UNIVERSITY of RWANDA

COLLEGE OF SCIENCE AND TECHNOLOGY

AFRICAN CENTER OF EXCELLENCE IN ENERGY FOR SUSTAINABLE DEVELOPMENT

TITLE: FEASIBILITY STUDY OF USING GEOTHERMAL HEAT PUMP FOR COOLING AND HEATING IN RWANDA

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A dissertation submitted to the African Center of Excellence in Energy for Sustainable development

College of Science and Technology

University of Rwanda in partial fulfillment of the requirements for the degree of

MASTERS OF SCIENCE IN RENEWABLE ENERGY

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Month and Year of submission: **June, 2020**

DECLARATION

I, the undersigned, declare that this thesis is my original work and has not been presented for a degree in university of Rwanda or any other university. All sources of material that used for thesis work have been acknowledged.

CYUZUZO Pacifique

Date of Submission: 09th June 2021

DEDICATION

This thesis is dedicated to my beloved husband HABINSHUTI Leonard who has always been there for me, to my daughter HABINSHUTI Emily Gaelle and my extended family.

ACKNOWLEDGEMENT

Our joy is large to be able to express recognition towards all those who have contributed to the realization of our Master in Renewable Energy program that have been carried out within Africa Center of Excellence in Energy for Sustainable Development during the period from the October 2018 to October 2020.

Our thanks are addressed firstly to ACE-ESD management for the acquiring intellectual formation and the encouragement to carry this program. We thank the Head of the Department and all the lecturers to whom we profited much knowledge.

I am grateful to express recognition towards all those who have contributed to the realization of my studying journey. First and foremost, I am grateful to the God tremendous blessings and love that endure forever.

My deepest gratitude goes to Prof NTAGWIRUMUGARA Etienne, Dr. James NTAGANDA, Dr. KAYIBANDA Venant, Dr. JMV Bikorimana, Dr MULOLANI Francis, Dr MULUGETA Gebrehiwot and Mr. Aphrodis NDUWAMUNGU for their professional supervision, encouragement and guidance during my studies.

We address also our thanking to the authorities of University of Rwanda College of science and technology and all the personnel who facilitates us to make this Master of Science in Renewable Energy an excellence.

In particular, we thank the Ag. Director of Africa Center of excellence in Energy for Sustainability Development Dr. KABIRI Charles, without forget all the technicians and engineers who helped us throughout this Program.

My healthier gratitude also goes to my supervisor Dr. GACE Athanase Dalson for his invaluable kind guidance and support. Finally, but not least I grateful to Four Point by Sheraton Hotel team, Rwanda Nation Archive contractor team, CIMERWA factory team, NAS apartment team and Mr. MUGISHA Godfrey and all colleagues from ACEESD for different supports.

ABSTRACT

Geothermal heat pump technology uses underground heat sources for cooling and heating of buildings. As the number of house connected to national grid is expanding to meet the target of 100% by 2024 to ensure universal access to electricity, decreasing the amount of electricity wasted air conditioners and heating as well as appliances that will help occupants and businesses to save money on their utility bills is highly needed. This makes cooling more affordable for more people. However, the is little information on the use of GHP in Rwanda. Therefore, this work has conducted a feasibility study on using GHP for cooling and heating buildings in Rwanda. Both computation and field data correction (surveys) have been used respectively for data generation and data validation. Based on the result large buildings can benefit more than small building by using geothermal heat pump technology the comparison of energy saving and cost saving between AHP, GHP and GHP with upgrade generated with effect of size. It is worthwhile to note that this study was limited to Kigali City and Rusizi district, thus further researches need to be carried out to extend this feasibility study over the whole country and feasibility study of Hybrid Geothermal Heat Pump and solar thermal collector use.

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LIST OF ABBREVIATION

UR: University of Rwanda

ACE-ESD: Africa Center of Excellence in Energy Sustainable Development

GHP: Geothermal Heat Pump

AHP: Air source Heat Pump

EHP: Electrical air source Heat Pump

HVAC: Heating Ventilation and Air Conditioning

GWP: Global Warming Potential

BTP: Building Technology Program

EERE: Energy Efficiency and Renewable Energy

VCL: Vertical Closed Loop

HCL: Horizontal Closed loop

AHU: Air Handling Unit

FPBS: Four Point by Sheraton

RNA: Rwanda National Achieve

BTU: British Thermal Unit

CHAPTER 1. INTRODUCTION

1.1 Background

Geothermal energy refers to the internal heat of the earth, the earth acts as a giant solar collector, absorbing approximately 50% of the energy emitted by the sun. Heat pump moves energy from one location to another, instead of creating heat by burning fossil fuels, unlike a gas furnace in refrigeration. This geothermal heat pump uses the earth or water to provide heating, cooling and hot water for the building. It is safe to a comfortable building with all building service to ensure wellness of user's hot water and cooling is one of the major services to be offered within the region. Most of these service use electrical power and with possibility of using geothermal heat pump it can offer better solution. However, in Rwanda the geothermal heat pump is not commonly used leading to lack/shortage of heating and cooling in most building. Geothermal heat pumps are an environmentally friendly and cost effective way to heat up a residential or commercial building. This device heats buildings by transferring heat from within the Earth. In this system, tubing is installed into the ground so that the refrigerant within may extract heat from the Earth and transfer that energy to a building through thermodynamics. Geothermal heat pumps take advantage of the constant temperature found below the surface of the Earth. This heating method is safe. There is no combustion involved, no emission of potentially dangerous gases, and no use of dangerous chemicals. A geothermal heat pump is an environmentally approachable alternative to non-renewable energy. A problem that occurs with geothermal heat pumps is the time and energy required to repair leakage in the tubing. When the tubing has a leak, the land has to be excavated to find the source of the leakage. This is an expensive time intense process for a modest maintenance repair. The Geothermal heat pump should be able to connect to other elements in case a building needs multiple units to produce enough heat to deep itself.it should be able to climb inside the system and contact the pipes in case of leakage. This design can be advertised toward residential building and commercial building because it will have the advantages of both the horizontal closed loop system and vertical closed loop system. Geothermal heat pumps are capable of heating and cooling building. The capacity of heat produced by a heat pump is measured. One ton of capacity is 12000BTU per hour. A Residential building can uses approximating three to five tons of heat capacity and two tons cooling [1]. The refrigerant first starts in the compressor where grind is more to the fluid, the refrigerant then transfers to the condenser where heat is cast off into a heat reservoir. Starting the condenser, the refrigerant passes through the expansion valve which lastly into an evaporator where heat is in use from the cold reservoir. The reservoirs are inside the house and under the ground. The seasons determine which reservoir is inside and which is underneath ground. For instance, through the summer, the heat reservoir is subversive and the cold reservoir is esoteric. This means that the refrigerant landfills heat into the ground at the condenser and elites up heat inside at the evaporator.

1.2 Problem Statements

The national cooling strategy developing and deploying technologies that can substantially reduce energy consumption in residential and commercial buildings [2]. In Rwanda, power generation is growing but also the infrastructures are growing day to day, the low consumption of electricity shall be promoted for more expansion. Building services that is electrified is one of major systems that consume the electricity, within Services that used earth heat sources the electricity bill can fall up to large. But this is not yet well known and applicable within the region. Certainly a feasibility study is needed to obtain more data on the matter. This feasibility study intended to assess the possibility of using this technology for saving power for buildings in Rwanda.

1.3 Objective

1.3.1 Main objective

The main purpose of this study is to examine if the use of the use of Geothermal Heat Pump Technology can trim down the electricity bill in Rwanda.

1.3.2 Specific objectives

This system, as it can work in several places below is the objective to be tackled Specific objectives are:

- Compare power consumption of Geothermal Heat Pump & Air Source Heat Pumps for Air Conditioning System.
- To examine the adequacy of GHP Technology in Rwanda as it requires the land for underground piping which have to be accessed in Case of Maintenance.
- Analysis of energy consumption for large and small building for its building services
- Analysis of cost for large and small building that used in building services.

1.4 Scope of the study

This study has been carried in three district of Rwanda which are Nyarugenge, Gasabo, Rubavu and Rusizi by taking different infrastructure including hotel, apartment, residential building, offices and industry for assessing feasibility.

1.5 Expected outcomes

Having tables that compare power efficiency of GHP Technology & AHP technology for Air Conditioning with Energy consumption saving rate and Cost saving and estimate how much energy one can save as the size of the building varies.

1.6. Significant of the study

Having a clear image on Application of GHP technology for saving energy and recommendation of system in building engineering service in buildings that ensure the users to be safe and comfortable at low cost and the feasibility of implementation within buildings in Rwanda Building.

1.7 Thesis outline

Apart from the first chapter that is the introduction, the thesis has four chapters: Chapter 2 presents the literature review of related research to the current study. Chapter 3 presents the methodology used for conducted successfully the research. Chapter 4 presents and analyses data. Chapter 5 gives conclusions and recommendations.

CHAPTER 2: LITTERATURE REVIEW

2.1 Introduction

Geothermal technology has the objective of finding alternative energy sources, GHP is expected to become a large part of the HVAC industry. Geothermal Heat Pumps are used to transfer heat from the ground to heat and cool buildings. In its most basic features, it consists of a thermal source in the earth or a pond a heat pump mostly located inside the building, the thermal productivity system to cool or heat the building space as well as heat water. During heating GHP pulls heat from the earth and transfers this heat to the indoor air conditioning equipment or water, during cooling mode GHP pulls heat from the indoor air and rejects the heat into the ground. Below figure shows the system elements [3].

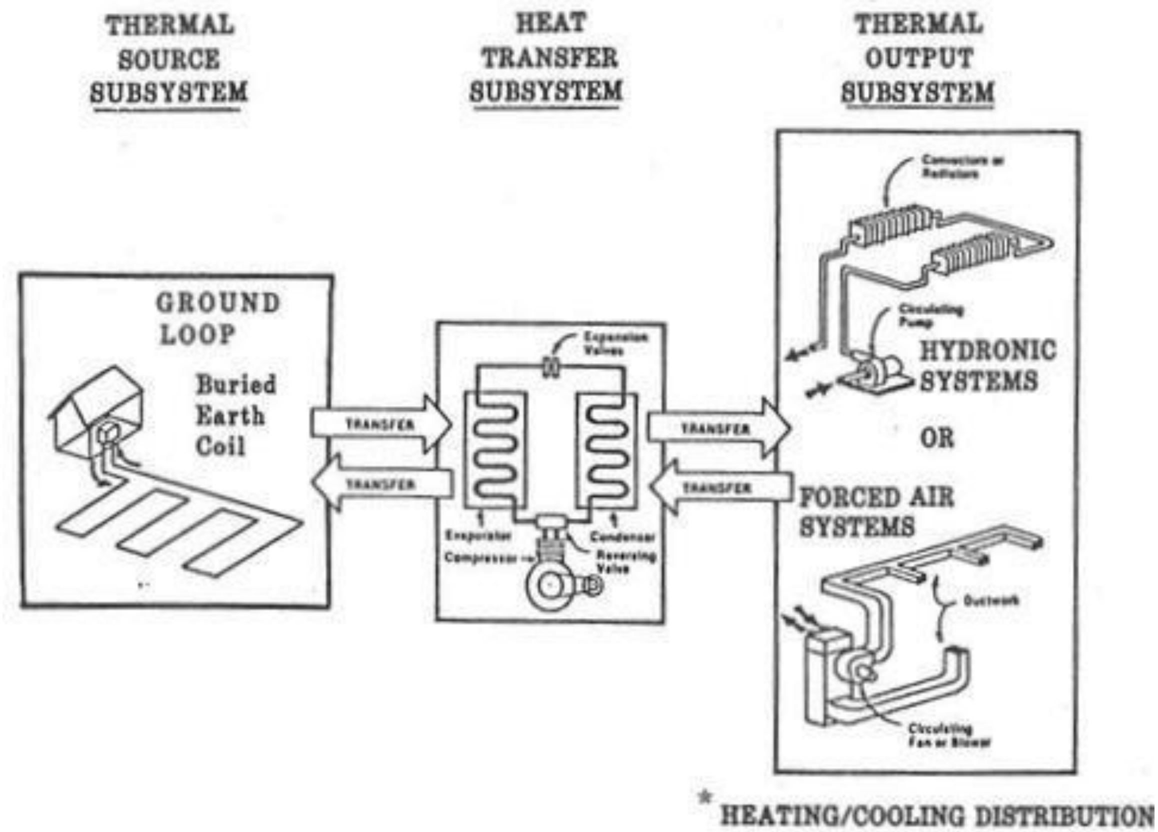

Figure 1: Geothermal system's element [1]

Once the Geothermal Heat Pump is functioning , the evaporator sources thermal energy from the ground loop that is buried in earth coil as the Figure 1 indicate . Cold refrigerant in a which is mostly liquid enters the evaporator. Extracted thermal energy from the ground get transferred to the cold refrigerant and for that reason the refrigerant evaporates and come to be a low-pressure vapor. The compressor collects vaporized refrigerant and as a result, grow its pressure and temperature once the vapor leaves the compressor, in that case temperature becomes more than the temperature of the ambient air. After exit the compressor, high temperature vapor drives into the condenser. Due to that, its temperature exceeds that of building's environment inducing, the heat removals from the condenser to the building. Because of this heat transfer, the hot refrigerant condenses into a high-temperature and high-pressure liquid. High-temperature liquid travels through an expansion valve which effects in reduction of pressure and temperature. The cold refrigerant enters the evaporator to start the cycle another time. For the duration of the cooling period, the route of the fluid's flow reverses, and consequently the direction of heat transfer. This implies that heat is removed from the conditioned space and is rejected into the ground. Desuperheater is another element that can be set up in some systems to be used for heating the water. This heat exchanger transfers thermal energy from hot vapor to a water tank to reduce or even reduce the required energy[4].

