MASTER THESIS

Geothermal Potency and Development

Final Version

August 2018

Rian Anugerah Halim

MSc in Environmental and Energy Management (MEEM)

Energy specialization

University of Twente

Student number: 2030098

Supervisors:

Maarten J. Arentsen
Beau Warbroek

Table of Contents

Contents

Abstract

Geothermal energy has been developed in more than a decade for the multifunctional purpose from direct heat use and electricity power generation. The uses of geothermal heat resources are applied based on the temperature condition. Normally, the high-temperature steam extracted from the reservoir used for powering the power plant to produce electricity. On the other hand low to medium geothermal heat mainly used for direct utilization for agriculture, household, industrial, etc. Developed resources of geothermal energy mainly located in the volcanic area since the conventional technologies are developed to exploiting the heat source from this certain type of geological location, while another advance technology and planning now currently being developed to utilize the geothermal in the different geological area. This research project is intended to delve more into the potential energy resource that can be used from geothermal energy, the technology to exploit the resource, and how the resource can supply which kind of energy for the society and its problems. At the end of this project of research, an expected outcome is a list of key points regarding the application and suitability perspective of geothermal energy to replacing the fossil fuels.

Keywords: geothermal energy, electricity generation, direct use, heat resources,

Chapter 1: Introduction

1.1 Background

Due to the problem of depleting proven reserve of fossil-based energy fuels especially oil and gas, less than 60 years is the estimated remaining time of world fossil fuels extraction if there are no more massive successful finding of oil and gas proved reserve in the near future (Knoema, 2017). On the other hand, the world still has a considerable amount of proven coal reserve and with that amount of reserve, coal still can be produced as long as 350 years ahead (IEA, 2017), while with the hazardous emissions and possibility of nature damaging in the coal firing and extraction phase, some countries are considering to reduce and even stop their usage of coal to fulfill energy needs.

With both of these reasons, renewable sources of energy are currently being developed for mass utilization and application. Although most of the renewable energy like solar panel, wind and hydro still facing a huge challenge with the uncertainty of the production source and gap between the peak of production and consumption time. At the same time, the availability of geothermal energy source is relatively stable through the year and not affected by the season (M.I. Kömürcü, 2009).

As an illustration, geothermal energy is adapting the oil and gas exploration and production technology, the heat source is extracted from the subsurface and can be used in a direct way, rather for heating systems or for the purpose of powering the electricity power plant with the heat steam from the geothermal well. The potential of geothermal energy worldwide is very massive, approximately 50.000 times more energy can be derived from geothermal resources than the total amount of energy can be used from oil and gas all over the world (Golusin et al, 2013).

For this reason, with the huge potential of energy can be extracted and delivered from the geothermal energy and its possibility to be an alternative to fossil fuels towards fulfilling the society energy needs with clean energy, doing the research regarding geothermal energy with the analyze of resource capacity, technology to exploit the resources and possibility of resources utilization are important for the future of geothermal energy as a sustainable energy.

1.2 Problem Statement

With the roaring of energy needs in the global, the reserve of fossil fuels are currently being declined since the phase of exploration and finding is not balanced with the usage and needs. On the other hand, western and developed countries especially the OECD group nations and most of the EU members trying to increase the share of renewable-based energy and partially decreasing the share of fossil fuels to reach the sustainable goal development and Paris Agreement.

