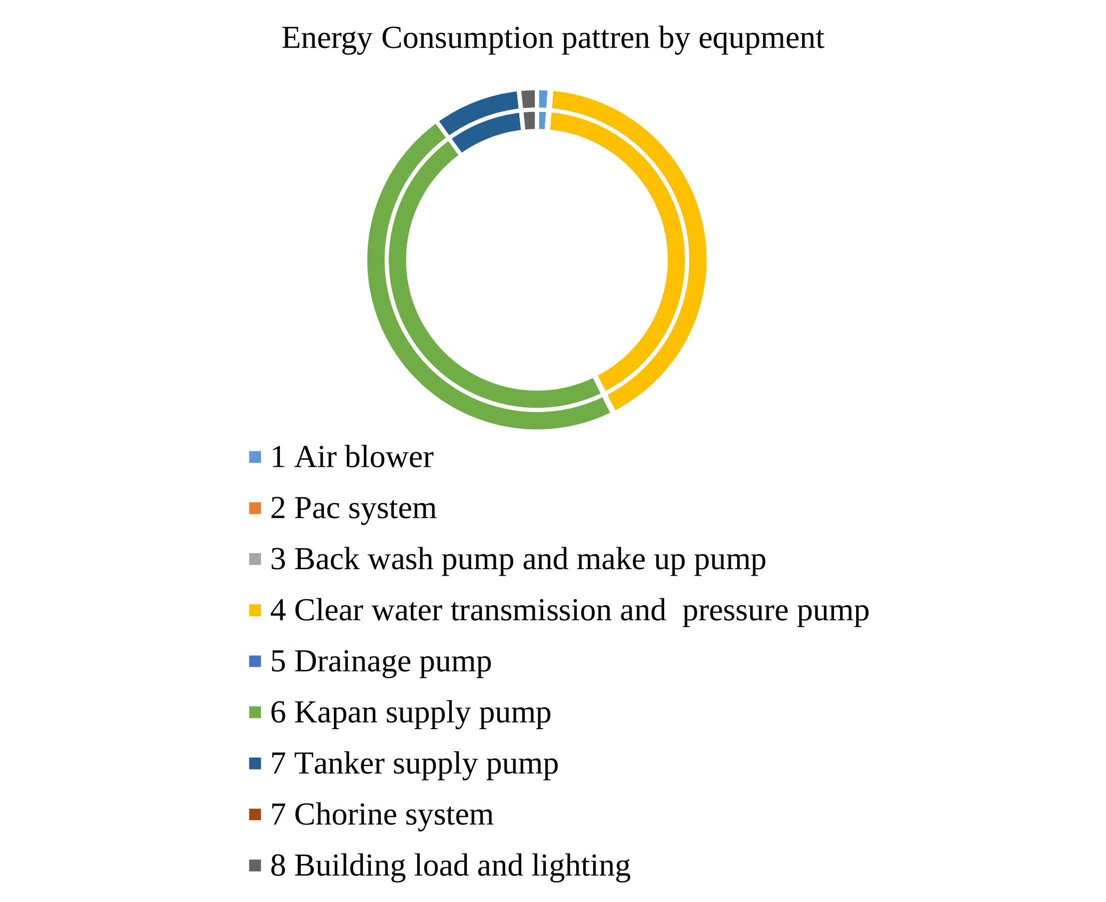


Figure 10: Daily Energy consumption pattern

Although connected load of air blowers is high they consume only 1.2 % of total consumption due to only one-hour operation and ground water does not come to water treatment plan. A chemical like slaked lime less used due pH value water near to 7. PAC and chorine system consume 0.03 % individually. Major energy consumes by tanker filling pump 8.28%, clear water transmission pumps 41.20 %, and Kapan supply pumps 47.32 %. So energy could be save giving more attention to two major energy consuming pumping systems which are transmission pump and Kapan supply pumping system.

4.3 Preliminary Auditing Water Treatment Plant

Preliminary auditing called as walk though audit. Secondary data like drawing, name plate of all energy consuming devices is studied. Data related to every water treatment process and component collected as follows.

4.3.1 Secondary Data Collection

This step's main goal was to gather secondary data from the institutions. The architectural/mechanical/electrical drawings and/or interviews with building operators/owners can be used to gather building attributes. Utility invoices were used to compile the energy usage patterns. The following are some examples of secondary data that can be collected in this step, with the essential goals for each activity highlighted in italics:

- Utility data records (to determine energy usage patterns)
- Information on the fuel types utilized and their pattern (to establish the fuel type)
- Utility rate structure
- List of electrical, mechanical and thermal equipment’s
- Perform utility energy use analysis institution type and size (to compare against typical indices)

4.3.2 Water Treatment Components and Processes

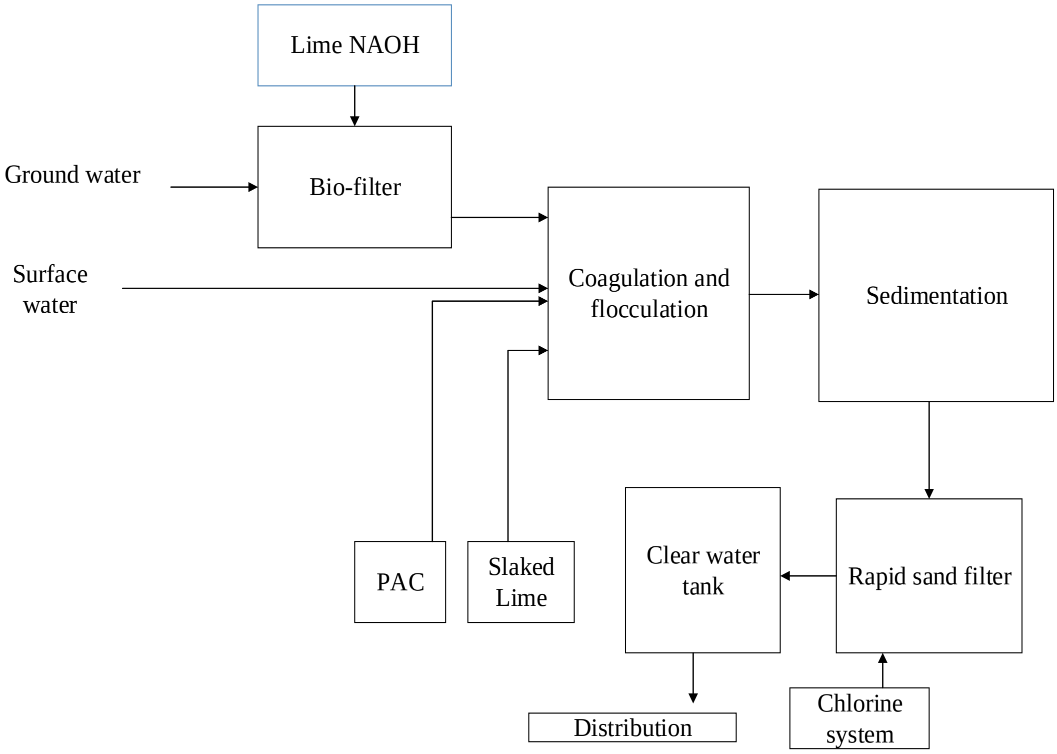


Figure 11: Water treatment process flow diagram

Figure 6 shows the actual water treatment process inside Mahankalchaur WTP. Water from ground water sources and surface water (Sundarijal) come to Mahankalchaur water treatment plant. Ground water first goes to bio filter where air blower used for aeration, remove iron and ammonia by ammonium bacteria present in the filter. NAOH used to maintain pH of water. Then these water go to flocculation and coagulant chamber and surface water come directly to the flocculation chamber where poly aluminum chloride (PAC) solution injection for flocs formation. The chlorine solution adds for pre chlorination work and slaked lime used to adjust pH of water. Water from ground and surface treated separately in sedimentation tank and hopper structure present at the beginning of sedimentation to drain out flocculation sludge to drainage basin. Water then goes to rapid sand filter (RSF) where ten units of filter present. After filtration water goes to clear water reservoir. Then water is pumped by transmission pump to service reservoir for distribution, kapan supply and tanker filling supply. Clear water also used to backwash the RSF by surface wash pumps and make up pump. Back washing drainage water goes to drainage basin. From drainage basin water is pumping and send to the governmental sewerage line.

There are seven (8) unit process in Mahankalchaur WTP as outlined below:

- Bio filter process and caustic soda feeding equipment
- Flocculation and Sedimentation basin, PAC and slaked lime feeding equipment
- Rapid Sand Filter
- Clear Water Reservoir (CWR) and Transmission pump equipment
- Sludge and drainage equipment
- Bleaching powder feeding equipment
- Water quality testing laboratory
- Kapan distribution and tanker filling distribution from Clear water tank

Each process and process equipment find out by preliminary auditing as below.

4.3.2.1 Bio filter process and caustic soda feeding equipment

Bio filter used to remove iron, ammonia of ground water (water from deep tube well). Filtration material is filled into the bio-filter tank for proper propagation of the microorganism. Air blowers provide air under pressure for diffusion. The nitration action of aerobic microorganisms to remove ammonia nitrogen from the ground water

This equipment shall be used only for four (4) months in the dry season (March-June).

Planned water quantity: Unit: m^3/day

Table 3: Data for ground water purification plan

Month	March	April	May	June
Ground water	13,400	15,400	19,100	13,800

In other months, circulating operation should be carried out by makeup pumps to prevent dying of the microorganisms.

Table 4: Bio filter equipment

Item	Type	Size/Details	No. of units
Make-up water quantity and make up pumps	Submersible pump	Capacity: ϕ 250 x 7 m^3/min x 5.5m Motor: 200V x 50 Hz x 11 kW	2 pumps
Air blower	Roots blower	Capacity: ϕ 125 x 14.8 m^3/min x 0.6 kg/cm^2 Motor: 400 V x 50 Hz x 30 kW	4 pumps (3 usual + 1 spare)

Caustic soda (NAOH) is used to maintain pH of ground water in bio filtration process. The caustic soda is first dissolved in the dissolution tank, then fed by the transmission pump to the storage tank from where fixed quantities are fed by the feeding equipment at suitable intervals.