The working principle of refrigerant in a geothermal system by taking reference to
Figure *2* is different than in Air source heat pumps system. The normal heat pump has more than one type of refrigerant such: a chemical mixture called R-410A that replaced the older R-22 and the current chemical mixture have R32 which have an efficient Global warming potential. A geothermal heat pump (GHP) is a central heating and cooling system that transfers heat to or from the ground. these systems use a heat pump to strength the transfer of heat from the ground [5].

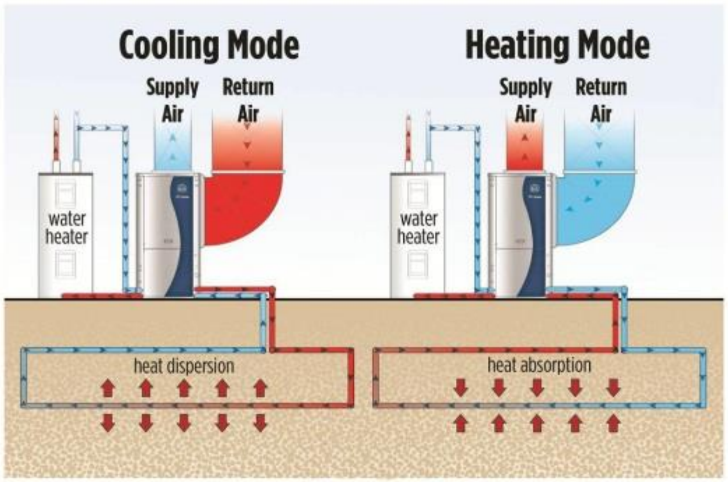

Figure 2: Geothermal Reticulation [6]

2.2 Related geothermal question

2.2.1 What does a geothermal heat pump system comprise of?

Commonly the geothermal heat pump has two major parts which are: The handling system that capture the fan and ductwork and distributes air in the spaces that intended to be heated or cooled. The ground water heat exchanger that captivates heat from the earth and discharges heat to the earth[7].

2.2.2 What is the variance between a geothermal power plant and a geothermal heat pump?

Geothermal power plants produce electricity by obliging hot steam from the earth's interior through a turbine. This power can be used to heat and cool homes. In the interim, geothermal heat pumps flow the fluid through underground pipes, where they captivate heat[8].

2.2.3 Just how Is Geothermal Energy Produced?

Geothermal power plants produce electricity by driving hot steam from the earth’s interior through a turbine. This electricity can be used to heat, power and cool Building, Geothermal heat pumps flow fluid through underground pipes, where they absorb heat. This heat is then take out, compacted, and distributed throughout the building using its existing ductwork, warming up it to whatever temperature. This funds that heat pumps are much more up-front solutions for residential cooling and heating, the power plants have to produce electricity initial before they can offer electric heat, but heat pumps could circulate immediately heat[7].

2.2.4 What is the best location to install a Geothermal System?

As the trivial ground temperatures from which geothermal energy is taken are moderately persistent, geothermal heating systems can be used almost universally. Even if, the features of the land adopt which systems might be more advantageous, and needs to be firm by your provider and installer.

Features that influence the variety of geothermal system to fit[9]:

A. Geology

Alignment and possessions of soil and rock can touch heat transfer amounts and consequently need to be taken into consideration for designing an adequate geothermal system[6].

B. Hydrology

Ground and surface water impact the type of ground loop that may be used, as well as groundwater can be used as an of the proper source for open-loop system, if the water superiority is sufficient.

C.Land Availability

The dimension and plan of the land and location of sprinkler systems can regulate the design of the geothermal system as well for the proper sizing and production of your building.

2.3. Operation for Geothermal Heat pump

Geothermal heat pumps involve four circuits as demonstrated in Figure 3 which are Refrigerant circuit, Distribution circuit, Hot Water circuit and ground loop circuit. The ground heat exchanger in a geothermal heat pump system exists made by a closed or open loop channel system. Most communal is the closed loop, in which high density polyethylene (HDPE) pipe is submerged horizontally at 4 to 6 feet deep or vertically at 100 to 400 feet deep. Geothermal heat pumps work by drum beat into the renewable solar energy kept in the ground to provide savings of up to 80% on heating and cooling costs[1]. While it operates in the same way to a standard heat pump, a geothermal heat pump contacts heat with the earth as a replacement of the outdoor air. Geothermal heating practices heat straight from the earth's core, such as hot coils, spouts and volcanic hot plugs. Ground source heat pumps captivate the sun's energy deposited in fairly shallow ground and upgrading this for use in residential and commercial building.

2.3.1 Distribution circuit

The system that allocates the conditioned water or air solution all through the building and outlays it to the component.

2.3.2 Refrigerant circuit

A wrapped and pressurized circuit of refrigerant counting compressor, expansion valve, water-to-refrigerant heat exchanger, air coil and retrogressive valve. With the efficiency if global warming potential the bet refrigerant can be either R32 or R 410.

2.3.3 Ground loop circuit

The piping system concealed in the ground has fluid that is distributed by pumps from the geothermal unit.

2.3.4 Hot water circuit

Water may be heated in a geothermal unit with a device named a desuperheater. A piping connection is through from geothermal unit to the geothermal heat pump. Most of these circuits is closed and wrapped from further there is no straight mixing. Conversely, heat energy does transferal from refrigeration circuit to other three circuits. The refrigerant flow will variate direction once the unit alterations modes of heating or cooling [10].

Circuits in a Geothermal Heat Pump

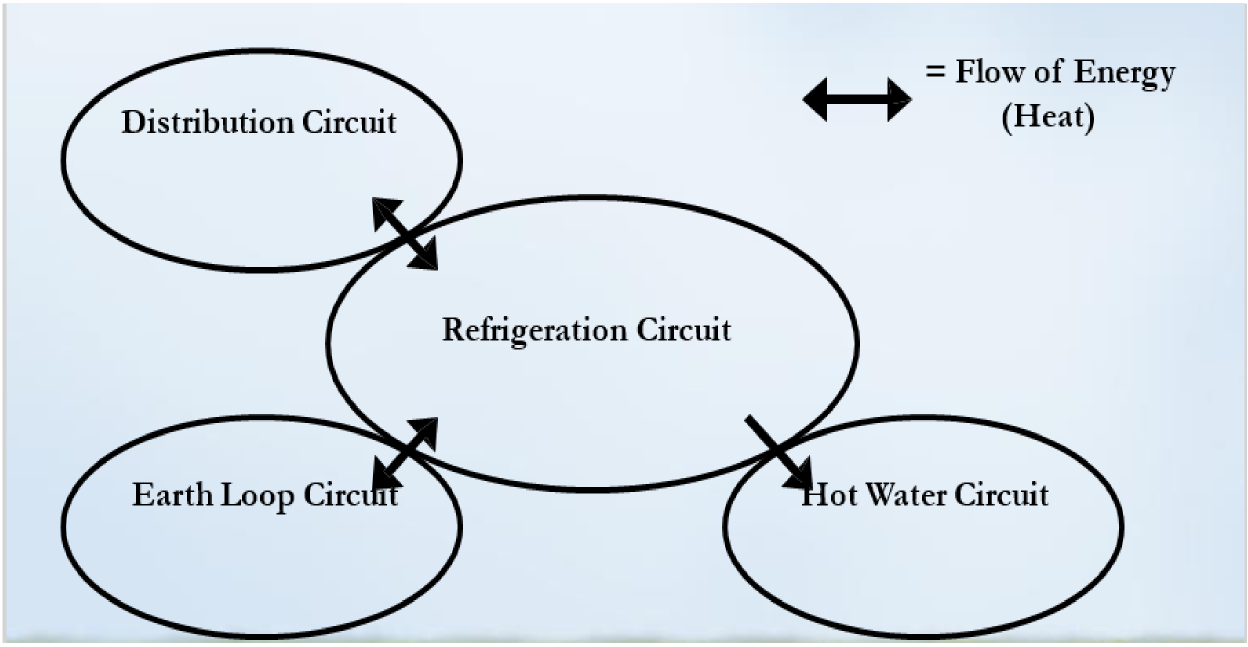

Figure 3: Circuit in a geothermal heat Pump[6]

2.4 Types of Heat Exchanger

In direction for the exchanger to change the refrigerant into the used a gas, it wants a heat source. There are two different kinds of heat sources which form two different heat pumps. There are more to one types of heat pumps which are ground source and air source heat pumps that use electrical. As the name suggests, the difference amongst the two pumps is whether the heat is reached from the ground or the air. There is only one type of air source heat pump, then again multiple ground source heat pumps. These different ground source heat pumps vary in the formation of pipes that are used as a heat exchanger to remove heat from the ground. There are two kinds of geothermal heat pumps[11]. These are the closed and the open loop systems. These two types of geothermal heat pumps mention on how the heat exchangers are located in the ground. Closed loop systems refer to a geothermal heat pump system that use contained fluid within the heat pump to source heat from the ground. Open loop systems use water that is sourced in the well as a running fluid. Even if there only one type of open loop system, but there are three for closed loop systems.

2.4.1 Horizontal Closed Loop (HCL)

Horizontal closed-loops ,Figure 4, is one of the common closed loop system in ground heat source the pipes are laid horizontally to captivate heat from the ground as seen in figure 4. This system is typically used in residential building because it is more cost competent for installation, particularly for new construction where enough land is available. Horizontal Closed Loop pipes are buried straight o in smaller areas [12].

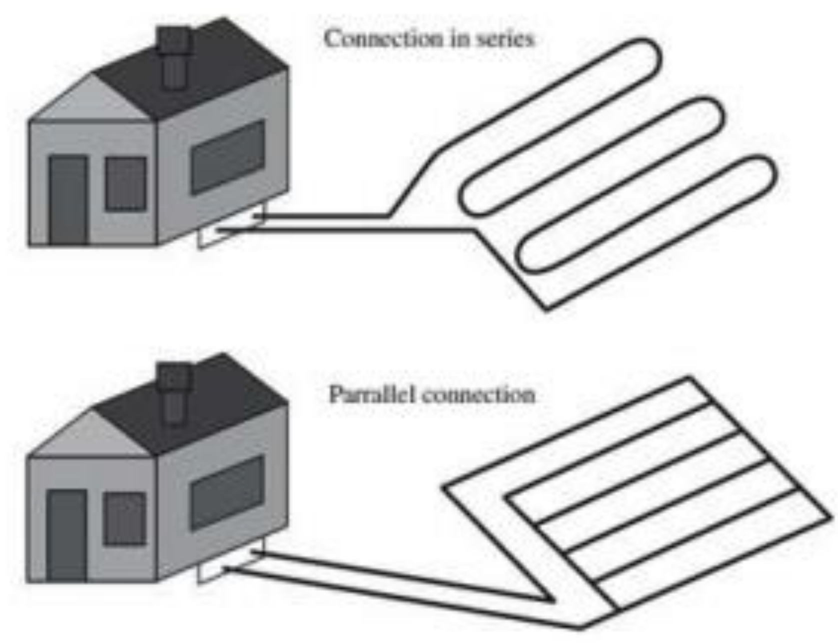

Figure 4: Horizontal Closed loop system[3]

So far we count three types of horizontal closed loops. Which are the extended slinky coil, overlapping slinky and straight type. They only different in how the ground heat exchangers are positioned in the underneath. The HCL with a straight pipe is when the pipe is reposed in the ground to the end of the trench and carried back to form a single closed loop for reticulation. The Horizontal closed loop system with an extended slinky coil as shows in Figure 5 come once a pipe forms slinky coils anywhere the loops don’t touch each other. The Horizontal Closed Loop with an overlapping slinky coil as shown in Figure 6 is the same as the with extended slinky coils, but it differs to the loops that overlapping each other.