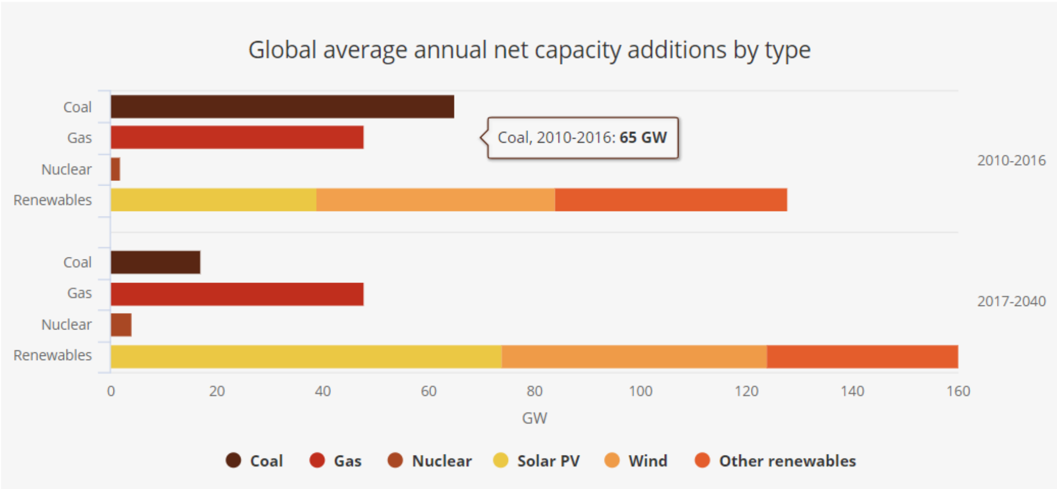

Figure 1, World energy capacity history-past-future statistic (IEA, 2018)

According to the International Energy Agency (IEA) statistic, the capacity of coal as the global main fossil-based electricity power plant source beside oil and gas will be declined from 65 gigawatts (GW) to less than 20 GW. Different from the coal, the capacity of renewables source would be rising from more than 120 GW to approximately 140 GW from 2017 to 2040.

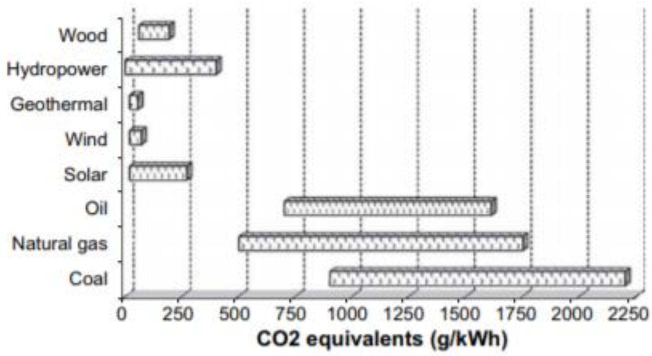

Figure 2, CO2 Emissions of energy Sources ((M.I. Kömürcü, 2009)

Based on figure 2, the emissions produced from geothermal energy is relatively lower than the other source of conventional and other renewables. With the massive potential of geothermal energy (as mentioned before in chapter 1.1) and also the benefit of lower CO_2 produced, the research of possibility and the current also future challenges in geothermal energy towards replacing the fossil fuels are important towards increasing the renewable energy for the society.

Since an energy of a geothermal resource can be defined simply as a reservoir inside of the earth subsurface from which heat can be exploited economically (compared with other sources of energy) and used for empowering the electricity powerplant or other heating industrial also domestic purpose in the near future (Gupa H, 2007), then one of the biggest challenge to extracting the energy is to make the energy reachable with the current technology.

1.3 Research Goals and Research Questions

The goal of this research is to contribute to the knowledge on the potential of geothermal energy to supply energy for the society. This goal will be approached by:

a. Elaborating the state of the art of geothermal energy theory

b. Analyzing the potential resource, technology to exploit and applications of geothermal energy can be used for the society, the writer focused the Netherlands as the place to analyze

Based on the elaboration and the analyzation, the ultimate outcome of this research is a recommendation of the suitability regarding geothermal energy capability of the Netherlands to replacing the fossil fuels.

Research Question

What is geothermal energy, where and how can it be applied and what is its potential to become an alternative for fossil-based energy?

The researcher will answer the research question with the help of these following two sub-questions bellow. Later, the researcher will also elaborate geothermal energy in the Netherlands, as an case illustration in order to give an impression of the potential of geothermal energy in a country with intensive energy demand like the Netherlands.

Sub-questions

Sub-questions 1: What is the current status, technologies, applications, resources of geothermal energy in the world?

Sub-questions 2: What are the main problems of current geothermal energy applications in term of physical, technical, and social?

1.4 Research Method

This research is intended to analyzing the capability of the resources, applications, technologies to utilize the resource and possible energy that geothermal energy can supply in term replacing fossil fuels in the Netherlands with the desk research based and secondary data sources analysis. Furthermore, the researcher will analyze the current application and condition of the geothermal resource in the Netherlands as an illustration of the potential with a description of physical, technical, and social problems involved. Finally, in the stage of data collections, the writer will do the secondary data assessment from documents, literature and reliable media sources then analyze the assessed data towards answering the research questions mentioned before and finishing the final step with the conclusions and recommendations.