Table 5: NAOH equipment of bio filter

Item	Type	Size/Details	No. of units
Dissolution tanks	Open vertical cylindrical (heat resistant polyethylene)	ϕ approx. 900 mm x height 880 mm Capacity: 0.5 m^3 (500L) Accessories (per tank) Fittings: 1 set; Agitator stand: 1 stand	2 tanks
Agitators	Reciprocal rotary agitator	196 cpm Motor: 0.75 kW x 400 V x 50 Hz	2 units
Transmission pumps	Magnet pump	25 A x 30 l/min x 10m Motor: 0.4 kW x 400 V x 50 Hz	2 units
Caustic soda storage tanks	Closed vertical cylindrical	ϕ approx. 1065 mm x height 1265 mm Capacity: 1m^3 (1000L)	2 units

	tank (polyethylene)	Accessories Fittings: 1 set; Direct-reading liquid level gauge: 1 unit; Manhole: 1 location; Air vent: 1 location; Agitator: 1 set	
Feeding equipment	Diaphragm pump	Capacity: a. 15A x 0.9 l/min x 3 kg/cm^2 x 1 unit b. 15A x 1.8 l/min x 3 kg/cm^2 x 2 units Motor: 0.2 kW x 400V x 50 Hz Accessories Back pressure valve: 1 piece. Safety valve: 3 pieces; Air chamber: 1 unit; Pressure gauge: 3 pieces	3 units (pump a. supplied as spare)
Instrument panel		MM-2	

4.3.2.2 Flocculation and Sedimentation Equipment, PAC feeding Equipment, Slaked Lime Feeding equipment

- **Flocculation and Sedimentation process**

To remove the suspended particulates from the water, flocculation processes are used. Sedimentation, on the other hand, is the tendency for suspended particles to settle out of the fluid in which they are entrained and come to rest against a barrier. It may be due to gravity, centrifugal acceleration or electromagnetism.

- **PAC Feeding Equipment**

PAC powder which is the coagulant for the flocculation and sedimentation process.
Electro-mechanical equipment used in Pac equipment

Table 6: PAC feeding equipment

Item	Type	Size/Details	No. of units
Dissolution tank	Open vertical cylindrical tank (polyethylene)	ϕ 900 mm approx. x 1010 mm (h) Capacity: 0.5 m3 Accessories: Fittings: 1 set Agitator: 1 stand	2 tanks
Agitator	Reciprocating rotary agitator	Reciprocating cycles: 196 cpm Motor: 0.75 kW x 400 V x 50 Hz	2 units
Transmission pumps	Magnet pump	Capacity: 40 A x 30 l/min x 10m Motor: 0.4 kW x 400 V x 50 Hz	2 motors
PAC storage tanks	Closed vertical cylindrical tank (polyethylene)	ϕ 1065 mm approx. 1265 mm (h) Capacity: 1 m2 Accessories: Fittings: 1 set; Direct sight level gauge: 1 gauge; Manhole: 1 location; Air vent: 1 location	2 tanks
Feeding equipment	Diaphragm pump	Capacity: a. 15 A x 0.1 l/min x 3 kg/cm2 b. 15 A x 0.5 l/min x 3 kg/cm2 Motor: 0.2 kW x 400 V x 50 Hz Accessories: Back pressure valve: 2 units; Safety valve: 4 units; Air chamber: 2 units; Pressure gauge: 4 units	4 units (2 units x 2)
Piping and valves		Pipes, valves, hard polyvinyl pipes for city water; ball valves, diaphragm valves Diameter: 50 – 15 A	1 set

- **Slaked Lime Feeding Equipment**

Slaked lime is used to adjust pH of water. Slaked lime is dissolved to a 20% solution converted to $CaCO_3$ and then transferred by transmission pump to the storage tank and fed at suitable intervals by the feeding equipment at the inlet of the flocculation and sedimentation tank.

Table 7: Slaked line feeding equipment

Item	**Type**	**Size/Details**	**No. of units**
Dissolution tank	Open vertical cylindrical tank (polyethylene)	ϕ 900 mm x 900 mm (h) Capacity: 0.5 m^3 Accessories: Fittings: 1 set Agitator: 1 stand	2 tanks
Agitator	Reciprocating rotary agitator	Reciprocating cycles: 196 cpm Motor: 0.75 kW x 400 V x 50 Hz	2 units
Transmission pumps	Magnet pump	Capacity: 25 A x 30 l/min x 20 m Motor: 2.2 kW x 400 V x 50 Hz	2 pumps
Slaked lime storage tanks	Open vertical cylindrical tank (polyethylene)	Approx. ϕ 1425 mm x 1570 mm (h) Capacity: 2 m^2 Accessories (per tank) Fittings – 1 set; Direct reading level gauge – 1 gauge; Manhole – 1 location; Air vent– 1 location; Agitator stand and agitator– 1 set	2 tanks
Feeding equipment	Diaphragm pump	Capacity: a. 15 A x 0.49 l/min x 3 kg/cm^2 (2 units) b. 15 A x 1.8 l/min x 3 kg/cm^2 (2 units) Motor: 0.2 kW x 400 V x 50 Hz Accessories:	4 units (2 units x 2)

Item	**Type**	**Size/Details**	**No. of units**
		Back pressure valve- 2 units; Safety valve - 4 units; Air chamber – 2 units; Pressure gauge – 4 units	
Piping and valves		Pipes, valves, hard polyvinyl pipes for city water; ball valves, diaphragm valves, etc. Diameter: 50 – 15 A	1 set
Instrument panel		MM-4	

4.1.1 Rapid Sand Filtration Washing Equipment

The Rapid Sand Filter (RSF) is used to remove turbidity, iron, and manganese from the raw water which is subjected to flocculation and sedimentation.

Table 8: Back wash of rapid sand filter equipment

Item	**Type**	**Size/Details**	**No. of units**
Surface washing pumps – 2 nos.	Suction Volute	Capacity: ϕ200 x ϕ150 x 4 m^3/min x 25 m Motor: 30kW x 400V x 50 Hz	2 pumps
Make up pumps- 2 nos.	Centrifugal	Capacity: ϕ100 x 1.2 m^3/min x 7m Motor: 2.2kW x 400 V x 50 Hz	2 pumps

4.1.2 Clear-Water Reservoir and Water Transmission Pump Equipment

To adjust and relief the unbalance between the filtered water and the water supply volume at the time of water transmission caused by rapid fluctuation of the demand. Also, functions as a surface washing pump well and a water supply pump well.

Electro-mechanical equipment in CWR as mention in table 8.

Table 9: Clear water equipment

Item	Type	Size/Details	No. of units
Transmission pumps	Suction Volute Pump	Capacity: ϕ300 x ϕ200 6.5 m^3/min x 9m Motor: 15 kW x 400 V x 50 Hz	4 pumps
Water supply pumps	Pressure type automatic supply unit	Capacity: ϕ50 x ϕ65 x 0.6 m^3/min Motor: 3.7 kW x 400 V x 50 Hz	1 set (2 pumps)
Bed drainage pumps	Submersible pumps for soil water	Capacity: ϕ50 x 0.1 m^3/min x 10 m Motor: 0.4 kW x 400 V x 50 Hz	1 set (2 pumps)

4.1.3 Sludge and Drainage Equipment

Sludge basin receives a large quantity of drainage in a short time when the rapid sand filter is washed and from hopper of sedimentation basin collected in drainage pond Electro-mechanical equipment in drainage pond found as follows.

Table 10: Sludge and drain equipment

Item	Type	Size/Details	No. of units
Drainage pumps	Submersible sewage pump	Capacity: ϕ100 x 2.0 m^3/min x 12m H Motor: 7.5 kW x 400V x 50 Hz	2 pumps
Dewatering pump	Submersible sewage pump	9 kW and 13.5 kW	2 pump

4.1.4 Chlorine Feeding Equipment

Beaching powder is nothing but a compound of lime and chlorine. It is used to disinfection of water. The bleaching powder is first dissolved in the dissolution tank, then fed by the transmission pump to the storage tank from where fixed quantities are fed by the feeding equipment at suitable intervals.

Table 11: Chlorine feeding equipment

Dissolution tanks	Open vertical cylindrical (heat resistant polyethylene)	Capacity: 1 m3 (1000L) Accessories (per tank) Fittings: 1 set; Agitator stand: 1 stand	2 tanks
Agitators	Rotary gear box type	Motor: 1.5 kW x 400 V x 50 Hz x1415 rpm	2 units
Transmission pumps	Centrifugal water pump	5.2 A x Qmax 55 l/min x H max 65 m Motor: 0.75 kW x 450 V x 50 Hz	2 units
Chorine solution storage tanks	Closed vertical cylindrical tank (polyethylene) Extra heavy	Capacity: 1m3 (1000L) Accessories	2 units
Feeding equipment	Diaphragm pump	Capacity: a. 15A x 0.9 l/min x 3 kg/cm2 x 1 unit b. 15A x 1.8 l/min x 3 kg/cm2 x 2 units Motor: 0.2 kW x 400V x 50 Hz	3 units (one pump supplied as spare)
Shifting pump	Centrifugal water pump	Qmax 120 lit/min *32 m Hmax	Shift to pre chlorination unit

Pre Chorine solution storage tanks	Closed vertical cylindrical tank (polyethylene)	Capacity: 1m3 (1000L) Accessories	1 units
Pre Chorine Feeding equipment	Diaphragm pump	Capacity: a. 15A x 0.9 l/min x 3 kg/cm2 x 1 unit	1 unit

4.1.5 Kapan Distribution and Tanker Filling Distribution System

Kapan distribution for local water supply and tanker filling pump used to feed tanker of KUKl**.**

Table 12: Kapan supply and Tanker filling pump

Item	Type	Size/Details	No. of units
Tanker filling pump	Centrifugal and submersible	11 kw and 5 kw	2
Kapan supply	Centrifugal and submersible	22 kw,30 kw ,30kw and 45 kw	3

4.3.3 Power Sources

Main source of power for MWTP is 11kv line feeder of NEA. Transformer capacity is 500 KVA air cooled (dry) transformer and approved load is 500 KVA

Diesel Power Generation Efficiency

Based on field trial during an energy audit, the electricity production for 450 KVA DG set was calculated as 8 kWh. The following values were observed during a detail audit.