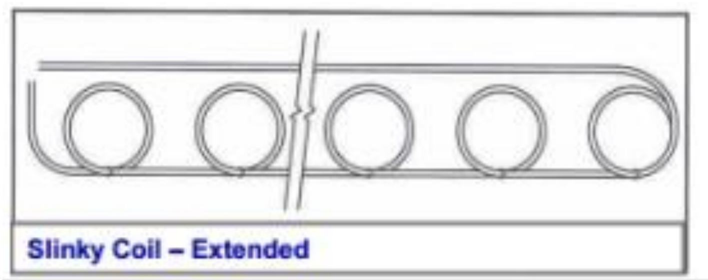

Figure 5: Slinky coil extended type[13]

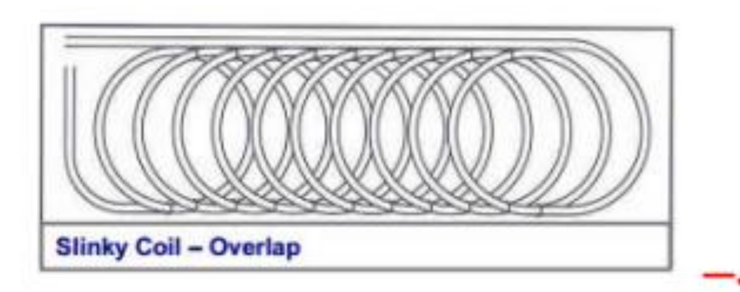

Figure 6: Slinky coiled overlap type[13]

2.4.2 Vertical Closed Loop

Vertical closed-loops with Figure 7 use the pipes that are placed in vertical holes frequently because there is no large land area to do horizontal closed loop system. With vertical closed loop there are two pipes which form a U-bend loop joining at the bottom of holes that are excavated several hundred centimeters down below the surface, this is usually used in large commercial buildings for the reason that the land area for horizontal loops can expensive.

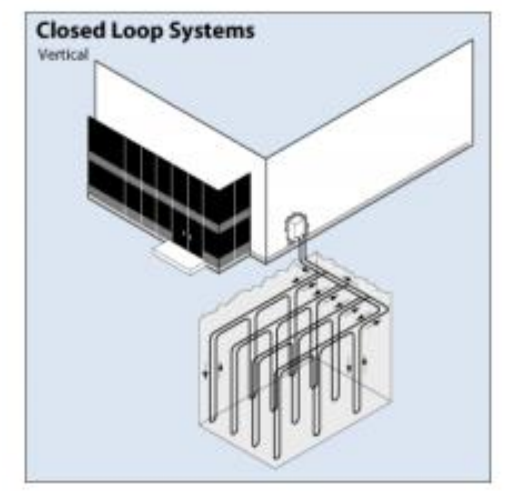

Figure 7: Vertical Closed loop system [3]

2.4.3 Lake and Pond Closed Loop

Closed loops in lake or pond are the cheapest choice of the three closed-loops systems. If there is a possibility near the Building, the pipes know how to be coiled and placed at the bottom of the lake or Ponds as seen in Figure 8. This method works the same as the other closed systems with only difference being that the closed loops removal the heat from the pond as well as the Earth to the building.13

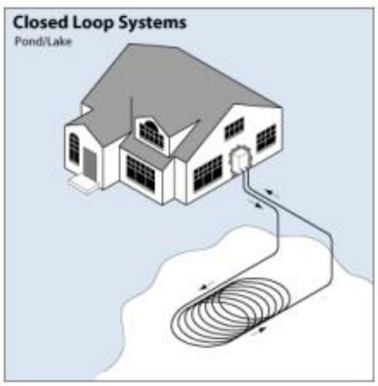

Figure 8: Pond Closed loop system[2]

2.5. Reticulation Component

2.5.1 Outdoor Components

Closed-loop heat pumps are also known as ground-coupled heat pumps, are the most mutual system type. With the system, the refrigerant within the indoor heat pump transfer heat to and from a dilute water and glycol mix within an outdoor ground heat exchanger via a liquid-to-liquid heat exchanger. The ground heat exchanger loop ii commonly pipes that use high-density polyethylene (HDPE). The heat pump controller works one or more pumps to circulate the water/glycol solution throughout the geothermal heat exchanger as necessary to come across the heating or cooling load. The glycol in the solution acts as an antifreeze to prevent the water that is in the system from freezing.

A. Air Handling Unit

An AHU is a solution that can control all air features in a large space especially in hospitals. With the unit kit both return air and supply air control connected to the coil of the handling unit, Variable Refrigerant Flow system can be applied to deliver clean conditioned air as per the reticulation in Figure 9.

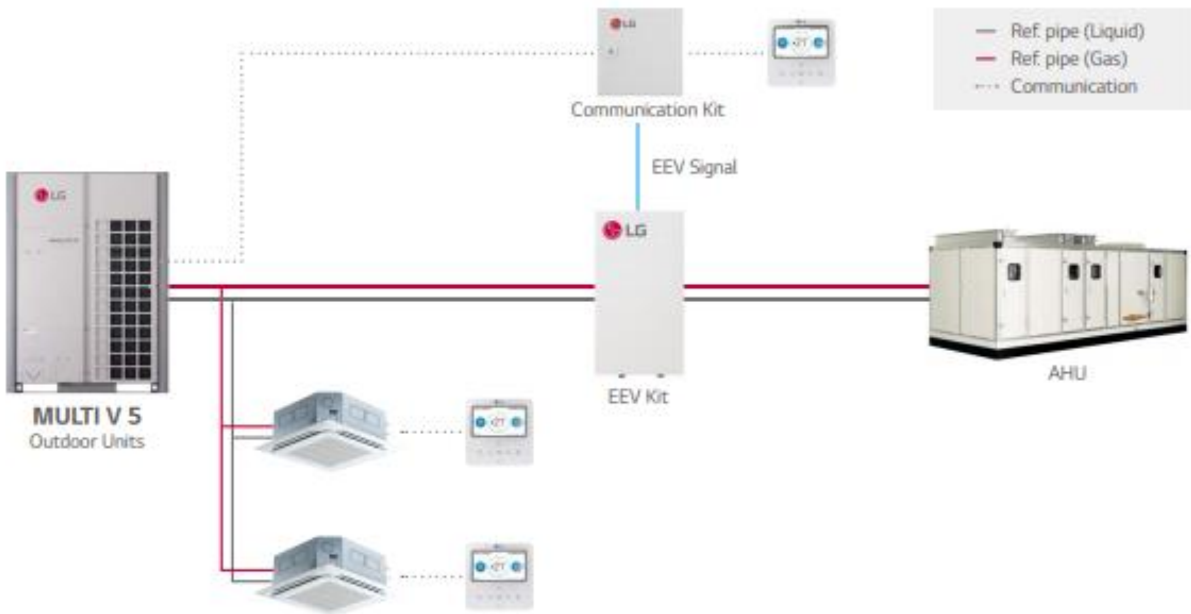

Figure 9: Air Handling Unit Reticulation [14]

B. Combined System

The Combined system as shown in Figure 10 is the mixed system for Cooling and heating place and Hot water supply by integrated a hydro kit that take the return air and use for heating water that save more energy with the building especially in Apartment and residential building .

Figure 10: Combined system reticulation[15]

C. Multi Split System

The multi split system is the mixed system for cooling and heating place that use one outdoor unit that Source the air in the place to be conditioned and supply to Multiple to 100 indoor units. As per Figure 11 the indoor unit can differ based on the preference of users

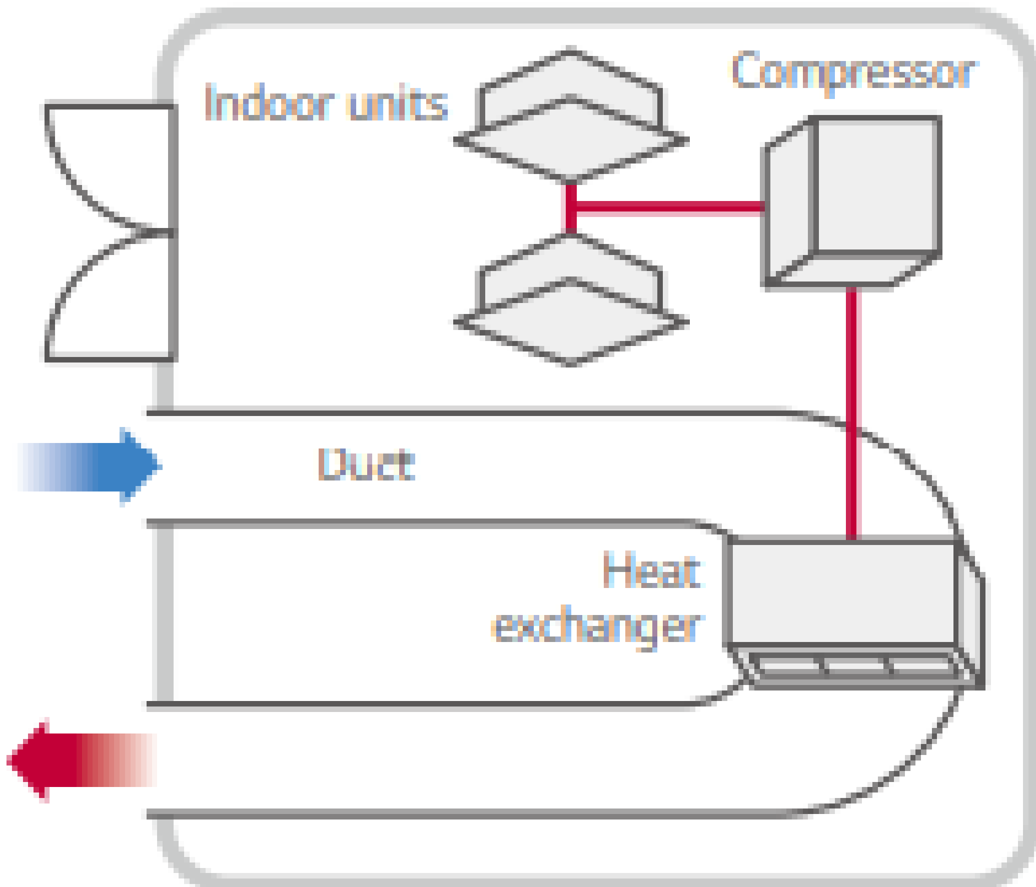

Figure 11: Multi split system reticulation [14]

2.5.2 Indoor Components

The usual thermal output system in a residential application handovers heat to either a forced air heating and cooling system, or the hydronic system for radiant floor heating mechanism, pool heating, or domestic water heating. A typical residential system has a 36,000 Btu/hr. Thermal capacity; however, manufacturers build product lines ranging from 1.5 to 6 tons to serve a variety Residential houses.

A. Wall Mounted Indoor Types

It is mounted indoor unit as presented on Figure 12 it mostly have wall with different discharge angles that can be programmed by using the remote control. • They are easily detectable to mention the space that have to be conditioned with clean air. drain pipe can be hidden from sight. Four way swing cool air reaches out to the entire room irrespective of where the machine is installed. The dominant ionizer protects from bad odors and harmful and contagious particles in the air with over millions ions to sterilize not only the air passing through them machine, but also surrounding surfaces to be safer, and cleaner environment. The interior of the indoor unit is maintained clean by drying off the heat exchanger, then sterilizing the interior once more the indoor temperature can be checked using the thermistors in the remote controller as well as from the indoor unit. There may be a significant difference between ceiling and floor air temperature. Two thermistors can boost indoor air temperature for a more comfortable environment.

Figure 12: Wall mounted Indoor Type[16]

B. Ceiling Cassette Indoor Types

This is a ceiling mounted type as mentioned in Figure 13 may different ways based on the air demand pipes are brought together in one place to minimize exposure. hanger covers hide installations to add a clean, sophisticated look. this indoor can only be installed on an open ceiling air flow direction is controlled automatically by motion sensor that detects the activity of people every 10 seconds. Human detection control allowing energy savings through saving operation & comfort through wind direction operation new multi-functional four-way cassette panel for large sizes with aesthetic shape the independent vane operation feature allows user to control vanes by desired and perceptible comfort flow.