1.5 Research Framework

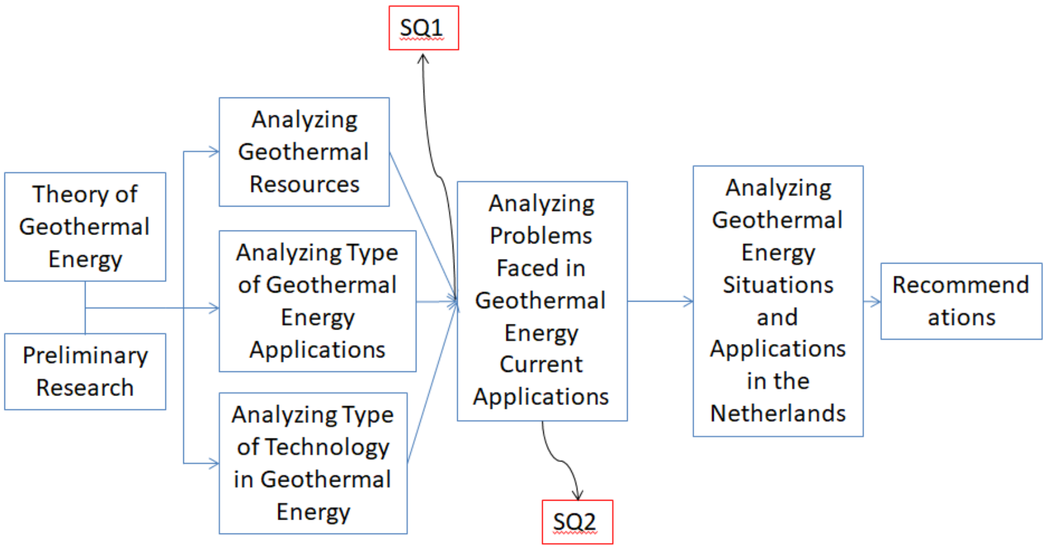

Figure 3, Research and Analytical Framework

Since the research question (RQ) of this research project of geothermal energy and development has only one RQ, then the researcher decided to add and develop two sub questions (SQ) of the research towards answering the central research question. For the first SQ, the writer will analyze the current state of geothermal as energy source in the world. This first sub-question may consist of the elaboration in the resources that geothermal has, application that possibly geothermal could supply and the current technology that geothermal energy could use to extract the energy. Later, the second or last sub-question will help the researcher to elaborate what kind of problems that geothermal have and possibly to face during the mass utilization with the three different dimensions: social, technical and physical problems. Next phase, in the chapter 5 researcher will serves an illustration from huge energy demand country like the Netherlands as an example of geothermal energy potential mass applications. Finally, the chapter 6 would be the conclusion and consists of the main question and sub-question answers.

Chapter 2: Geothermal Energy and World Status Review

Nowadays, geothermal energy is one of the options of renewable energy source that not massively being used, although the energy from geothermal is utilized for a long time, the industry still tackling a way to make this energy common and suitable with the energy trilemma concept (Energy security, energy equity, and environmental sustainability).

Furthermore, this chapter of geothermal energy and world status review will acknowledge what is geothermal energy from the system, energies from geothermal itself, application and also the current status of geothermal energy globally with their main challenge of it development.

2.1. Geothermal Energy

Geothermal energy is classified as renewable source and unlimited source of heat and electrical energy. With the ultimate benefit of the environment and the undependability with the condition of weather thus the energy of geothermal can be supplied at all time of the day and week.

On a human timescale, geothermal energy also classified as an unlimited or inexhaustible energy source (Stober & Bucher, 2016). Since most of the heat extraction process does not diminish heat resource below the surface but the produced water also normally injected into the reservoir within the injection well.

Source of the geothermal energy is extracted heat, this heat is radiating from the center of the earth since 4.5 billion years ago, with more than 6.400 KM deep and scientists predicted that around 42 million of megawatts (MW) of energy flowing from the centre into surface of the earth with primarily by conduction (GEA, 2014). Furthermore, the geothermal energy source usually ranged and located from the shallow reservoir into ultra-deep of thousands KM in the earth subsurface.

The geothermal energy also can be used in the range of needs and source capability, from low thermal heat for district heating and agricultural needs to high temperature thus can be utilized for the steam power plant which can supply the electricity needs of an area or even a town.