Table 13: DG set information

Manufacturer	Nishihatsu AC generator
Fuel Consumption	16.67 Liters/day
L/kwh	25

4.4 Detail Energy Auditing

Detail energy auditing is done after preliminary auditing was finished. From preliminary auditing it was found that transmission pump and kapan supply system are major energy consuming areas where energy and cost can be saved.

4.4.1 Power Logger Data and Specific Energy Consumption

Detail energy audit was done with data logger and find energy consumption during seventeen hours and following information has been find out

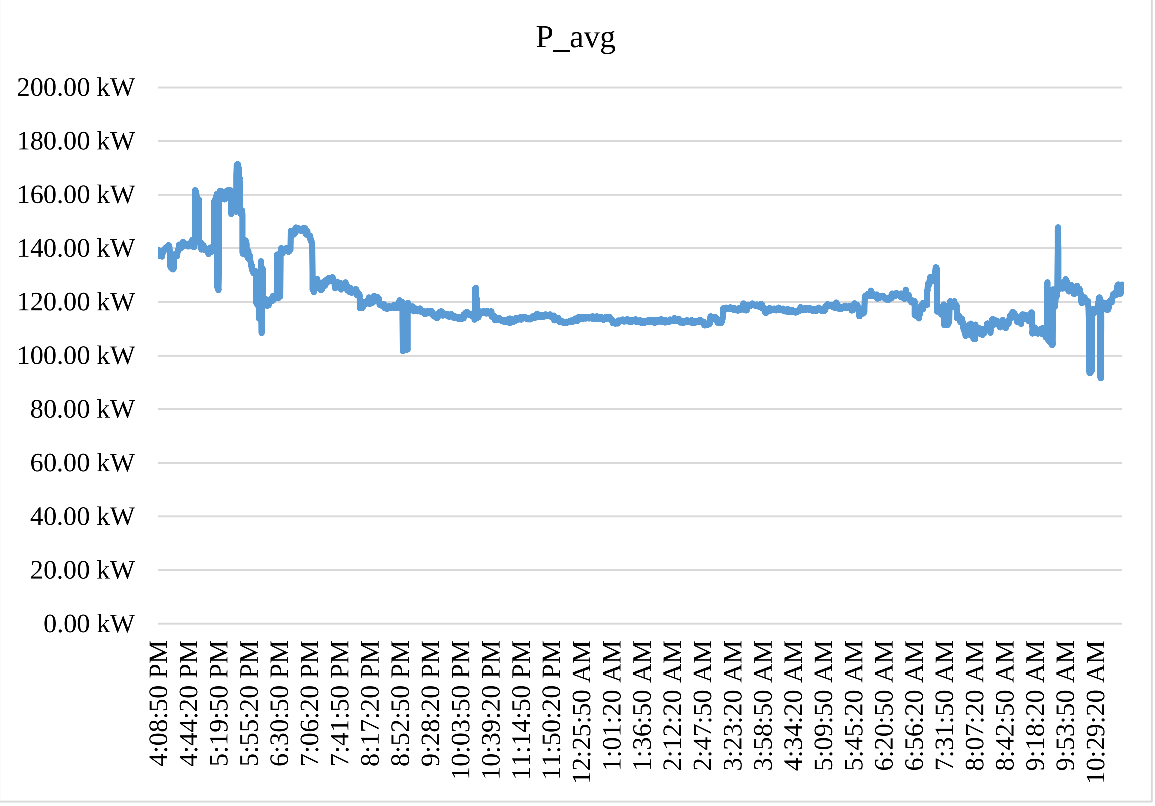


Figure 12: Energy Consumption during 17 hour

Energy consumption during 17 hours is 2274.85 kWh

Water supply during hours is 17000 cubic meter

Specific energy consumption = Total energy consume/total volume of water

It is found that specific energy consumption of WTP found 0.1338 kwh/cub. m

4.4.2 Energy Consumption Analysis

Monthly energy bill of last 22 months is collected and energy consumption analysis is done as below:

4.4.2.1 Energy Consumptions

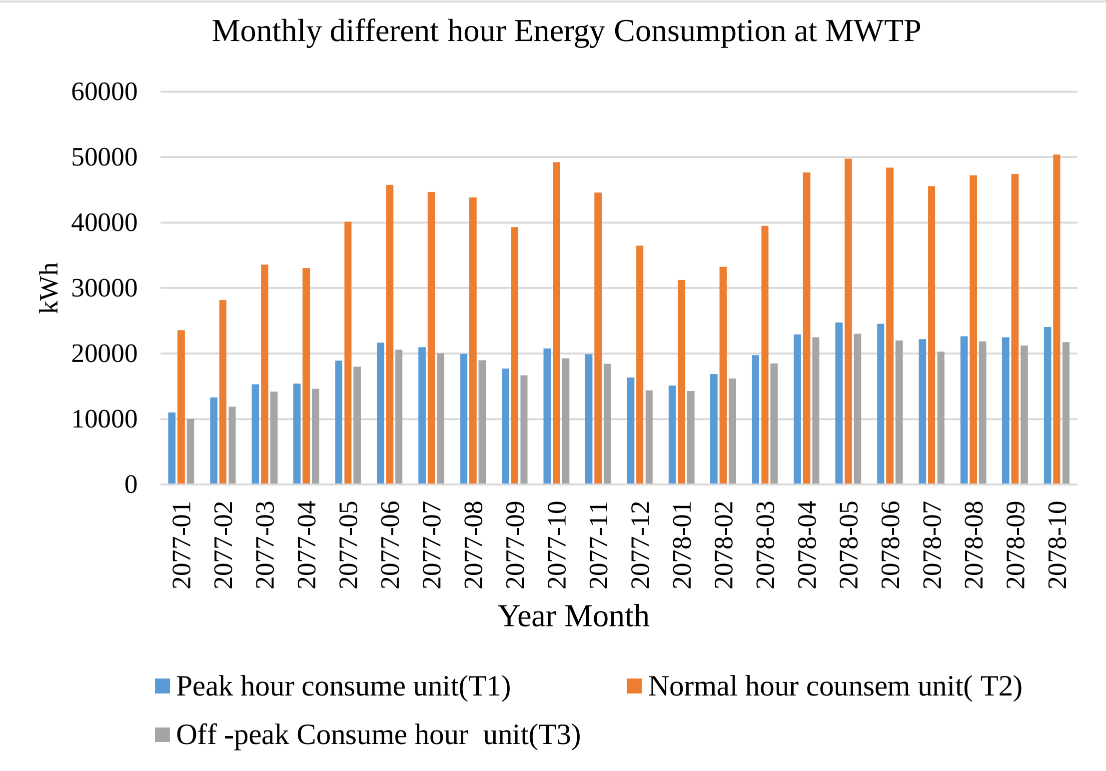


Figure 13: Monthly energy consumption different load hour

Last 22-month data collected and observed. It is found that the monthly energy consume at normal hour is maximum and energy consume at off peak hour is minimum. From above chart, it is found that during Baiskha of 2078 peak hour consumption is 10,982 kWh and off peak hour energy consumption was 10035 Kwh which is lowest energy consumption during 22 months. Energy consumption ratio on peak hour, off peak hour and normal hour increases from year 2077 to 2078 due to rehabilitation and maintenance of equipment like air blower, dosing pump and addition of new pump to Kapan supply system. Off peak hour and peak hour energy consumption is nearly equal. So it is found that energy consumption inside plant mainly depends upon pump operation. Thus quantity of water available inside plant proportional to energy consumption.

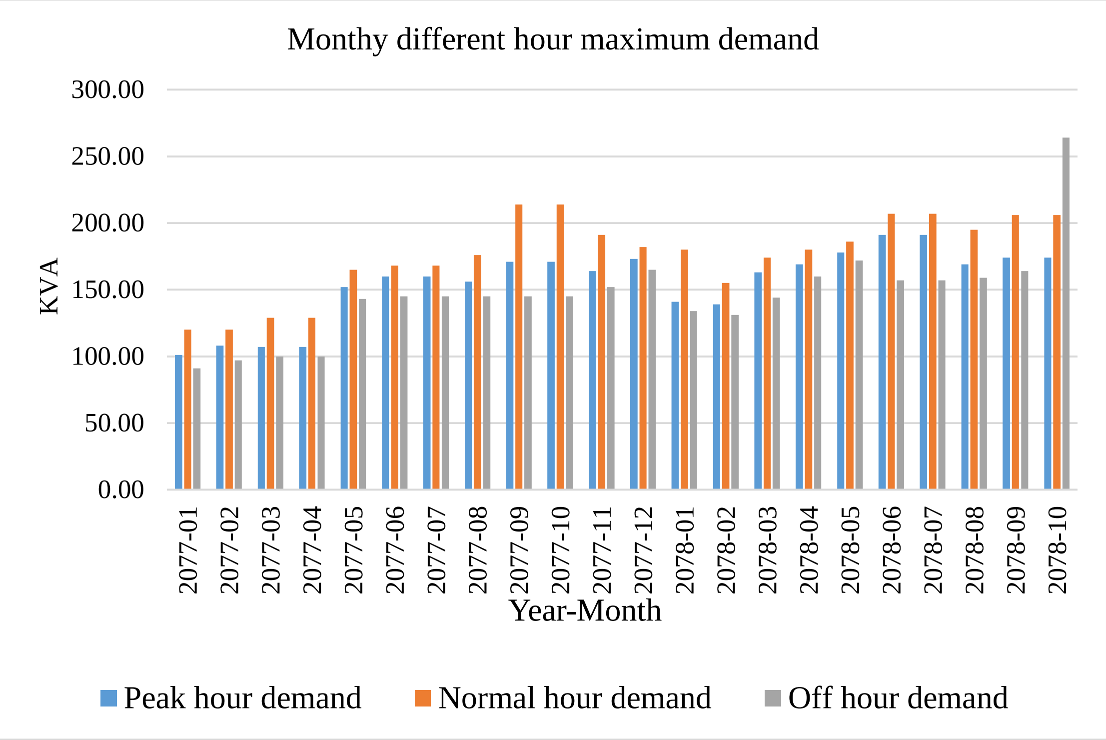


Figure 14: Monthly different loading hour

Demand inside the plant during normal hour is the maximum and minimum on off - peak hour. Demand is maximum at day time due to the office, blower and some of chemical pump mainly operates at daytime. The load demand inside plant varies 91 KVA to 274 KVA throughout 22 months. Demand increases from 2077 to 2078 some of new pump added inside clear water reservoir for Kapan and tanker supply.