Figure 13: Ceiling cassette indoor type[17]

C. Concealed Duct Indoor Types

The indoor temperature can be tested using the thermistors in the remote controller as well as from the indoor unit as per Figure 14. there may be a significant difference between ceiling and floor air temperature. two thermistors can optimize indoor air temperature for a more comfortable environment. The high static duct allows the air intake at the rear or bottom under installation condition. Air intake at the rear or bottom

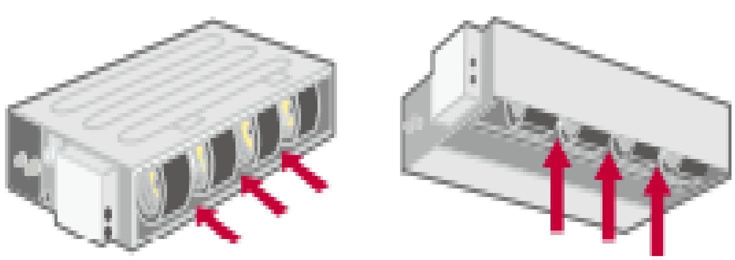

Figure 14: Concealed Indoor Type [11]

2.5.3. Compressor

Once the compressor is working going into a compressor once is cold gas with low pressure as per Figure 15. The compressor is responsible for boosting the pressure of the gas through density and maintaining the rate of the refrigerant flow in it. Different compressors types can be used for heat pumps. a modern variation that is being increasingly used is the scroll compressor.

Figure 15. Scroll compressor unit[1]

The halves of Scroll compressor as per Figure 16 are the main component that boost the pressure for working with time that lead to the maximization of high energy efficiency . As shown in the Figure 17 the gas into into the compressor it open the sealed off the gas compressed discharged pressure reached at center port and continuous suction and discharge take place .

Figure 16. Two halves of a scroll compressor[15]

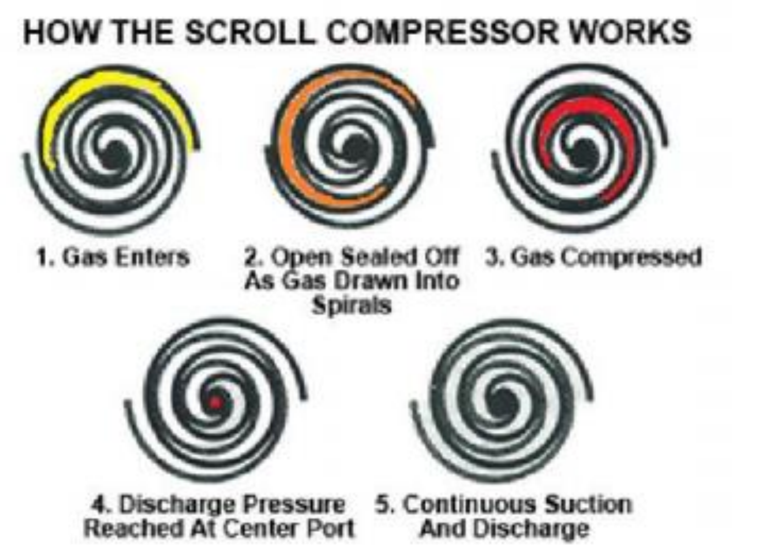

Figure 17. Scroll compressor process[9]

2.5.4 Expansion Valve

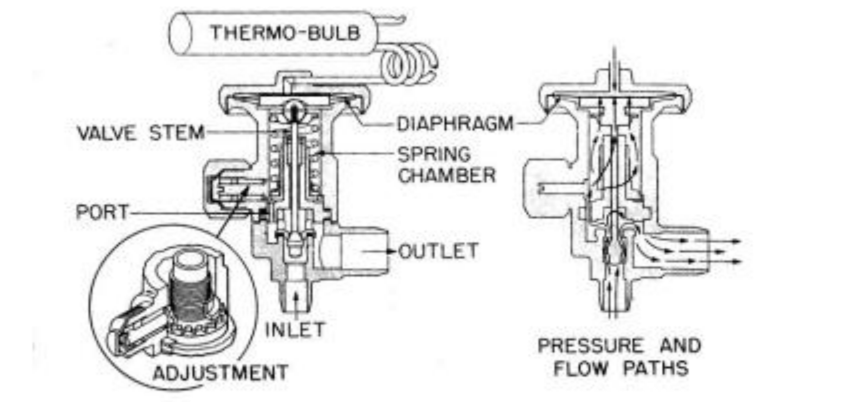

Figure 18. Thermostatic expansion valve[2]

In the expansion valve as Presented in Figure 18 the refrigerant pass into the expansion valve as a cool liquid within high pressure and deliver a cold liquid gas mixture at low pressure. An expansion valve regulates the pressure of the liquid refrigerant going into the evaporator. There is a sensor at the end of the evaporator to observer the temperature of that. There is a needle in the expansion valve that adjusts the flow of refrigerant passes through the valve based off the temperature at the termination of the evaporator.

2.5.5 Vapor-Compression Cycle

The Vapor-Compression Cycle shown in Figure 19 include all the typical expansion for the system. This cycle labels the flow and cycle of the working fluid inside a heat pump. The cycle starts at the departure of the evaporator and the intake of the compressor and moves counterclockwise until it goes back to the intake of the compressor again. The temperatures, pressures, and enthalpy used in this section are based on a rough calculation of average temperatures, enthalpy and pressure used for a heat pump. These quantities are subject to change based off of multiple variables including, but not limited to soil kind, size of building as well as location.

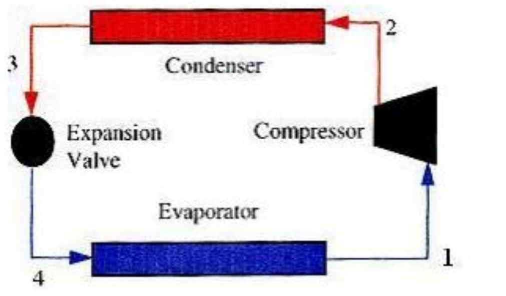

Figure 19. Vapor compression cycle

Table 1. Status of vapor compression cycle

1-2 Compression	2-3 Condenser	3-4 Expansion Valve	4-1 Evaporator
• Constant Entropy • Adiabatic (q≈0) • Pressure increase • Temperature increase	• No pressure change • Phase change • Vapor to liquid	• Constant Entropy • Adiabatic (q≈0) • Pressure drop • Temperature drop	• No pressure change • Phase change • liquid to Vapor

2.6 Advantages and Disadvantages of Geothermal Energy

Geothermal energy is now believed to be one of the most beneficial sources of energy. Not because is it a renewable source of energy but is also present in greatest areas, overtaking even some conventional sources in numerous aspects. is even bearing in mind a construction of the longest power connector of the world, which would deliver more renewable energy to building that do not have

Geothermal energy has many advantages, particularly when compared to conventional sources of energy in the world:

1. Geothermal energy tracing is good for the Environment as geothermal energy is take out from the earth without burning fossil fuels and geothermal fields produce practically no radiations.

2. Geothermal Is a Trustworthy Source of Renewable Energy Geothermal energy also has many advantages when compared to other renewable sources like wind, solar or biomass. It is an exceptionally

constant source of energy.

3. High Efficiency of Geothermal Systems

Geothermal heat pump systems use less electricity than conventional systems for heating or cooling, and with their flexible design they can be adjusted to different positions, requiring less space for hardware equipment.

4. The life span of geothermal heat pump is long as presented in Figure 20 is the highest reliable source compared to Solar ,wind and biomass as highlighted the availabity factor is advanced .

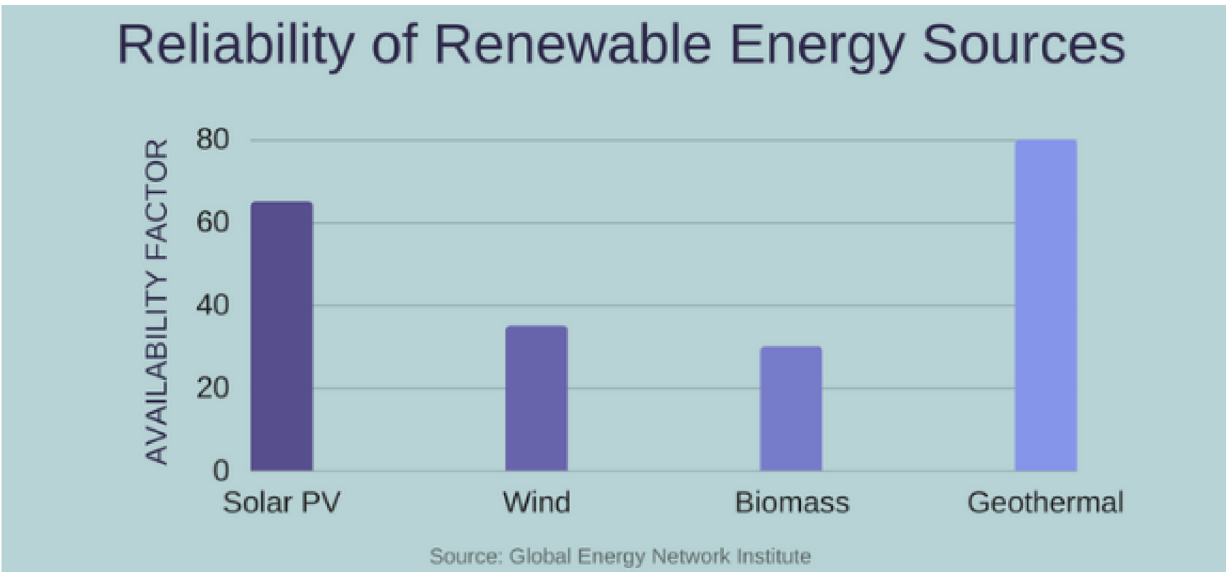

Figure 20. Reliability of renewable energy sources[11]

Disadvantages of Geothermal Energy

However, there are always two sides of the coin so let's have a look at the cons of geothermal energy:

1. Environmental Concerns about Greenhouse Emissions even if, the amount of gas released is considerably lower than in the case of fossil fuels.

2. High Investment Costs for Geothermal System as the return on such investment is very promising, being able to earn the investment back within 1 to 10 years.

4. Land Requirements for Geothermal System to Be Installed. That makes geothermal systems rigid to be implemented for landholders in big cities as shown in Figure 21 it is not enough to purchase the geothermal heat pump you have to have a land and if the land is not big enough vertical ground source heat pump might be the best option for the users [11].

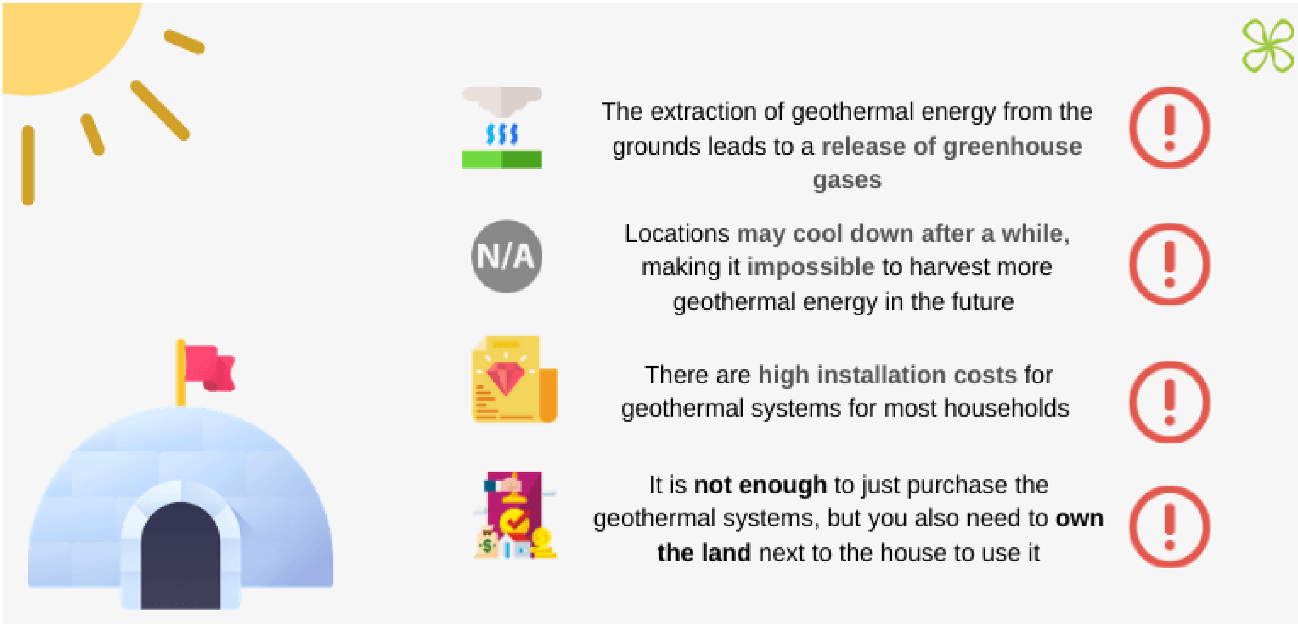

Figure 21. Land requirements[11]

2.7 Geothermal Energy System Cost

After all this evidence on the advantage and disadvantage of geothermal energy, the main question remains: how much do you really have to invest in order to get your own geothermal system up and running in your building?