2.1.1 Geothermal Energy Systems and Models

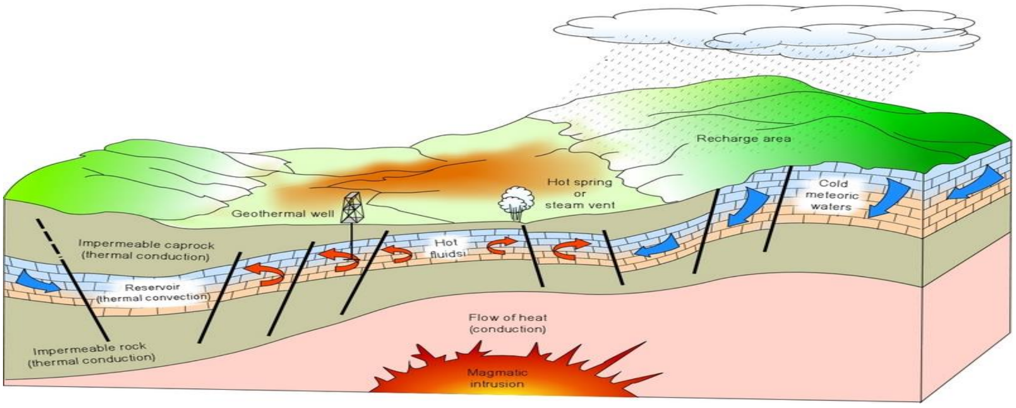

Figure 4, Ideal Geothermal Energy System (IGA, 2004)

From the figure 4 above, the geothermal system can be explained systematically by heating the water with the thermal from the upper crust of the earth in a restricted space then transferred from the thermal source to the heat sink in the earth free surface (IGA, 2004), the system of geothermal normally consists of three main elements: heat source, reservoir and a fluid itself whom carrying the heat and can also be described as the heat media from subsurface to the surface.

Also as can be seen in the figure 4, the heat source of the geothermal energy system is come from magma. The thermal from magma is conducted to the lower impermeable rock and then heating the water whom traped beetwen those two impermeable rock. Both of impermeable matrix also has different functions, the lower one act as a heat conductor, and the upper matrix used as a caprock.

This geothermal reservoir is fluid contained rocks below the surface which can be economically profitable if the heat content from the heat rocks volume extracted to the surface to deriving the energy. The temperature of the geothermal reservoir can be classified into four types:

1. **High Temperature Reservoir:** The high temperature reservoir usually provide sufficient thermal to make electricity from the steam. This type of reservoir has more than 150^{o} C and normally located in active volcanic area.

2. **Middle Temperature Reservoir:** This kind of reservoirs has a weaker temperature compared with the first one, with the capability of 100^{o} to 150^{o} C Despite the

temperature is lower, the middle temperature reservoir allows sufficient extraction of electricity production using a volatility of the fluids (although the capacity is much lower compared with the high temperature). Usually the reservoir located in the place that geological contexts and geothermal gradients higher than the median. The application of the middle temperature heat can be optimized for urban heating and also industrial processes.

3. **Low Temperature Reservoir:** The low temperature reservoir can have a heat content between 30_o and 100_o C. Location of this type of reservoir usually located in favorable geological context with deep aquifers. The gradient of the heat is between the average in the domain and the extraction of the heat implicates hot groundwater pumping from the aquifer and re-inoculate it to the ground following the heat is being delivered. These type of heat can be applied for direct district heating and also industrial processes.

4. **Very Low Temperature Reservoir:** With the temperature below 30_oC, the possibility of the heat application is for the heat exchanger. The application can be used for domestic use and air conditioning of agricultural purpose. These types of reservoirs can be found in common places since the efficiency only determined by the subsurface thermal inertia in common geothermal gradient conditions (ICGC, 2018).

Furthermore, the fluids from geothermal energy can be found in a different phases. From liquid phase, steam phase, or mixture between both of the phase. The type of the steam system can affect the geothermal production technology which known as direct steam cycle, separated steam cycle, combined cycle, etcetera (Nenny Saptadji, 2001)

2.1.2 Energies from Geothermal

Since the earth hold a lot of potential varieties of energy widely from horizontal surface and shallow to deep subsurface, the geothermal energy also reserves a different type of energy possibilities and sources from different layers of the earth.