Approved demand inside water treatment plant is 500 KVA. For 91 KVA demand, Load factor (LF) is 18.2% and for maximum demand, LF is 52.8%. It means, water treatment plant equipment like air blower hypo and lime pump not in operation. So connected load is high almost 500 KVA but the actual running load is nearly 138 KVA.

Total: Energy consumption and electricity bill of twenty-two months

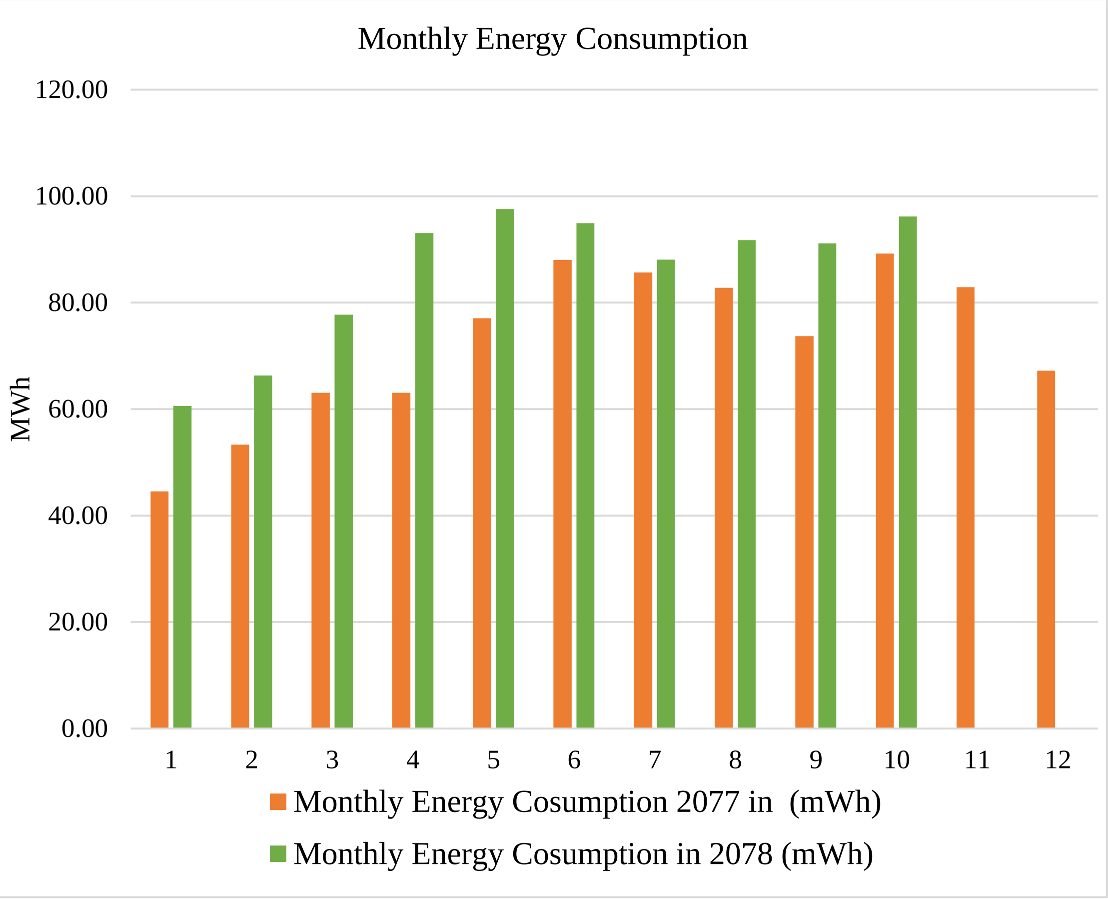


Figure 15: Monthly energy consumption during 2077 and 2078

In year 2077 average monthly energy consumed was found 72.56 MWh and yearly consumed energy was found 870.75 MWh. In year 2078 BS, ten-month data was collected and it was found that 85.75 MWh monthly energy consumed and energy consumed during ten months was found that 857.49 MWh. Form year 20077 BS to 2078 BS monthly energy consumption is straight line growth as shown in figure 15.

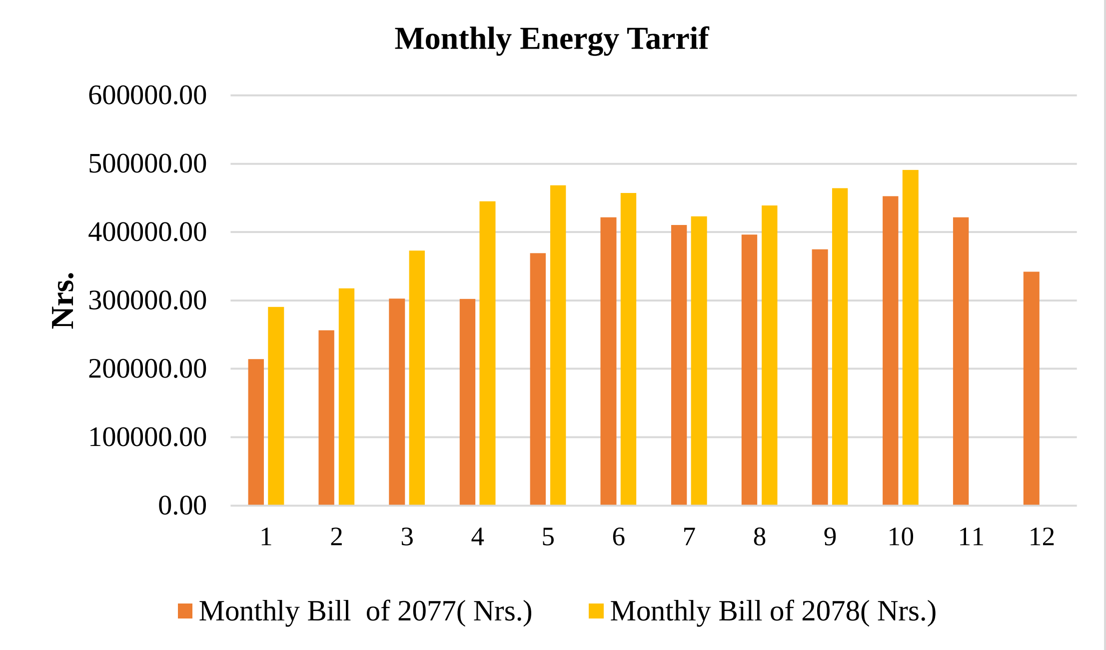


Figure 16: Monthly energy bill 0f 2077and 2078

In 2077 average monthly bill paid for energy tariff is NRS.3, 55,309.48 and yearly paid to NEA NRS.42.63, 713.70**.** Average energy cost NRS. 4, 16,857.31 per month in year 2078 and NRS. 41, 68,573.10 paid to NEA during ten months. From year 2077 to 2078 BS, as bill directly proportional to no of unit energy consumes, the monthly bill of each month of 2078 greater than previous year 2077 BS bill.

4.5 Energy Efficiency Opportunities inside water treatment plant

Some of energy efficient method during analysis discuss as follows.

4.5.1 Lighting System Improvement

Present Condition

In case of Mahanklachaur water treatment plant 0.17% of the total electrical consumption are due to lighting system. While observing the various sections we found that there is a higher possibility of energy saving opportunities in lighting system. After observing the presence of inefficient tube lights and CFL which could be easily replaced by energy efficient lighting technologies. The number of inefficient lights that were seen during the walk through audit and detailed energy audit in different buildings is shown in table.

Table 14: Lighting load inside MWTP

S.N	Area	Light type	No of total light	Rating (watt)	Operation hour	Unit consumed by inefficient light (Wh)
1	Bio filter (NaoH+air blower room)	Led bulb	8	11	0.5	44
2	Power room and generator room	Led bulb	16	11	0.17	29.92
3	PAC and lime room	Led bulb	16	11	1	176
4	Pump operator room	Led bulb	6	11	13	858
	Daily consumed (kWh)					1.11
	Annual consumed(kWh)					398.85
	Initial investment		46.00	270 per light		12420.00
	Annual energy saving (kWh)					1050.75
	Annual bill saving	peak hour rate 6.30			Nrs	6619.72
	Payback period (year)					1.88

Cost Benefits Analysis

The most suitable cost benefit is payback period. Two types of payback period calculation of lighting system following.