As we have determined in one of o posts a geothermal ground source heat pump can cost from $13,000 to $20,000, whereas an air source heat pump hovers around $7,000-$11,000.

Below is an estimate numbers on geothermal installation for a 100m² house:

Even though geothermal systems are higher compared to other heating or cooling systems, they have Very lower operating costs and deliver extra energy per unit.

100 m² house	
Average Lifetime	18-23 Years
Payback Time	10Years
Average Installation Cost	1,500,000
Energy Bill Reduction	40%-80%

2.8 Cooling &Heating Technology

2.8.1 Geothermal heat pump Technology

System aimed at Geothermal as presented in Figure 22 uses underground heat sources such as soil, ground water, lake, river as renewable energy for cooling and heating of a building. water or antifreeze solution is circulated from end to end the closed or Open loop in High Density Poly-Ethylene pipes buried beneath the earth's surface. It is a highly efficient and eco-friendly system. The Circulating water temperature range is between -5°C ~ 45°C - Antifreeze should be applied depending on the application.

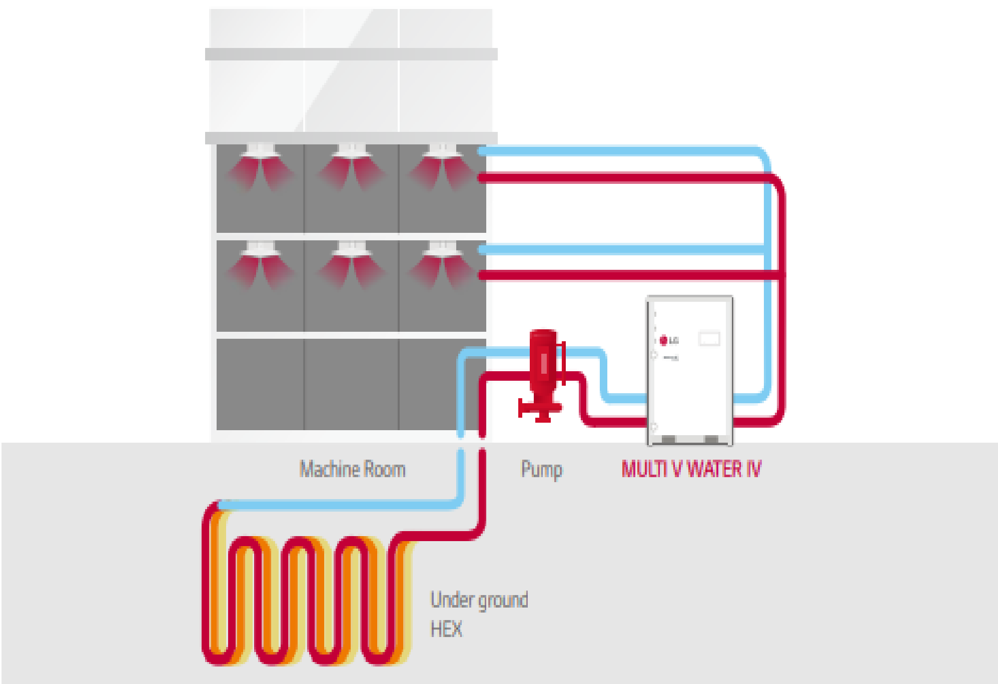

Figure 22: Geothermal technology reticulation[4]

2.8.2 Chiller System Technology

The main chiller components are the Compressor, Condenser, Evaporator, Expansion Valve, Power Panel, Controls unit and the Water Box. Generally, the chiller cools the cold water storage, which, in turn, provides the space cooling to the building. The chiller can be directly connected to the building in the case that the temperature of the cold storage is too high to cool the building, but the chiller can operate with heat from the hot storage.

2.8.3 Air Source System Technology

Air source heat pump move heat than generate heat, heat pumps can provide equivalent space conditioning at operating conventional heating or cooling appliances. An air-source heat pump can provide competent heating and cooling. When properly installed, an air-source heat pump can deliver one-and-a-half to three times more heat energy to a home than the electrical energy it consumes. This is possible because a heat pump moves heat rather than converting it from a fuel like combustion heating systems do. Air-source heat pumps have been used for many years in nearly all parts of the United States, but until recently they have not been used in areas that experienced extended periods of subfreezing temperatures. However, in recent years, air-source heat pump technology has advanced so that it now offers a legitimate space heating alternative in colder regions.

2.9 Criteria for Selection Distribution Equipment

2.9.1 Ocean black fin heat exchanger

Ocean Black Fin" heat exchanger is specially designed for durable and long-lasting performance even in corrosive environments. The black coating is applied for protection from various corrosive external conditions and the hydrophilic film keeps water from accumulating on the heat exchanger’s fin, minimizing moisture buildup. This improvement in durability prolongs the product’s lifespan and lowers both the operational and maintenance costs.

2.9.2 Dual sensing control

The cooling load is based on the amount of both sensible heat load and latent heat load. Most importantly, the cooling load is keen to, and thus, greatly affected by external humidity, rather than the outdoor temperature. For this reason, Dual Sensing Control applied function senses both temperature and humidity and applies sensed data for load control in order to obtain in-depth understanding of sensible heat load and latent heat load. This helps preventing excessive cooling load supply and offers the most pleasant and comfortable cooling environment the users want combined with reduction in energy consumption.

2.9.3 Biomimetic technology fan

Enhanced core parts like biomimetic technology-based fans, 4-sided heat exchanger as opposed to 3-sided heat exchanger of previous model and compressor with increased efficiency and capacity allow large capacity for outdoor units. A single unit of can provide up to 26HP.

2.9.4 Ultimate inverter compressor

As the core technology of the air system the Ultimate Inverter Compressor boasts its ultimate efficiency and durability as shown in Figure 23 designed by taking into consideration on the technology and innovation of smart oil management compressor reliability and efficiency are improved with an oil sensor that allows oil balancing and oil return.

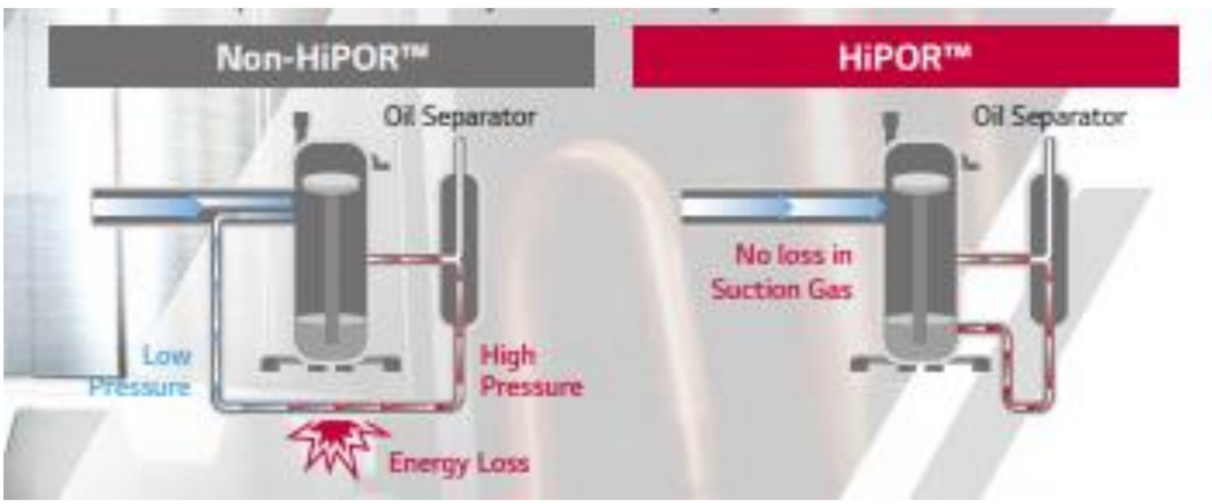

Figure 23: Ultimate inverter Compressor [9]

2.9.4 Continuous heating

Improved technologies such as Dual Sensing Control, Partial Defrost and Smart Oil Management enhance Continuous Heating for increased heating capacity and indoor comfort. The delayed and partial defrost technologies minimize unnecessary operational consumption to provide consistent heating. Efficient even in Low-Temperature, High-Humidity Environments

2.9.5 Auto dust removal

Enhanced Stability from Environmental Constraints This feature in removes dust on outdoor unit heat exchanger. The outdoor unit fan(s) rotate reversely to blow off the dust. Once the accumulated dust on the heat exchanger is removed, the fan(s) rotates normally and unit goes back to normal operation[15].

2.10. Summary on key literatures

As per the above characteristic of Geothermal Heat Pump and Air Source Heat Pump working principle and equipment to be coupled with the system and assure the improved performance this will be utilize to have the adequate underground loop based on the location to ensure once is either the horizontal loop or vertical which will give the estimated depth of underground heat to be trapped[3]. A review of the geothermal heating and cooling systems that marks geothermal energy distribution systems as well an overview of Geothermal Heat Pump with a discussion of ground heat exchangers will contribute to data collection and analysis for surveyed project. through usage of renewable and clean energy resources that is suitable alternative to supersede fossil fuels consumption for environmental pollution reduction for heating and cooling energy utilization in buildings both commercial and residential buildings[6].

Since the temperature in the ground is higher than the atmosphere's temperature, sometimes it is sufficient for heating or only preheating. Furthermore, put on and captivating advantage of heat pumps highly increases heat removal from the ground. Cooling in hot seasons takes place once underground temperature is cooler than temperature above the ground and the difference enables good use of it for cooling with the weather season. Again, heat pumps used in contrary manner (cooling manner) can enhance the efficiency and the temperature provided for cooling can be lowered this will help on temperature comparison by taking focus on the survey made. When cooling inserting heat into the ground, heat is exchanged from a cooling coil low-temperature medium to a refrigerant flowing in the Geothermal Heat Exchanger high-temperature medium. But, in heating seasons heat removal from the ground, heat is exchanged with a refrigerant flowing in the Geothermal Heat Exchanger low-temperature medium to a heating coil high-temperature medium this will give deep understanding on the best heat exchanger compared to the existing one with the Inverter Air Source Heat Pump[4].

By Comparing both systems an Air-Source Heat Pump brings outdoor air, which itself has a high temperature to exchange heat but a Geothermal Heat pump uses a ground temperature that has a lower temperature than outdoors air, so we are expecting the efficiency can depend on temperature difference. Most importantly, and once the installation increase with the region the operation and maintenance cost can fall down. Therefore, Greenhouse Gas emissions have decreased and the price of energy is highly reduced. Through this study all will be the basics to assess the feasibility study within the area with focus at Rwanda[9].

CHAPTER 3. METHODOLOGY

3.1 Method

This research will be based on data collection by using the questionnaire that have types of Indoor unit air conditioning with their power rating and the outdoor unit for their power consumption and record the total consumption. Within observation of land that can hold the technology of Geothermal Heat Pump we will ensure the feasibility of it for energy saving.

3.2 Procedure

I have to approach hotels, apartment, office, industrial plants with HVAC air conditioning system that have used with high energy efficiency ratio brand as their energy efficient ratio so far is lowest at Rwanda market and recording the power rating of mounted machine, I request the Daily Peak Occupancy so that the quantification of daily power consumption on a peak day will be estimated. Prior for Site selection I have to confirm that there is open space that can hold the underground pipe for GHP technology and through compilation and analysis of information we will have to manipulate and controls variables to determine effect**.** By filling the questionnaire of the power consumption and detection of underground temperature of location as well as take into consideration building size, operation and maintenance it will give an overview on the use of Geothermal Heat Pump for better cost.

3.3 Tools

This research will be use the questionnaire for data collection, the meter for land coverage and peer to peer information for land to provide the adequate comparative analysis that will be based on by computing the tables that hold the information of using the Geothermal Heat Pump technology and the use of Electrical Heat Pump Technology within Total Power Consumption all will be subjected to the reduction of 60% to 98% based on the Technology which is adequate for the area and location. The questionnaire below focuses on project with air conditioner that use inverter not the one with ON & OFF mode because are the one with average lower power consumption. The soil temperature sensor has been used to track the underground temperature and metrology data for region air. Based on the building size the GHP computational software have been used to assess various saving rate of building services and rated formula for the savings.