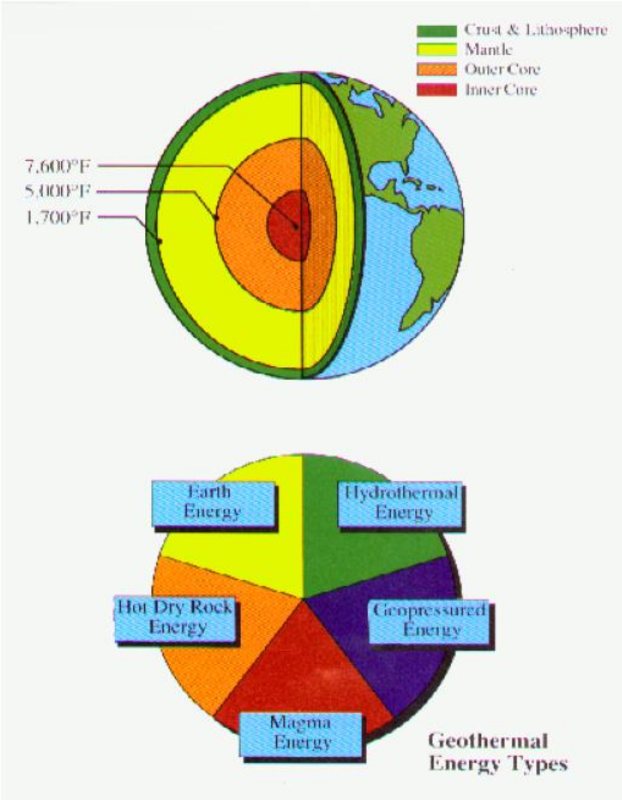

Figure 5, Geothermal Energy Types (Saptadji, 2001)

Figure 5 explained the differentiation and classification of geothermal energy. The geothermal energy separated into 5 different types: earth energy, hydrothermal energy, hot dry rock energy, magma energy, and geopressured energy. The geothermal energy from the figure above is classified by different layers of the earth, from the crust & lithosphere into the ultra-deep inner core with also ultra-high temperature.

From the 5 different options of geothermal energy above, the energy derived from hydrothermal energy system mostly being developed and utilized, since the pore of the matrix usually containing fluids and the reservoir depth quite reachable whom also effecting the economic aspect of geothermal energy utilization.

The system of hydrothermal utilizes the heat content fluids in the porous matrix that can be used for energy generating with the specific enthalpy level (high or low). The high enthalpy systems mostly related with high volcanic activity areas and advanced geothermal gradients then can be utilized for electricity generating power plants. On the other hand, low enthalpy system can be utilized in ordinary domain with normal to moderate geothermal gradient and usually it used for direct usage of geothermal energy generation (Stober & Bucher, 2016).

2.1.3 General Applications of Geothermal Energy

The applications of geothermal energy mostly classified by direct and indirect (power generating) utilization. Both of classification usually differentiate by climate, geothermal capability, and also needs.

Direct uses of geothermal energy are utilizing the surface manifestation and also subsurface thermal resource of geothermal capability to fulfill the certain energy purpose. The direct use of geothermal mostly utilized in the sub-tropic and cold climate in term of fulfilling the necessity of sustainable space heating.