Simple Payback

For cost benefit analysis, taking Peak time cost of electricity is6.3NRS. / kWh
Total number of lights 68
Number of inefficient lights 46
Daily energy consumption 9.31 kWh
Recommended lights 11W LED
PER unit cost of 20W LED NRs. 270
Indicative investment NRs. 12420
Annual energy saving 1054.31kWh
Annual cost saving NRs. 6642.13
Simple payback period 1.87 years

Discounted Payback

Interest Rate	10.00%
MARR	10.00%
investment	12420.00
annual saving	6619.72
Annual maintenance (2%)	248.40
Net annual saving	6371.32

Table 15: Cash flow and discounted payback period of lighting system

Year	Cash flow	DF	PV of cash flow	Discounted payback
0	-12420.00	1.00	-12420.00	-12420.00
1	6371.32	0.91	5792.11	(6,627.89)
2	6371.32	0.83	5265.55	(1,362.34)
3	6371.32	0.75	4786.87	3,424.52
4	6371.32	0.68	4351.70	2.28 years

Consider minimum attractive rate of return 10% and annual maintenance of Nrs 248.40 and net annual bill saving of lighting is Nrs.6371.32. It is recommended to replace the tube lights into LED. Based on the illumination required on water treatment plant 11W

LED with a market price of NRs. 270 is recommended. The LED has an added advantage of producing less heat, high lumens per watt and large lifecycle.

4.5.2 Filter Wash Water conservation and Improved System Cost Benefit Analysis

Large quantity of drainage water accumulated in short interval of time during back washing of rapid sand filter as well of other equipment. Sludge and drainage basin sufficient for storing backwashing water and drainage other from clear water equipment.

Sludge and drainage basin having dimension of width 8m *length 10 m *depth 3.5 m
With following parameter
Effective capacity: 224 cubic m per basin = 448 cubic meter
Four back washing of filter = 448 cubic meter waste water
No of rapid sand filter basin = 10
There are four pump two new dewatering pump and two old sludge pump. In present condition, two pump operated first to dewatering drain water then sludge pump operates to drain out sludge to sewerage line.

In dry season, surface water has less turbidity so back -washing of RSF done two days per rapid sand filter basin. Four back wash could full drainage basin (448 cubic m). If these waste water pumping and reuse to intake chamber of MWTP, then annual revenue can generate. All calculation as below

There are ten RSF basin inside WTP
Volume of Drainage basin 448 cubic meter
Four back wash of filter = 448 cubic meter
In Dry season (Poush to Baiskha) one filter basin wash per two day
No of back washing in dry season =75
Total volume of water in back washing during dry season 8400 cubic meter
In Wet season 4 month very high turbidity and 3 moth high turbidity of Surface water came from sundarijal of Bagmati River.
Volume during 4 month53760 cubic meter

Volume during 3 months5040 cubic meter
Annual water wastage of water 67200 cubic meter
If plant reused 60% of waste water and reaming 40 contain more sludge drain out. Volume of water is 40320 cubic meter that can be reuse and considering lowest consumer rate of KUKL water charge for 1 unit (1000 liter) = NRs.32
Annual revenue could waste water generate NRs. 1290240

There are two submersible pump 13.5 kw and 9 kw inside WTP whose capacity is 1000 LPM that can pump water in one hour 60 cubic meter in one hour so total operation hour 336 for each pump

Existing Sludge Pump Scheduling for Reuse of Filter Wash Water

In dry season of water supply filter back wash two alternative day and in wet season four unit per day. During wet season one back washing of filter in peak hour time

no of peak hour for pump operation	224
normal hour for pump operation	448

Let suppose both pump operate simultaneously 24-hour total peak time sharing by both pump (112 hours each)
Peak hour energy unit 2520 kWh
Peak hour energy bill will (NRS.) 15876
Normal hour energy consume will 6120kWh
Normal hour energy bill (NRS) will 38556
Total annual operating cost (NRS) will 54432
Annual net saving (NRS.) will 1235808.00

Capital investment for new HDPE pipe line to return water from drain basin to water inlet tank is NRS. 373591.40. Detail calculation as table 15 and annex A.

Table 16: Cost saving from waste water and payback period

S.N	Description	Amount	Remarks
1	Annual revenue of water after reuse from wastage (NRS)	1505280.00	KUKl ½ ’’ line rate
2	Total annual pump operating cost (NRS.)	54432.00	
3	Net revenue generate from waste water	1450848.00	
4	Initial investment for system operation (pipe line and fittings)	373591.40	
5	Payback period (Year)	0.26	
6	Payback period in (Month)	3.09	

4.5.3 Peak Hour Load Shifting and Energy Bill Saving Opportunities

There are many chemical pumps, air blowers, clear water pump and drainage pump. Among them water transmission from CWR to the SRT and Kaplan supply pump are transmission pump almost operate 16-20 hours in the dry season and 22 hours in the wet season. Other chemical pump and air blower operate very less time around one hour per day. Operation of pump affected by water distribution table which is prepared by KUKL head office and Mahankalchaur branch. Water distribution inside Kathmandu valley is very critical and complex process because of demand and supply gap. During the field visit and studying log sheet and water distribution table, it was found that the pump is resting at normal hours and almost fully operate at peak hour.

Table 17: Transmission pump shifting and annual bill saving

S.N	Description	Amount (NRS.)
1	Annual pump operation bill without load shifting	14,10,840
2	Annul pump operation bill with peak hour load shifting	136,6200
3	Net annual saving	44,640

From above table 16, by shifting two hours from peak hours to normal hour WTP can save annual NRS. 44640

4.6 Energy Efficiency in Mahanakclachaur Water Treatment Plant

The ratio of mechanical power output to electrical power input, usually stated as a percentage known as energy efficiency. Considerable variation exists between the performance of standard and energy-efficient motors.

Clear water reservoir and transmission pump
Two no of basin whose
Effective capacity: 3.7 m *(8.25+9.7*4 m +3.55) 3.3*2=1235.6 cubic meter
Water shifting from CWT to SRT and distributed from SRT though gravity flow system but for Kapan distribution water distributed directly from CWR to main pipeline.

Table 18: MWTP capacity of service reservoir tank

S.N	Reservoir	Branch	Capacity (m^3)
1	Mahankalchaur	Mahankalchaur	4250
2	Mahankalchaur	Mahankalchaur	4250
3	Mahankalchaur	Mahankalchaur	4500
		Total	9000

4.6.1 Replace Inefficient Pump Motor by Energy Efficient pump

Present Situation

During the detailed energy audit, it was observed that submersible induction motor is used for water pumping in the Mahankalchaur water treatment plant. The pump is operated for around 16-20 hour in dry season and 22- 24 hours a day in wet season throughout the year. The motor and pump has been in use for more than a decade and has been repaired two years to four year regular times.

Table 19: Pumping load inside water treatment plant

S.N	Pump No	Rated power	Power consumed	Flow in cubic m /s	Operating head (m)	Pump efficiency	Remark
1	Pump 1	15 kW	16.37 kW	0.10	6	36%	Transmission pump
2	Pump 2	15 kW	15.61 kW	0.08	6	32%	Transmission pump
3	Pump 3	15 kW	16.40 kW	0.10	6	38%	Transmission pump
4	Pump 4	15 kW	18.02 kW	0.09	6	29%	Transmission pump
5	Pump 1	30 kW	28.06 kW	0.07	4	10 %	Back wash pump
6	Pump 2	30 kW	28.06 kW	0.07	4	10 %	Back wash pump

During detail analysis, it is found that transmission pump efficiency decreases up to 28% from nearly 80 % during installation time. Also filter backwash pump efficiency have 10%, which is poor in operation. From local Nepalese market, more efficient pump supply by KSB Nepal (Shrestha Brothers). Efficient pump and its market rate as follows.

Table 20: Efficient pump data supply by Vendor

S.N	Name of Pump	Type	Duty Point	Pump Model	HP	RPM	Rate
1	Surface Washing Pumps	Volute Casing	4 m3/min @ 25m	ETN 100-80-160 GG	30HP	2900	436,000.00
2	Make Up Pumps	Centrifugal	1.2m3/min @ 7m	ETN 080-065-160 GG	3HP	1450	179,500.00
3	Transmission Pumps	Volute Casing	6.5m3/hr @ 9m	ETN 200-150-200 GG	10HP	1450	450,000.00

It is found that surface washing pump, transmission pump and make pump found in the market more efficient and less capacity.

Cost Benefits:

Both simple payback period and discounted payback period calculation of efficient pump as follows.

Simple Payback

Table 21: Efficient pump annual saving and payback

Net kwh saving yearly				182,849.56
Average TOD charge (4.8)				877,677.90
Initial investment	set	Unit price		
Transmission pump	3	450,000.00	1,350,000.00	1350000.00
Make up pump	1	179,500.00	179,500.00	179500.00
Back wash pump	1	436,000.00	436,000.00	436000.00
Sub total				1965500.00
VAT				255515.00
Grand total				2221015.00
Annual energy bill saving				877677.90
Payback period				2.53 years

Initial investment NRS 2221015.00

Annual bill saving by efficient pump NRS 877677.90

From table 20, payback period of efficient pump is 2.53 years.

Discounted Payback

MARR	10.00%
Investment	2221015.00
Annual saving	877677.90
Annual maintenance (2.5%)	55525.38
Net revenue	822152.53

Table 22: Discounted payback of efficient pump

Year	Cash flow	DF	PV of cash flow	Discounted payback
0	-2221015.00	1.00	-2221015.00	-2221015.00
1	822152.53	0.91	747411.39	(1,473,603.61)
2	822152.53	0.83	679464.90	(794,138.71)
3	822152.53	0.75	617695.36	(176,443.35)
4	822152.53	0.68	561541.24	385,097.89
5	822152.53	0.62	510492.04	3.31

From above table and cash flow discounted payback period of efficient pump is 3.31 years.

It is recommended to replace bake wash pump and make up pump as well as transmission pump having capacity 30HP, 3HPand 10HP for energy consumption reduction.

4.6.2 Replace Star Delta Motor Starter with Variable Frequency Drive

Present Condition:

VFDs (variable frequency drives) are a more efficient technology that allows the pump speed to be adjusted to match the flow conditions. By altering the frequency of the motor's power source, a VFD may adjust the motor's speed. As a result, the VFD balances the electrical power supplied to the pump with the hydraulic power required to pump the water. When the flow rate is very variable, a variable frequency drive (VFD) is perfect. Because affinity laws for centrifugal pumps show that even a minor change in motor speed can cut pump energy by up to 50 percent, energy savings from VFDs can be significant. From observation it is best to used VFD in Kapan water supply system of KUKL.