Table 2. Research questionnaire

UNIVERSITY OF RWANDA

ACE-ESD AFRICAN CENTER OF EXCELLENCE IN ENERGY FOR SUSTAINABLE DEVELOPMENT

FEASABILITY STUDY OF GEOTHERMAL HEAT PUMP USE FOR COOLING AND HEATING IN RWANDA.

QUESTIONNAIRE FOR HVAC CONSUMPTION		
	DATE:	
	I.E No.	
PROJECT:		
STRUCTURE:		
DRAWINGS:		

LOCATION	HVAC SYSTEM		QUANTITY	POWER RATING	TOTAL POWER CONSUMPTON
PUBLIC AREAS	SINGLE INVERTER	CEILING CASSETTE			
		CEILING CONCEILED DUCT			
		CEILING SUSPENDED			
		FLOOR STANDING			
		SINGLE PACKAGE			
	MULTI INVERTER	MULTI PIPING TYPE			
		DB BOX TYPE			
		WALL MOUNTED TYPE			
	OUTDOOR UNIT	FLOOR MOUNTED			
		WALL HUNG			
ROOMS	INDOORS	CEILIND CASSETTE			
		LOW STATIC CCD			
		MIDDLE STATIC CCD			
		CEILING SUSPENDED CCD			

Date of closure : ……………………………………………………………

CHAPTER 4: RESULTS AND DISCUSSION

4.1 Data Collection

These data have been collected in three district which are: Nyarugenge, Gasabo, Rubavu and Rusizi it carried in four types building that include hotels, apartment, industry and residential Building all with LG air conditioning facility with Energy Efficient Ratio for 3.335 EER.it have been selected as the brand to be used as is the one with high energy efficiency compared with various with brand which is almost five on the current market.

4.1.1 Four Point by Sheraton Hotel

Sheraton Hotel is a five-star hotel with 158 Bedroom and public area that covers three floors it has all types for Indoor unit as it has kitchen, meeting rooms, offices, dining and lounges area as well as building services on a peak day once the hotel is full in hot season their consumption will go up to 827.7364 Kw. By having the having the external current space that is within compound the vertical loop can be efficient to manage the land area. The survey held on hot spring season with the Temperature of 26deg C and with use of digits' thermometer in 1.856 m sensor 22deg C once we take into consideration the cooling target to 18 deg C by using rated formula this lead to 80Percent saving.

4.1.2 MUGISHA Residential house

This house is located at Kacyiru it has Three Bedroom within Dining and Living room that have Air conditioning with inverter mode, all the Indoor unit are the concealed duct types on the peak day when building is fully occupied in hot season the power consumption can goes up to 39.4259 Kw. By having the having the external current space that is within compound the Horizantal loop can be efficient to manage the land area The the survey held on hot spring season with the Temperature of 26deg C and with use of digits' thermometer in 1.4 m sensor 22deg C once we take into consideration the cooling target to 18 deg C by using rated formula this lead to 80Percent saving

4.1.3 Rwanda National Archive Building

This Building has a centralized air Conditioner that holds one type of compact ceiling cassette unit with the outdoor unit. On a peak day with full occupancy the power consumption goes up to 200.564 Kw. By having the having the external current space that is within compound the vertical loop can be efficient to manage the land area. The survey held on hot spring season with the Temperature of 26deg C and with use of digits' thermometer in 1.78 m sensor 22deg C once we take into consideration the cooling target to 18 deg C by using rated formula this lead to 80Percent saving.

4.1.4 NAS Apartment

This apartment covers five floors with 24 Unit that have the ceiling suspended concealed duct unit in total for 53 units and outdoor unit per each wing. On the Peak day once is full occupied the power consumption goes up to 127.951 Kw. By having the having the external current space that is within compound the vertical loop can be efficient to manage the land area. By having the having the external current space that is within compound the vertical loop can be effective to manage the land area. The survey held on hot spring season with the Temperature of 26deg C and with use of digits’ thermometer in 1.92m sensor 22deg C once we take into consideration the cooling target to 18 deg C by using rated formula this lead to 80Percent saving

4.1.5 CIMERWA Factory

This factory is located at Rusizi it system covers all offices and services centers it have wall mounted indoor unit that have the rated power rating for 1.8 Kw and their power consumption goes up to on a peak day 290.644Kw. By having the having the external current space that is within compound the both pond loop and vertical loop can be competent to manage the land area. The survey held on hot spring season with the Temperature of 26deg C and with use of digits’ thermometer in 1.39m sensor 22deg C once we take into consideration the cooling target to 18 deg C by using rated formula this lead to 80Percent saving

By using GHP that take into consideration coupling with further devices such as despuheter that help uses to use the return to heat the water this device makes the system power full and save more as most water heaters consume between 2.2Kwh to 4.3Kwh by using the return this will lead us on the saving of power up to 40-60%. Once we use the geothermal computational devices by taking into consideration more than one service of cooling by using air conditioning that can coupled with the hepa filter for the clean air that may help in effective measure to control the respiratory pandemic, the saving on the system upgrade always will require a big geothermal heat pump to reach the target of eighty percent on cooling and have a saving for further building services. As will be identify in the data analysis will clearly shows efficiency of data collection with taking into consideration the Air condition system only and the use in various building services by using computation tools sush as GHPC that will lead on the advice for adequate saving.

4.2 Data Analysis

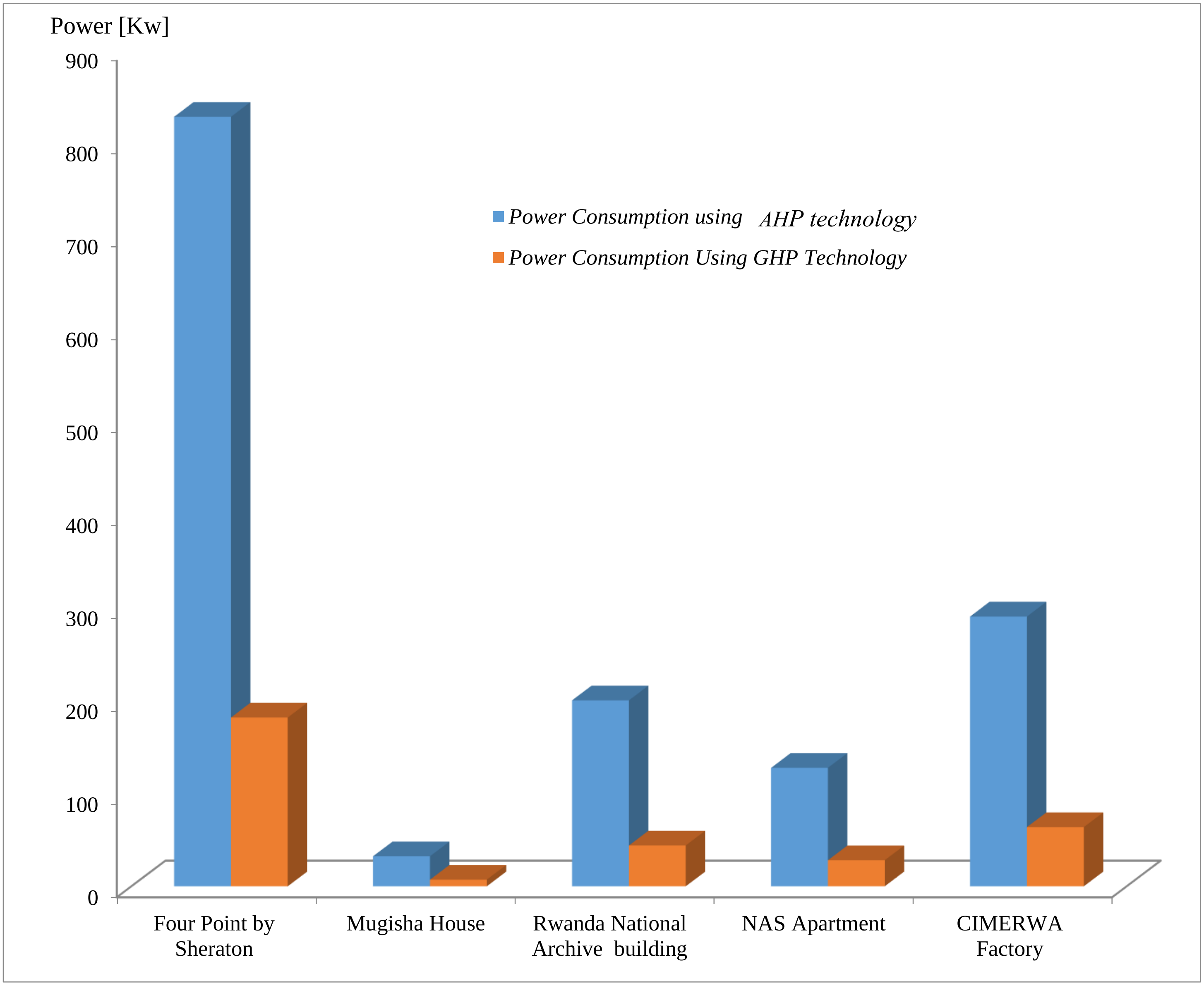

Figure 24. Data from the Surveyed locations

The figure above Figure 24 compares the power output for both an electrical pumps and geothermal heat pumps at the 5 considered buildings. As can be seen from the figure, the geothermal heat pumps generated power largely exceeds the power generated by eclectic heat pumps. It is observed that in average one can save 78% of the cost of electricity if GHPs are adopted in cooling and heating in the buildings in Rwanda.

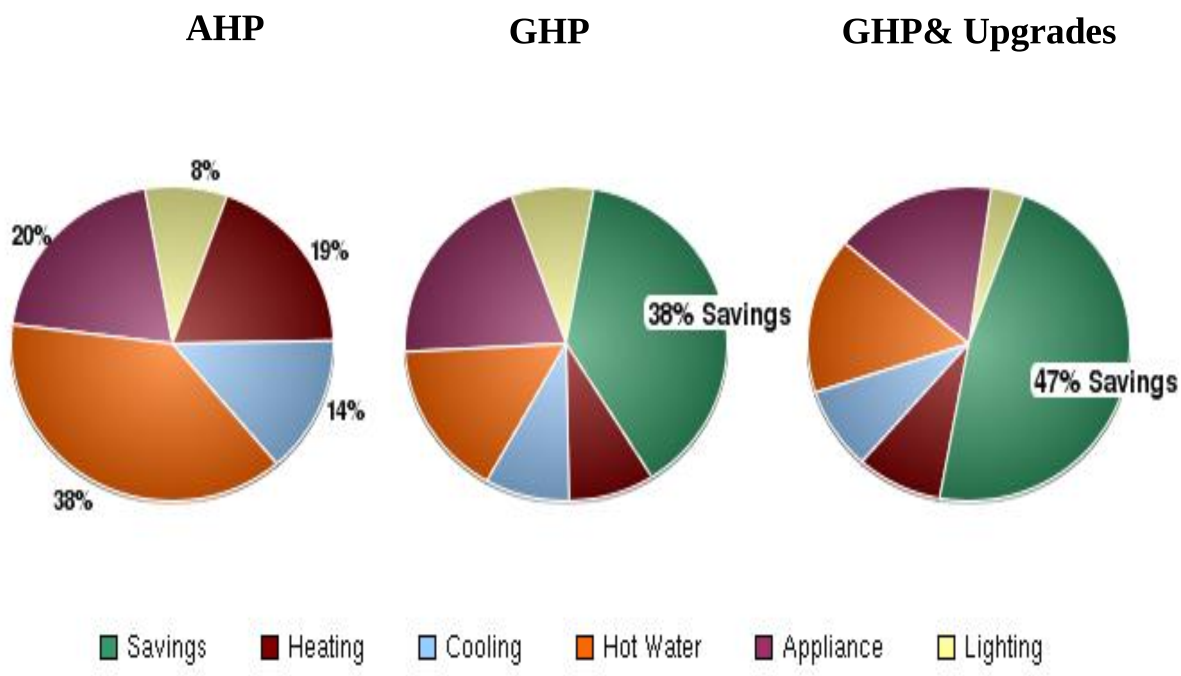

Figure 25. Energy consumption at Mugisha House

Figure 25 presents the energy consumption at Mugisha House, the smallest building of the five considered houses. It shows the portions of energy used for respectively, heating, cooling, keeping hot water and using various appliances. In addition to that, it illustrates the various rates of energy saving compared to usage of Air Source Heat Pumps. It is clearly seen that the use of GHP saved up 38% of energy. And, when upgraded with Energy Star and CFL florescence appliances the energy consumption reduces by 47%. Therefore, one can notice that for optimal use of energy for any given building, GHPs need to be always coupled with upgrading appliances.