Kapan system have 47.32% load and it is fluctuating with the flow and head. During study if was found that generally load vary 5% and sometime up to 20% of full load. So installation of VFD to those systems improve efficiency of system as well as save energy.

Table 23: Energy saving by VFD calculation

S. N	Description of item	Rating(kw)	Hour use	Power save at 80% load(kw)	Power save at 95 % load (kw)	Energy save (80%)E1	Energy save (95%)E2
	Wet season						
1	centrifugal 1450 rpm	22	4	10.74	3.14	42.94	12.55
2	centrifugal 1450 rpm	30	24	14.64	4.28	351.36	102.69
3	submersible 2985 rpm	22	24	10.74	3.14	257.66	75.31
4	submersible 2985 rpm	45	0	21.96		0.00	0.00
	Daily					651.97	190.55
	seven month					136913.28	40014.87
	Dry season						
1	centrifugal 1450 rpm	22	3	10.74	3.14	32.21	9.41
2	centrifugal 1450 rpm	30	18	14.64	4.28	263.52	77.02
3	submersible 2985 rpm	22	18	10.74	3.14	193.25	56.48
4	submersible 2985 rpm	45	0	21.96		0.00	0.00
	Daily					488.98	142.91
	Five month					73346.40	21436.54

Cost Benefit Analysis

Simple payback and discounted payback are cost benefit analysis tool.

Simple Payback

Table 24: VFD payback period

VFD Rating	No of set	Price (NRS.)
22KW	2	381000.00
30 KW	1	455000.00
Sub Total		836000.00
VAT		108680.00
Total investment (NRS.)		944680.00

From table 23, Yearly total energy save at 80% load is 210259.68 kWh and annual bill saving for 80% loading is NRS. 10, 09,246.46 with Payback period 0.94 years. Most of time load mainly varies at 5% of full load. Yearly total energy save at 95 % load is 61451.41 kWh and annual bill saving for 95 % loading is NRS. 294,966.76 with simple payback period is 3.30 years.

Discounted Payback Period

Table 25: Discounted payback period of VFD

Year	Cash flow	DF	PV of cash flow	Discounted payback
0	-944680.00	1.00	-944680.00	-944680.00
1	285519.96	0.91	259563.60	(685,116.40)
2	285519.96	0.83	235966.91	(449,149.50)
3	285519.96	0.75	214515.37	(234,634.13)
4	285519.96	0.68	195013.97	(39,620.16)
5	285519.96	0.62	177285.43	137,665.27
6	285519.96	0.56	161168.57	4.22 Years

From table 24, discounted payback of VFD is 4.22 years. VFD is recommended for the Kapan water supply system as load varies from 5 % to 20%. Tanker supply pumps have constant flow so for energy saving and cost reduction star delta starter should replace by VFD.

4.6.3 Optimization of Diesel Generator Operations

Present Situation

During the energy audit, it was found that 380KW, 3-phase diesel generator is operating in manual mode. The diesel generator consumed on average around 30 liters of diesel per hour and 48 liters of fuel per month. The random output of the diesel generator was measured P.F. meter. The reading obtained is as shown in Table 25.

Table 26: Output of diesel generator

Phase	Current	Voltage	Power	Power factor
R	238 A	396 volt	138 KW	0.89
Y	222 A	396 volt	139 KW	0.89
B	223 A	396 volt	138 KW	0.89

Recommendation

- It is optimization of dg operations recommended to maintain a log book which can give accurate data regarding the fuel consumed, hours in use and energy produced
- An automatic control should be implemented so that the generator can turn on and off easily and automatically.

Table 27: Generalization of energy investment decision

S.N.	Energy Conservation Opportunities	Types of investment
1	Shifting peak load from peak hour to normal hour	Less Cost
2	Regular cleaning of air blower silencer	
3	Tighten the belt of air blower to control abnormal sound	
4	Turning off AC, Fan and Light while not in use	
6	Replace v belt by flat belt at air blower	
7	Check valve of pump regular observe and maintain	
8	Replace tube light by Led light	
19	Reuse filter wash waste water from drain	More Cost Demanding
10	Efficient transmission pump ,make up pump and filter washing surface washing pump	
11	Install VFD for Kapan supply pump	

CHAPTER FIVE: CONCLUSION AND RECOMMENDATION

5.1 Conclusion

Approved demand inside water treatment plant is 500 KVA but load inside plant varies maximum 274 KVA to 91 KVA during the twenty-two previous months. So load factor, inside the plant vary from 18.2 % to 52.8 %. Load factor inside water treatment plant is low due to higher connected load but few equipment in operation. Specific energy consumption inside the plant is 0.1338 kWh/cubic meter.

In 2077 BS year, yearly consume energy was found 870.75 MWh and yearly paid energy bill to NEA NRS. 42.63, 713.70. Based on this data it is conclude that

- 46 number of 40 watts each halogen light replaces by 20 watt led bub which save 0.12 % of total kWh and 0.16% of total annual bill with simple payback 1.88 years. Considering 10% MAAR and 2% annual maintenance cost, 0.16% of total annual bill save with discounted payback period of 2.28 years.
- Two hour from Peak hour shift to normal hour can save annual 1.05% of energy bill.
- Efficient pump which replace existing transmission pump, back wash and make up pump save annual 21% of energy and 20.58 % of annul energy bill. While considering 10% MARR and 2.5 % annual maintenance, 19.28% annual bill could save with discounted payback period 3.25 years.
- VFD can be used in Kapan supply pump whose load varies from 20% to 5 % of full load. 23.67% of electricity bill. At 5% load variation, VFD save 7.06% energy and 6.92% of annual bill while considering MARR 10% with 1% annual maintenance save 6.7 % of annual energy bill.

Overall 10.69% energy and 27.66% energy bill with NRS .3178115.00 investment could be save annually using led bulb, efficient pump and VFD. Considering MAAR 10% and annual maintenance cost 26.13% of annul energy bill could be save.

5.2 Recommendations

Following recommendations have been drawn from the study:

- Use led light where halogen tube
- Use efficient pump instead of old transmission, backwash and make up pump inefficient pump and use VFD where Flow of pump varies
- Peak hour lad shifts to save energy bill and Re-use filter backwash water and save money

REFERENCES

Abu Shmeis, R. M. (2018) Water Chemistry and Microbiology. 1st edn, Comprehensive Analytical Chemistry. 1st edn. Elsevier B.V. doi: 10.1016/bs.coac.2018.02.001.

Bartaula, R. (2016) 'Performance evaluation of water and wastewater treatment plant in Kathmandu Valley', Performance evaluation of water and wastewater treatment plant, pp. 1–120.

Bora, K. (2008) 'University of Ljubljana (Icpe), Ljubljana Master ' S Degree Thesis Energy Management in Pulp and Paper Industry : a Case Study of Cachar Paper Mill'.

Chanpiwat, P. and Sinha, S. (2014) 'Quantitative approach to select energy benchmarking parameters for drinking water utilities', Pipelines 2014: From Underground to the Forefront of Innovation and Sustainability - Proceedings of the Pipelines 2014 Conference, pp. 1237–1253. doi: 10.1061/9780784413692.119.

Consultancy, G. (no date) 'Energy Audit Guidelines for Commercial Sectors'.

Dubey, B. et al. (2012) 'Energy audit and energy conservation potential for water treatment plant', Water and Energy International, 69(4), pp. 42–46. doi: 10.9790/1684-0120409.

ECBC (2001) '3 . ENERGY MANAGEMENT AND AUDIT Energy Audit : Types And Methodology', Energy, pp. 54–78.

Elias, Z. and Jaya, S. (2017) 'Energy Efficiency Strategies for Sewage Treatment', (2), pp. 18–20.

Farhaoui, M. and Derraz, M. (2016) 'Review on Optimization of Drinking Water Treatment Process', Journal of Water Resource and Protection, 08(08), pp. 777–786. doi: 10.4236/jwarp.2016.88063.

GWP-Nepal & JVS (2018) 'Water Nepal : A Historical Perspective'.

Hoff, H. (2011) 'Hoff, H. (2011). Understanding the Nexus. Background Paper for the Bonn 2011 Conference: The Water, Energy and Food Security Nexus. Stockholm:

Stockholm Environment Institute.', Stockholm Environment Institute, (November), pp. 1–52.

Horne, J., Turgeon, J. and Byous, E. (2011) 'Energy Self-Assessment Tools and Energy Audits for Water and Wastewater Utilities', p. 70. Available at: http://water.epa.gov/infrastructure/sustain/upload/EnrgMgmtWebcst_Dec2011.pdf.

Howley, M. et al. (2012) 'in Ireland 1990–2011Energy', Energy Policy Statistical Unit, Sustainable Energy Authority of Ireland.

Kharal, D., Officer, S. E. and Secretariat, E. C. (2011) 'Energy Efficiency Initiatives in Nepal', Productivity, 51(4), p. 291. Available at: http://search.proquest.com/openview/45dc2a5a05210be6296bcfc3c2e36d9d/1?pq-origsite=gscholar.

Kumar, A. (2015) 'Lecture 8 : Water treatment processes Previous lecture re-cap • Introduction of water treatment schematic concepts', p. 32.

Kumar Tamrakar, N. and Sharma, H. P. (2016) 'Institutional Capacity Assessment of KUKL', (February).

Lee, M. et al. (2017) 'Water-energy nexus for urban water systems: A comparative review on energy intensity and environmental impacts in relation to global water risks', *Applied Energy*, 205(March), pp. 589–601. doi: 10.1016/j.apenergy.2017.08.002.

Leiby, V. M. and Burke, M. E. (2011) 'Energy Efficiency Best Practices for North American Drinking Water Utilities'.

'MahankalChaur OMM 1994 .pdf' (no date).

Ministry of Power (2001) 'The Energy Conservation Act', *The Gazette of India*, 60(2), p. 22. Available at: http://powermin.nic.in/sites/default/files/uploads/ecact2001.pdf.

MoEWRI (2019) 'National Energy Efficiency Strategy 2018', 2075(January), p. 20. Available at: http://www.moewri.gov.np/images/category/National-Energy-Efficiency-Strategy-2075.pdf.

Nepal Electricity Authority (2021) 'Nepal Electricity: Annual Report 2020/2021'.

Available at: www.nea.org.np.

SEAI (2017) ‘Energy Audit Handbook’, *Seai*. Available at: http://www.seai.ie/resources/publications/SEAI-Energy-Audit-Handbook.pdf.

Talwar, M. (2016) ‘Case Study: Energy Audit’, *International Research Journal of Engineering and Technology*, pp. 159–163. Available at: www.irjet.net.

US EPA (2000) ‘The History of Drinking Water Treatment’, *Public Health*, (4606), pp. 1–4. Available at: http://www.epa.gov/ogwdw000/consumer/pdf/hist.pdf.

ANNEX A: DETAILS CALCUALTION TABLES

Table 28: Pipe line Installation Calculation

S.N.	Description of works	No	Length(m)	Breadth (m)	Height(m)	Qty	Unit	Rate	Amount
	Part- A								
A	**Civil works:-**								
3	Earthwork excavation in boulder mixed soil								
	for laying 110mm dia. HDPE pipe	1.00	130.00	0.60	0.90	70.20			
					Total =	70.20	cu.m	1444.52	101405.30
4	Laying & jointing of 110mm dia. HDPE pipe	1.00	150.00			150.00	m	207.51	31126.50
5	Installation of 4" dia. fittings	2.00				2.00	no	1963.63	3927.26
10	Backfilling with manual compaction in boulder mixed soil	1.00	As per S.N. 3			70.20	cu.m	561.45	39413.79
	Sub total amount of part- A=								**175872.85**
	VAT @ 13 % =								**22863.47**
'otal amount of (part-A),Civil work=									**198736.33**
B	**Part- B(Material expenditure)**								
1	110mm dia. HDPE pipe (6Kg/cm2)	1.00	150.00			150.00	m	790.22	118533.00
6	4" mechanical coupling	1.00				1.00	no	2160.00	2160.00
9	4" sluice valve	1.00				1.00	no	18250.00	18250.00
10	4" dia. Flange	2.00				2.00	no	2348.00	4696.00
12	Nut bolts	32.00				32.00	no	250.00	8000.00
13	Rubber washer	1.00				1.00	meter	3100.00	3100.00
	Sub total amount of part- B=								**154739.00**
	VAT @ 13%=								**20116.07**
Total amount of Part-B(materials)=									**174855.07**
	Total amount of part A+B=								**373591.40**
	In words:- Rs. Three lakh seventy three housand five hundred ninety one rupees and fourty paisa only rupees only.								

Table 29: Power logger data

Time	Voltage	Current average	Power average	KVA average	PF_average	kWh_Total
4:08:50 PM	396.87 V	238.33 A	138.46 kW	155.26 kVA	**0.89**	0.38 kWh
4:17:10 PM	398.14 V	240.00 A	139.96 kW	156.96 kVA	**0.89**	0.39 kWh
4:17:20 PM	398.07 V	240.24 A	140.12 kW	157.08 kVA	**0.89**	0.39 kWh
4:20:00 PM	397.98 V	240.74 A	140.74 kW	157.49 kVA	**0.89**	0.39 kWh
4:20:10 PM	397.78 V	240.70 A	140.86 kW	157.54 kVA	**0.89**	0.39 kWh
4:40:00 PM	396.10 V	246.07 A	141.69 kW	158.01 kVA	**0.90**	0.39 kWh
4:50:00 PM	395.11 V	239.19 A	140.84 kW	156.83 kVA	**0.90**	0.39 kWh
5:00:00 PM	391.12 V	238.89 A	140.37 kW	156.66 kVA	**0.90**	0.39 kWh
5:40:00 PM	395.71 V	253.93 A	154.88 kW	168.22 kVA	**0.92**	0.43 kWh
5:50:00 PM	395.05 V	234.93 A	138.80 kW	155.74 kVA	**0.89**	0.39 kWh
6:00:00 PM	392.82 V	228.57 A	131.79 kW	149.72 kVA	**0.88**	0.37 kWh
6:30:00 PM	383.45 V	227.52 A	121.43 kW	146.05 kVA	**0.83**	0.34 kWh
7:00:00 PM	395.20 V	251.11 A	147.41 kW	163.78 kVA	**0.90**	0.41 kWh
8:00:00 PM	401.34 V	218.34 A	123.73 kW	149.47 kVA	**0.83**	0.34 kWh
8:30:10 PM	403.34 V	214.89 A	118.90 kW	148.51 kVA	**0.80**	0.33 kWh
9:30:10 PM	407.45 V	212.37 A	116.58 kW	145.06 kVA	**0.80**	0.32 kWh

11:02:40 PM	407.27 V	209.02 A	112.86 kW	142.70 kVA	**0.79**	0.31 kWh
11:02:50 PM	407.32 V	211.40 A	113.50 kW	143.24 kVA	**0.79**	0.32 kWh
11:30:00 PM	411.40 V	210.67 A	114.19 kW	145.09 kVA	**0.79**	0.32 kWh
12:46:20 AM	411.41 V	211.45 A	113.72 kW	145.50 kVA	**0.78**	0.32 kWh
12:59:50 AM	413.44 V	210.38 A	113.82 kW	145.48 kVA	**0.78**	0.32 kWh
1:00:00 AM	413.56 V	210.19 A	113.66 kW	145.38 kVA	**0.78**	0.32 kWh
1:36:30 AM	414.16 V	209.58 A	112.48 kW	144.56 kVA	**0.78**	0.31 kWh
2:07:50 AM	415.94 V	209.88 A	112.82 kW	145.33 kVA	**0.78**	0.31 kWh
2:08:40 AM	416.45 V	209.70 A	112.80 kW	145.40 kVA	**0.78**	0.31 kWh
2:08:50 AM	416.60 V	209.66 A	112.72 kW	145.37 kVA	**0.78**	0.31 kWh
2:22:20 AM	414.00 V	209.52 A	112.30 kW	144.23 kVA	**0.78**	0.31 kWh
3:07:50 AM	413.71 V	209.87 A	112.42 kW	144.95 kVA	**0.78**	0.31 kWh
4:07:30 AM	414.67 V	216.34 A	117.55 kW	148.50 kVA	**0.79**	0.33 kWh
4:31:10 AM	416.02 V	214.90 A	116.32 kW	147.80 kVA	**0.79**	0.32 kWh
4:45:50 AM	415.79 V	215.45 A	117.17 kW	148.49 kVA	**0.79**	0.33 kWh
4:46:00 AM	415.95 V	215.42 A	117.29 kW	148.62 kVA	**0.79**	0.33 kWh
5:14:10 AM	411.58 V	216.20 A	118.51 kW	148.24 kVA	**0.80**	0.33 kWh
6:21:20 AM	407.00 V	220.16 A	121.74 kW	147.32 kVA	**0.83**	0.34 kWh

6:53:10 AM	397.38 V	219.61 A	120.34 kW	143.09 kVA	**0.84**	0.33 kWh
7:01:20 AM	395.83 V	212.31 A	114.80 kW	140.27 kVA	**0.82**	0.32 kWh
7:01:30 AM	395.68 V	212.55 A	114.89 kW	140.31 kVA	**0.82**	0.32 kWh
7:01:40 AM	395.88 V	212.43 A	114.85 kW	140.35 kVA	**0.82**	0.32 kWh
7:01:50 AM	395.96 V	212.52 A	114.97 kW	140.48 kVA	**0.82**	0.32 kWh
7:02:00 AM	396.35 V	212.93 A	115.10 kW	140.70 kVA	**0.82**	0.32 kWh
7:02:10 AM	396.70 V	212.08 A	114.86 kW	140.59 kVA	**0.82**	0.32 kWh
7:37:00 AM	397.36 V	222.43 A	113.18 kW	145.06 kVA	**0.78**	0.31 kWh
7:55:50 AM	387.85 V	226.04 A	109.55 kW	139.29 kVA	**0.79**	0.30 kWh
8:02:00 AM	398.00 V	222.48 A	111.36 kW	143.69 kVA	**0.77**	0.31 kWh
8:36:00 AM	391.00 V	220.52 A	112.06 kW	139.81 kVA	**0.80**	0.31 kWh
8:54:50 AM	391.19 V	227.79 A	115.64 kW	142.78 kVA	**0.81**	0.32 kWh
9:03:50 AM	392.07 V	227.32 A	115.28 kW	142.80 kVA	**0.81**	0.32 kWh
9:25:00 AM	395.13 V	219.77 A	109.32 kW	139.57 kVA	**0.78**	0.30 kWh
9:45:50 AM	396.53 V	246.39 A	147.84 kW	161.97 kVA	**0.91**	0.41 kWh
10:00:00 AM	398.09 V	223.33 A	124.63 kW	146.43 kVA	**0.85**	0.35 kWh
10:35:40 AM	401.59 V	207.19 A	92.04 kW	133.47 kVA	**0.69**	0.26 kWh
10:44:40 AM	400.69 V	218.21 A	117.02 kW	141.55 kVA	**0.83**	0.33 kWh

10:44:50 AM	400.90 V	218.55 A	117.17 kW	141.72 kVA	**0.83**	0.33 kWh
10:45:00 AM	400.77 V	218.87 A	117.75 kW	142.15 kVA	**0.83**	0.33 kWh
11:00:10 AM	389.07 V	219.44 A	124.38 kW	144.52 kVA	**0.86**	0.35 kWh
11:01:20 AM	389.54 V	224.45 A	125.91 kW	145.84 kVA	**0.86**	0.35 kWh