On the other hand, the Figure 26 shows the energy consumption at RNA, the largest building among the 5 considered in this study. In this case the energy consumption dropped by 39% when GHP is used instead of AHP while it drops by 49% when a GHP is upgraded with energy saving appliances. By comparing Figure 25 and Figure 26 it notable that the larger the building is, the higher the energy saving rate gets.

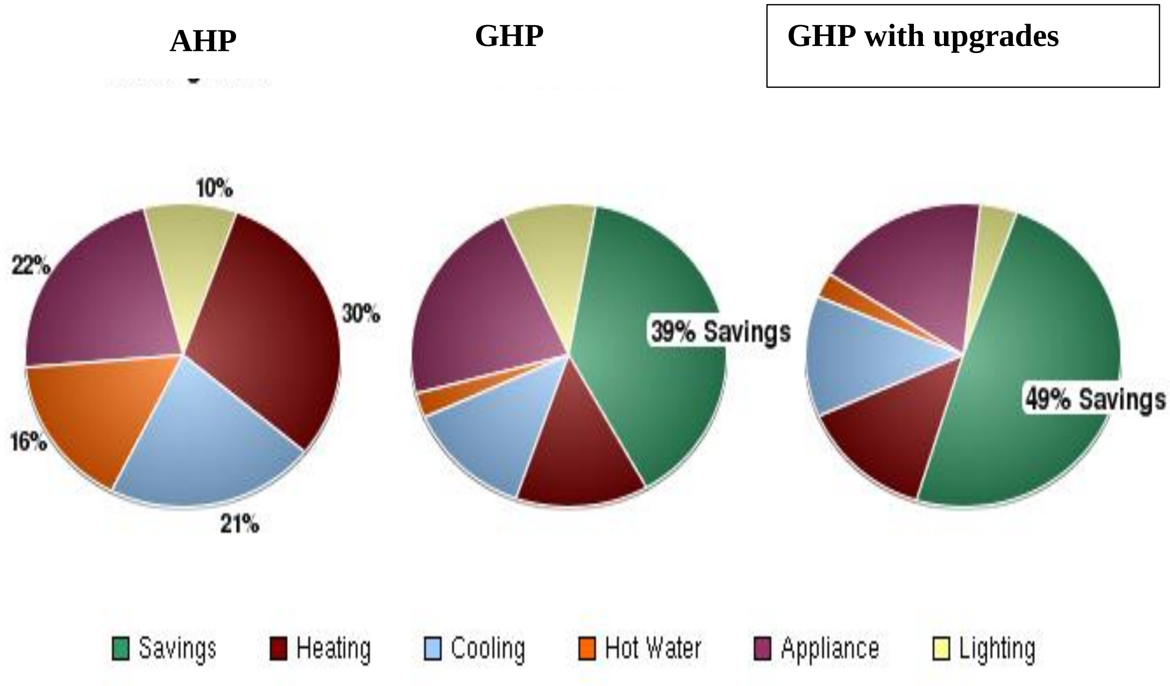

Figure 26. Energy consumption at RNA

Having observed that the energy saving rates are not the same for large and small buildings, it is remarkably worthwhile to analyze the change of energy saving with regards to variation of building size. It assumed that the GHP are upgraded with Energy Star and CFL florescence. Such analysis is presented in Figure 27. As can be seen from the figure, the rate of energy saving grew faster when the building size increases from 810 sq. to 1280sqm. And, it increased steadily increases as the size of the building varies between 1280sqm and 43400sqm. Above 43400sqm the energy saved remained constant at 45%. One can note that large buildings benefits from use of GHPs, but there is a threshold beyond which the energy saving rate becomes independent of the size of the building. It is also necessary to observe that small building can benefit more from possible extensions as small changes in size correspond to large increments of saved energy.

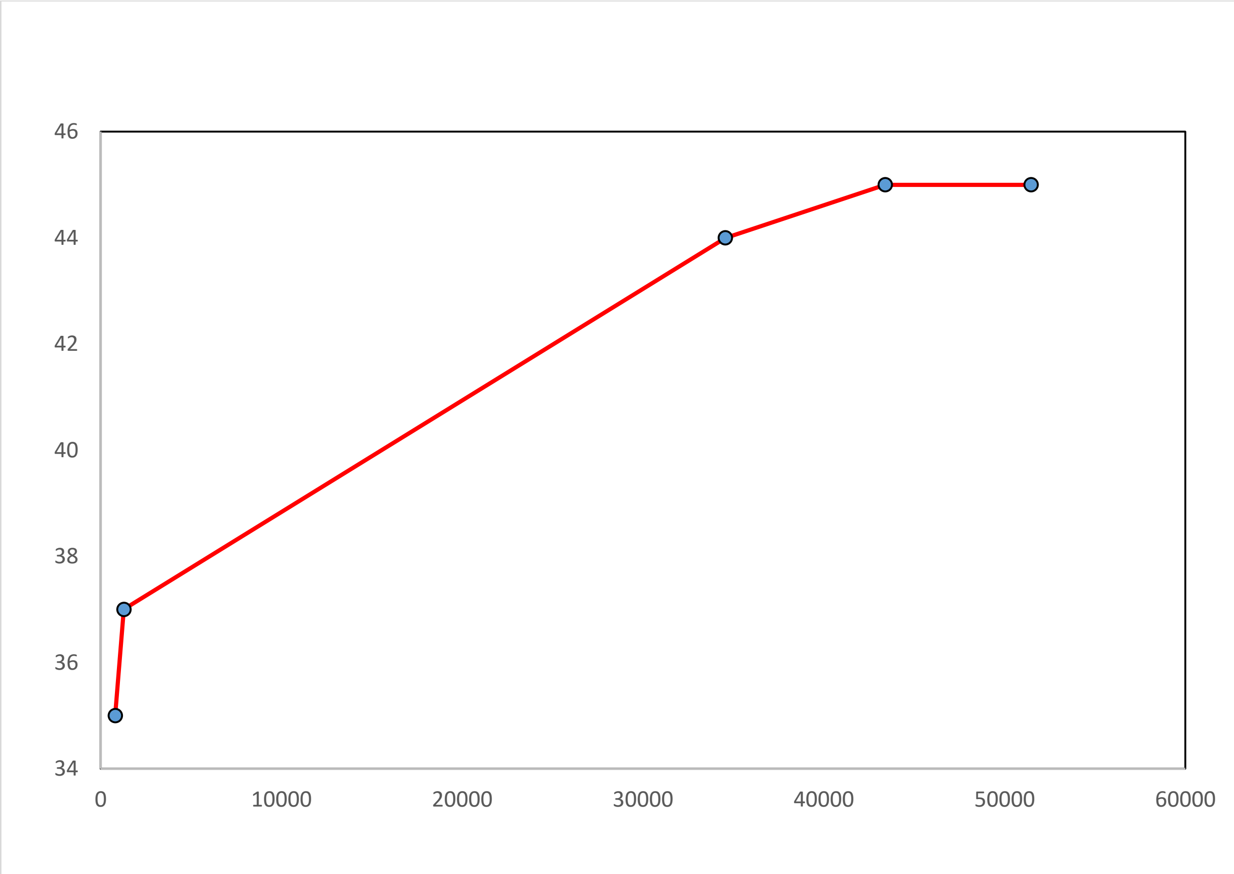

Figure 27. Variation of rate of energy consumption saving with size of the building.

Figure 27 presents variation of rate of energy consumption saving with size of the building, the smallest building of the five considered houses is Mugisha house and largest building considered is RNA Building. It shows the energy consumption used for respectively, heating, cooling, keeping hot water and using various appliances. In addition to that, it illustrates the various rates energy consumption saving compared to usage of Air Source Heat Pumps. It is clearly seen that the use of GHP saved up 38% of cost. And, when upgraded with Energy Star and CFL florescence appliances the Cost saving increase up to 47%. Therefore, one can notice that for optimal use of energy for any given building, GHPs need to be always coupled with upgrading appliances.

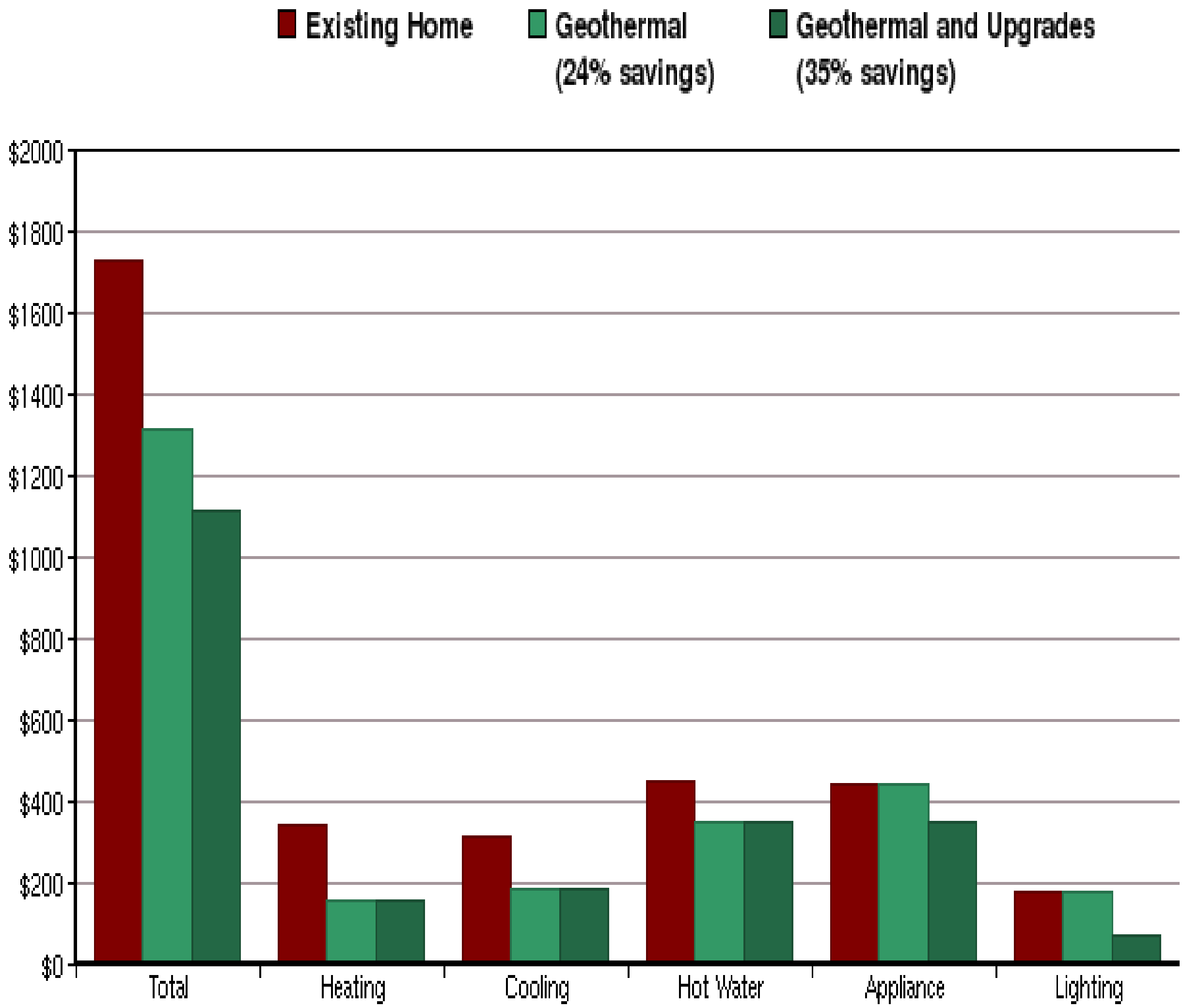

Figure 28: Mugisha house Energy cost per year

Figure 28 estimates the energy cost used per year at Mugisha house, among the building that considered in the study. It is the smallest among them. This mention that the performance cost building service with use of appliance with high energy efficiency rate by using the Geothermal Heat Pump technology the cost saved up 24% percent than using air source technology, within using Geothermal Heat Pump with upgrades the saving raises up to 35%. As a result, we can notice that for peak use of energy for any given building, GHPs need to be always coupled with Energy Star appliances and if it coupled with upgrade can serve more for building saving.