2263.31 kWh

Table 30: Load analysis of plant

S.N	Process Name	Process Name	Motor Rating	Voltage(v)	Current (A)		
					R	Y	B
1	Bio filter equipment	Air blower 1	30kW	395	35.2	40	35
		Air blower 2	30 kW	395	43.9	39	40
		Air blower 3	30 kW	395	32	40	35
		Air blower 4	30 kW	395	34	35	43
2	PAC equipment	PAC dissolution tank Agitator 1	0.75 kW	396	1.2	1.3	1.2
		PAC dissolution tank Agitator 2	0.75 kW	396	1.2	1.2	1.2
		Solution transmission pump no 1	0.4 kW	396	1.8	1.8	1.8
		Solution transmission pump no 2	0.4 kW	396	1.8	1.8	1.8
4	Clear water transmission	Transmission pump 1	15 kW	396	29.5	31.5	25.5
		Transmission pump 2	15 kW	396	28	27	30
		Transmission pump 3	15 kW	396	28	30	31
		Transmission pump 4	15 kW	396	32	32	33
5	Plant continous water supply	Pressure pump	3.7 kW	396	6.7	7.3	6.5
6	Water distibution	Kapan submersible small	30KW	396	55.7	54.7	57.6
		Kapan centifula(chhpro)	30KW	396	48.1	38.4	41.6
		Tanker filling pump 1	11KW	396	14.8	14.8	14.8
		Tanker filling pump 2	3KW	396	6.4	6.5	6.4

Table 31: TOD meter different hour energy consumption

S.N	Date(BS)	Peak hour consume unit(T1)	Normal hour consume unit(T2)	Off -peak Consume unit(T3)
1	2077-01	10982	23568	10035
2	2077-02	13284	28142	11899
3	2077-03	15331	33573	14174
4	2077-04	15392	33075	14631
5	2077-05	18916	40142	18001
6	2077-06	21681	45783	20564
7	2077-07	20970	44705	20026
8	2077-08	19976	43845	18969
9	2077-09	17696	39316	16681
10	2077-10	20763	49234	19248
11	2077-11	19892	44578	18460
12	2077-12	16347	36491	14382
13	2078-01	15107	31231	14274
14	2078-02	16867	33254	16174
15	2078-03	19757	39519	18481
16	2078-04	22930	47684	22486
17	2078-05	24756	49787	23053
18	2078-06	24554	48409	22005
19	2078-07	22199	45565	20294
20	2078-08	22660	47227	21865
21	2078-09	22477	47412	21242
22	2078-10	24054	50393	21777

Table 32: Monthy energy cosumption and bill

Month	Monthly Energy Consumption 2077 in (MWh)	Monthly Bill of 2077(NRS)	Monthly Energy Consumption in 2078 (MWh)	Monthly Bill of 2078(NRS)
1	44.59	214075.20	60.61	290491.40
2	53.33	256413.20	66.30	317547.50
3	63.08	302570.00	77.76	373043.80
4	63.10	302167.50	93.10	445026.20
5	77.06	369041.60	97.60	468341.90
6	88.03	421688.00	94.97	457029.50
7	85.70	410312.90	88.06	423008.80
8	82.79	396414.90	91.75	439065.90
9	73.69	374670.70	91.13	464278.90
10	89.25	452672.30	96.22	490739.20
11	82.93	421598.20		
12	67.22	342089.20		

Table 33: VFD energy saving calculation

S.N	Description of item	Rating	hour use	80 % loading(kw)	95 % loading (kw)	power save at 80% laod(kw)	power save at 95 % laod (kw)	energy save (80%)E1	energy save (95%)E2
	wet season								
1	centrifugal 1450 rpm	22	4	11.264	18.86	10.74	3.14	42.94	12.55
2	centrifugal 1450 rpm	30	24	15.36	25.72	14.64	4.28	351.36	102.69
3	submersible 2985 rpm	22	24	11.264	18.86	10.74	3.14	257.66	75.31
4	submersible 2985 rpm	45	0	23.04	38.58	21.96		0.00	0.00
	Daily							651.97	190.55
	seven month							136913.28	40014.87
	dry season								
1	centrifugal 1450 rpm	22	3	11.264	18.86	10.74	3.14	32.21	9.41
2	centrifugal 1450 rpm	30	18	15.36	25.72	14.64	4.28	263.52	77.02
3	submersible 2985 rpm	22	18	11.264	18.86	10.74	3.14	193.25	56.48
4	submersible 2985 rpm	45	0	23.04	38.58	21.96		0.00	0.00
	Daily							488.98	142.91
	Five month							73346.40	21436.54
	Yeraly total energy save at 80% load and 95% laod respectively							210259.68	61451.41
	Average Annual money save for 80% and 95% loading respectively							1,009,246.46	294,966.76

Table 34: Transmission, Backwash and make up pump energy calculation

S.N	Efficicient Equipment Name	Specification	Unit in operation	Rating	Operating hour	Energy consumption(kWh)	Yearly kWh
1	Surface washing pump	Volute Casing 4 m3/min @ 25m 30 HP 2900 RPM	1.00	22.38	0.40	8.95	1879.92
2	Make up pump	Centrifugal 1.2m3/min @ 7m ,3 HP 1450 RPM	1.00	0.22	0.40	0.09	18.80
3	Trasmission pu	Volute Casing 5m3/hr @ 6m,10HP 985 RPM	3.00	7.50	24.00	540.00	113400.00
	dry					549.04	115298.72
1	Surface washing pump	Volute Casing 4 m3/min @ 25m 30 HP 2900 RPM	1.00	22.38	0.20	4.48	671.40
2	Make up pump	Centrifugal 1.2m3/min @ 7m ,3 HP 1450 RPM	1.00	0.22	0.20	0.04	6.71
3	Trasmission pu	Volute Casing 5m3/hr @ 6m,10HP 985 RPM	2.00	7.50	18.00	270.00	40500.00
							41178.11
		total					**156476.83**
	wet						
1	Trasmission pu	16.37 kW	3.00	16.37	24.00	1178.47	247479.74
2	Back wash pun	28.06 kW	1.00	28.06	0.40	11.22	2357.04
3	Make up pump	2.3	1.00	2.30	0.40	0.92	193.20
						1190.62	250029.98
	dry						
1	Trasmission pu	16.37 kW	2.00	16.37	18.00	589.24	88385.62
2	Back wash pun	28.06 kW	1.00	28.06	0.20	5.61	841.80
3	Make up pump	2.3	1.00	2.30	0.20	0.46	69.00
						595.31	89296.42
		Total Annul energy					**339,326.40**

Table 35: Overall simple payback

S.N	Description	Initial kwh	After efficient kwh	Anuual energy save(kWh)	Anuual money save (NRS.)	Investment(N rs)	Payback period(Yr.)
1	Helogen tube light repalce by LED bulb	3350.40	2299.65	1050.75	6619.72	12420.00	1.88
2	Water trasmission ,make up and fiter wash pump	339326.40	308735.23	30591.16	877,677.90	2221015.00	2.53
3	VFD used in kapan area pump			61451.41	294966.756	944680.00	3.20
	overall			93093.32	1179264.38	3178115.00	2.69
				10.69%	27.66%		

Table 36: Overall discounted payback period

S.N	Description	Initial kwh	After efficient kwh	Anuual energy save(kWh)	Anuual money save (NRS.)	Investment(N rs)	Disconted payback period(Yr.)
1	Helogen tube light repalce by LED bulb	3350.40	2299.65	1050.75	6371.32	12420.00	2.28
2	Water trasmission ,make up and fiter wash pump	339326.40	308735.23	30591.16	822,152.53	2221015.00	3.25
3	VFD used in kapan area pump			61451.41	285519.956	944680.00	4.22
	Overall			93093.32	1114043.80	3178115.00	3.25
					26.13%		

ANNEX B: EQUIPMENT FOR ENERGY ADUIT

The requirement for an energy audit such as identification and quantification of energy necessitates measurements; these measurements require the use of instruments. These instruments must be portable, durable, easy to operate and relatively inexpensive. The parameters generally monitored during energy audit may include the following: Basic Electrical Parameters in AC system: Voltage (V), current (I), Power (kW), Apparent Power (demand) (kVA), reactive Power, energy consumption (kWh), and Frequency (Hz), Harmonics etc. Basic Electrical Parameters in DC system: Voltage (V), Current (I), Power (kW), Energy Consumption (kWh) etc. Parameters of importance other than electrical are: temperature & heat flow, radiation, air and gas flow, liquid flow, revolution per minute (RPM), air velocity, noise and vibration, dust concentration, total dissolved solid (TDS), pH, moisture content, relative humidity, flue gas analysis – carbon dioxide, oxygen, carbon monoxide, oxides of sulphur, oxides of nitrogen, combustion efficiency etc. The following energy monitoring/measuring equipment is needed to conduct energy audit in commercial sectors:

Table 37: Equipment's for Energy Audit

SN	Equipment's	Equipment's Image	To Measure
1.	Electrical Power logger (Three Phase)		Used to measure electrical parameters such as kVA, kW, PF, Hertz, kVAr, Amps and Volts, etc.
2.	Electrical Power Clam Meter		Used to measure electrical parameters such as kVA, kW, PF and Ampere.
3.	Ultrasonic Flow meter		This device is used to measure flow of fluid inside pipe
4.	Tachometer		Used to measure speed of motor

ANNEX C: PUBLICATION

Topic: Energy Consumption Analysis and Energy Saving Opportunities: A Case Study of Mahankalchaur Water Treatment Plant, Kathmandu, Nepal

Accepted on "International Journal of Engineering and Applied Sciences"

Acceptance mail is as:

Congratulations!!!

Your manuscript with Paper ID: **IJEAS0902001** has been Accepted for publication in IJEAS and only after receipt of duly formatted copy of final paper, the same shall be published in the IJEAS. Your Review Report is as follows:

Review Report	
Paper ID:	IJEAS0902001
Title of the Paper:	Energy Consumption Analysis and Energy Saving Opportunities: A Case Study of Mahankalchaur Water Treatment Plant, Kathmandu, Nepal
Accepted or Not:	Accepted