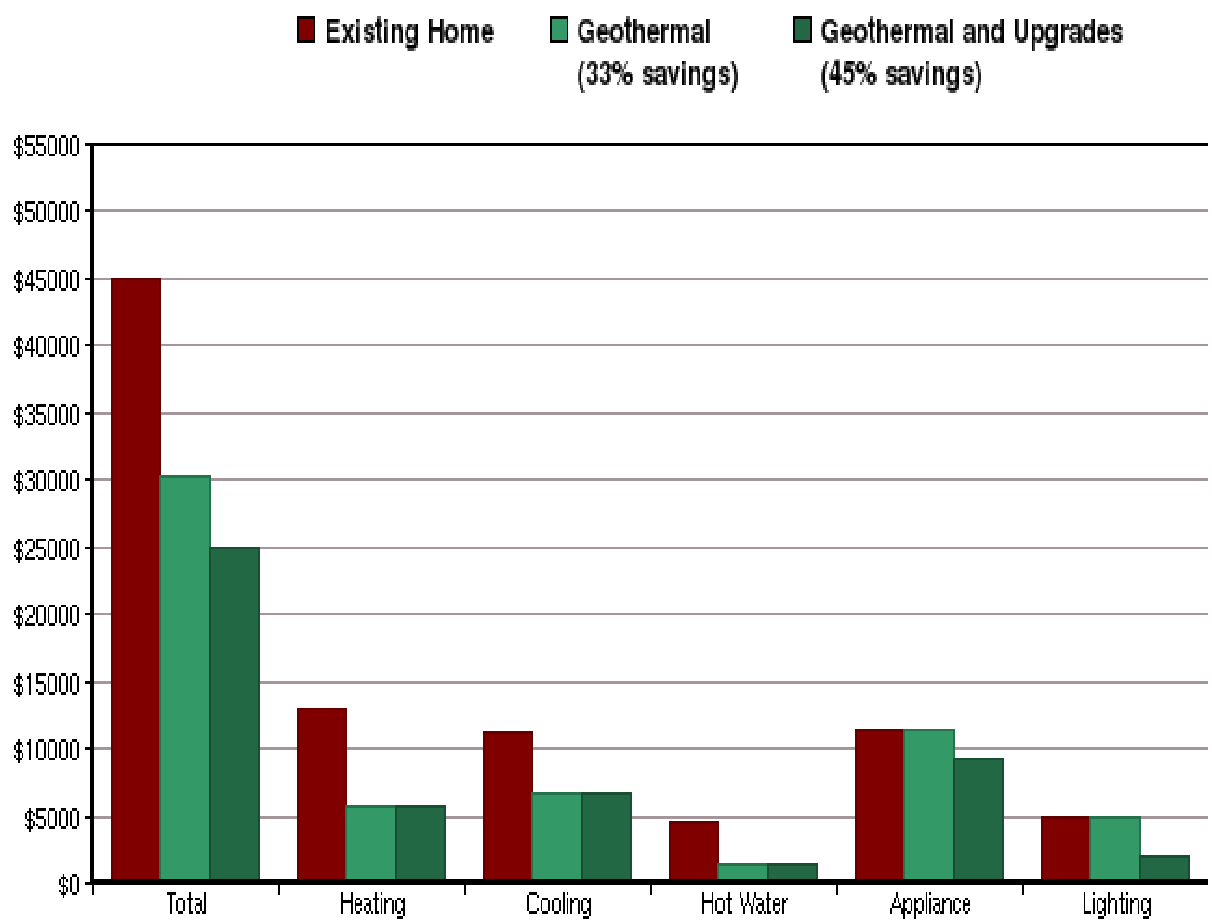

Figure 29: RNA House Energy cost per year

Figure 29 mention the energy cost that consumed relatively to the space at Rwanda National achieve building. Due to the floor plan is the largest building among the ones considered during the study. It demonstrates the cost recycled for building services that uses appliances with the building respectively. In count to that, it clarifies the various rates of cost saving compared to the application of Air Source Heat Pumps. It is obviously seen that the use of Geothermal heat pump saved up 33% of cost. And, when geothermal heat pump with upgrades used and coupled with Energy Star appliances the cost saving increase up to 45%. Thus, we notice that for best use of energy for any given building, Geothermal Heat Ps need to be always coupled with equipment with high energy efficiency and as much as the use can to couple it with its upgrades. Referring to Figure 28 and Figure 29, one may remark that as the building gets large, the more energy cost is saved by using GHPs. This strongly agree with the findings at Figure 27.

CHAPTER 5: CONCLUDING DISCUSSION

In this research a number of significant findings are obtained. First and foremost, it is observed that if GHPs technology is used for only cooling and heating the users can save up to 78% of the cost of electricity. On the other hand, when cooling and heating is coupled with use of energy consuming appliances the savings on energy used reduces to less than 49% while the saving on total cost of both the energy and servicing works remains between 24% and 45%. It worthwhile to note that once the GHP technology becomes fully established in Rwanda, the savings on cost will surely improve as the labor will get experienced and cheap in that area. Moreover, it was observed that as a building needs larger GHPs the more savings due to increased speed of compressors.

Even if the Startup cost for GHP technology for building services is high, it is more efficient than Air Source Heat pump operation for building services due high operation cost. In Rwanda, as developing country I would like to recommend the use of GHP as energy saving system. This is useful for growth of manufacturing industry that the country envisions.

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APPENDIX

Table 3. Data from four Point by Sheraton Hotel

UNIVERSITY OF RWANDA

ACE-ESD AFRICAN CENTER OF EXCELLENCE ENERGY FOR SUSTAINABLE DEVELOPMENT

FEASABILITY STUDY OF GEOTHERMAL HEAT PUMP USE FOR COOLING AND HEATING IN RWANDA.

QUESTIONNAIRE FOR HVAC CONSUMPTION

DATE: on 18th september

LR No. 2

PROJECT: Ukupisha House

STRUCTURE: Residential Air conditioning

DRAWINGS: Resid_001

LOCATION	HVAC SYSTEM		QUANTITY	POWER RATENG	TOTAL POWER CONSUMPTON
PUBLIC AREAS	SINGLE INVERTER	CEILING CASSETTE			
		CEILING CONCEILED DUCT	2	2.31 kw	3.234 kw
		CEILING SUSPENDED			
		FLOOR STANDING			
		SINGLE PACKAGE			
	MULTI INVERTER	MULTI PIPING TYPE			
		DB BOX TYPE			
		WALL MOUNTED TYPE			
	OUTDOOR UNIT	FLOOR MOUNTED	1	44.79	31.3194 kw
		WALL HUNG			
ROOMS	INDOORS	CEILIND CASSETTE			
		LOW STATIC CCD			
		MIDDLE STATIC CCD	3	2.32	4.872
		CEILING SUSPENDED CCD			

Total Power consumption on Peak days 39.4259 kw

Date of closure : 18th september 2020

Table 4. Data from MUGISHA Residential house

UNIVERSITY OF RWANDA ACE-ESD AFRICAN CENTER OF EXCELLENCE ENERGY FOR SUSTAINABLE DEVELOPMENT

FEASABILITY STUDY OF GEOTHERMAL HEAT PUMP USE FOR COOLING AND HEATING IN RWANDA.

QUESTIONNAIRE FOR HVAC CONSUMPTION

DATE: on 14th sept 2020

LR No. 1

PROJECT: Four Point Brighton Hotel

STRUCTURE: Hotel with BES (CAC)

DRAWINGS: —

LOCATION	HVAC SYSTEM		QUANTITY	POWER RATING	TOTAL POWER CONSUMPTON
PUBLIC AREAS	SINGLE INVERTER	CEILING CASSETTE	9	1.5kw	25.2kw
		CEILING CONCEILED DUCT	24	2.31kw	66.525kw
		CEILING SUSPENDED	—		
		FLOOR STANDING	—		
		SINGLE PACKAGE	12	4.5kw	40.30kw
	MULTI INVERTER	MULTI PIPING TYPE	17	3.2kw	35.08kw
		DB BOX TYPE	—		
		WALL MOUNTED TYPE	—		
	OUTDOOR UNIT	FLOOR MOUNTED	6	186.02kw	447.40kw
		WALL HUNG	2	22.371	17.897kw
ROOMS	INDOORS	CEILIND CASSETTE	—		
		LOW STATIC CCD	154	1.59kw	166.3354kw
		MIDDLE STATIC CCD	16	2.32kw	25.987kw
		CEILING SUSPENDED CCD	—	—	—

Total consumption at Peak day = 827.7364kw

Date of closure : on 16th September 2020

Table 5. Data from Rwanda National Archive

UNIVERSITY OF RWANDA

ACE-ESD AFRICAN CENTER OF EXCELLENCE ENERGY FOR SUSTAINABLE DEVELOPMENT

FEASABILITY STUDY OF GEOTHERMAL HEAT PUMP USE FOR
COOLING AND HEATING IN RWANDA.

QUESTIONNAIRE FOR HVAC CONSUMPTION

DATE: 19th September 2020

LE No. 3

PROJECT: Rwanda National Archives

STRUCTURE: Commercial Air conditionning

DRAWINGS:

LOCATION	HVAC SYSTEM		QUANTITY	POWER RATING	TOTAL POWER CONSUMPTON
PUBLIC AREAS	SINGLE INVERTER	CEILING CASSETTE	65	1.54	70.07
		CEILING CONCEILED DUCT			
		CEILING SUSPENDED			
		FLOOR STANDING			
		SINGLE PACKAGE			
	MULTI INVERTER	MULTI PIPING TYPE			
		DB BOX TYPE			
		WALL MOUNTED TYPE			
	OUTDOOR UNIT	FLOOR MOUNTED	1	126.92 kw	130.494 kw
		WALL HUNG			
ROOMS	INDOORS	CEILIND CASSETTE			
		LOW STATIC CCD			
		MIDDLE STATIC CCD			
		CEILING SUSPENDED CCD			

TC on Peak day 200.564 kw

Date of closure : 20th october 2020

Table 6. Data from NAS Apartment

UNIVERSITY OF RWANDA

ACE-ESD AFRICAN CENTER OF EXCELLENCE ENERGY FOR SUSTAINABLE DEVELOPMENT

FEASABILITY STUDY OF GEOTHERMAL HEAT PUMP USE FOR COOLING AND HEATING IN RWANDA.

QUESTIONNAIRE FOR HVAC CONSUMPTION

DATE: 21th September 202[illegible]

I.R No. 4

PROJECT: NAS Appartement

STRUCTURE:

DRAWINGS:

LOCATION	HVAC SYSTEM		QUANTITY	POWER RATING	TOTAL POWER CONSUMPTON
PUBLIC AREAS	SINGLE INVERTER	CEILING CASSETTE			
		CEILING CONCEILED DUCT			
		CEILING SUSPENDED			
		FLOOR STANDING			
		SINGLE PACKAGE			
	MULTI INVERTER	MULTI PIPING TYPE			
		DB BOX TYPE			
		WALL MOUNTED TYPE			
	OUTDOOR UNIT	FLOOR MOUNTED	1	74.57	52.19 kw
		WALL HUNG	1	22.37	15.659 kw
ROOMS	INDOORS	CEILIND CASSETTE			
		LOW STATIC CCD			
		MIDDLE STATIC CCD			
		CEILING SUSPENDED CCD	63	1.62 kw	60.102 kw

Total consumption | 27.951 kw

Date of closure : 24th September 2020

Table 7. Data from CIMERWA-RUSIZI

UNIVERSITY OF RWANDA — ACE-ESD AFRICAN CENTER OF EXCELLENCE ENERGY FOR SUSTAINABLE DEVELOPMENT

FEASABILITY STUDY OF GEOTHERMAL HEAT PUMP USE FOR COOLING AND HEATING IN RWANDA.

QUESTIONNAIRE FOR HVAC CONSUMPTION

DATE: 29th/ept/2020

LR No. 6

PROJECT: CIMERWA (Rusizi)

STRUCTURE: Commercial Air conditioning

DRAWINGS: —

LOCATION	HVAC SYSTEM		QUANTITY	POWER RATING	TOTAL POWER CONSUMPTON
PUBLIC AREAS	SINGLE INVERTER	CEILING CASSETTE			
		CEILING CONCEILED DUCT			
		CEILING SUSPENDED			
		FLOOR STANDING			
		SINGLE PACKAGE			
	MULTI INVERTER	MULTI PIPING TYPE			
		DB BOX TYPE			
		WALL MOUNTED TYPE	30	1.8kw	129.6kw
	OUTDOOR UNIT	FLOOR MOUNTED			
		WALL HUNG	3	22.3kw	161.064kw
ROOMS	INDOORS	CEILIND CASSETTE			
		LOW STATIC CCD			
		MIDDLE STATIC CCD			
		CEILING SUSPENDED CCD			

Total Power Consumption Per day 290.644kw

Date of closure : 30th September 2020