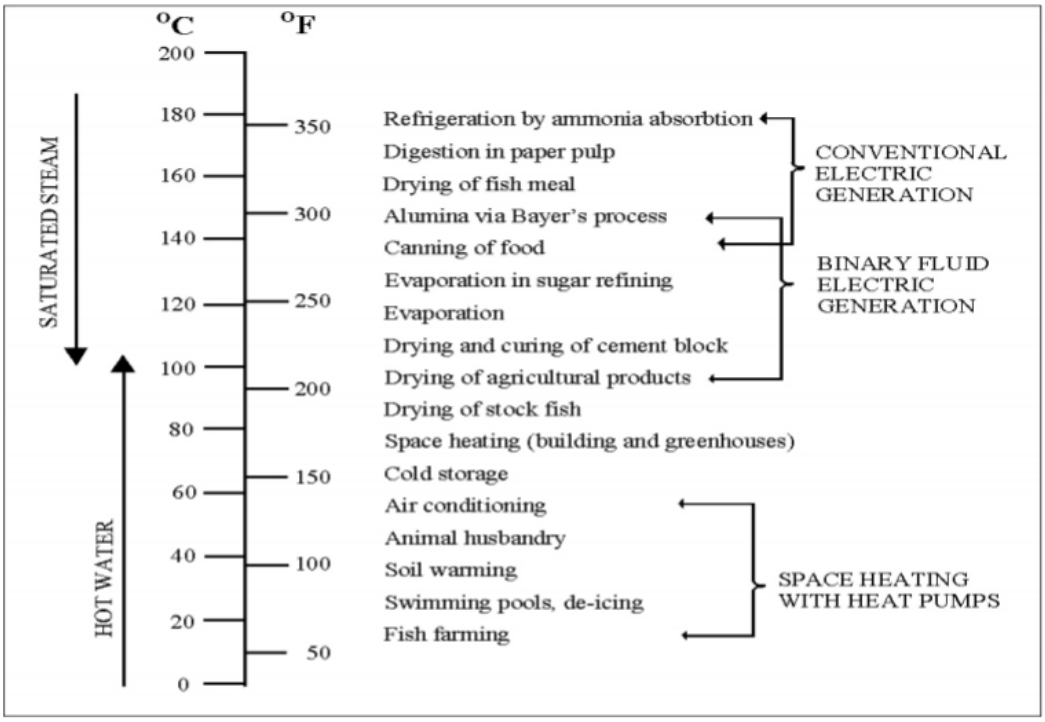

Figure 6, Lindal Diagram (Jack Kiruja, 2011)

As it can be observed from the lindal diagram above, the fluids with thermal content under 100^{o}C are mainly utilized for urban heating and agricultural needs, while the fluids above 100^{o}C are mainly applied for industrial usage such as drying and evaporating purpose (Jack Kiruja, 2011). The direct utilization of geothermal energy usually uses heat pump, heat exchanger, and pipeline as the main tools.

Furthermore, indirect geothermal utilizations or usually mentioned as geothermal power plants is an utilization of hydrothermal resources system that requires a high temperature (more than 150^{o}C) who come from dry steam wells either water wells (EIA, 2017). The high thermal water or steam used to powering the electricity turbine. The utilization of this kind of geothermal energy is usually located in a high activity of volcanic area.

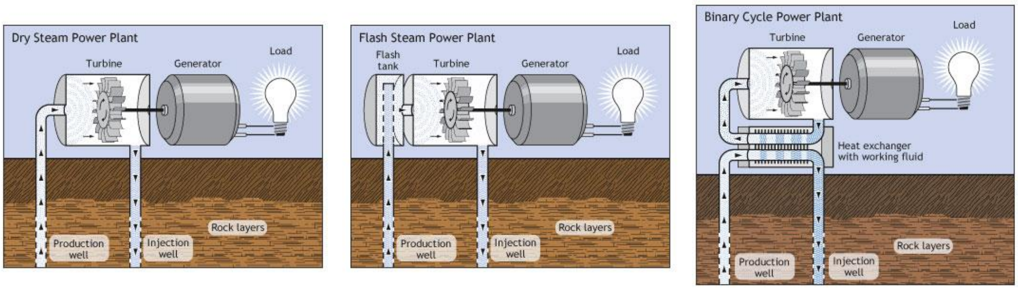

Figure 7, Type of Geothermal Power Plant (PSU, 2015)

According to the type of geothermal power plant figure above, there are three main systems of geothermal power plants:

1. **Dry Steam Power Plant**: This power plant is the most simplest among the other geothermal power plants. The heat steam produce from production well entered the turbine and powering the electricity generator, while the minimum amount of fluid and steam being injected again after the heat produced into the generator (Eliasson, Þórhallsson, et al, 2008).
2. **Flash Steam Power Plant**: This power plant is used when the fluid arrived in the well head in a saturated condition. The fluid flowed out into a flasher until it evaporating, and then the amount of vapor streamed into the turbine to produce and electricity.
3. **Binary Cycle Power Plant**: Mostly the fluid from subsurface used for this kind of power plant have to be around 200°C, or have to be heated until it become sufficient. The fluid came from the subsurface utilized to heating the organic fluid that will make the electricity turbine work while the subsurface fluid being injected again after the organic fluid heating finished. On the other words, the binary cycle power plant work as a heat exchanger machine (Saptadji, 2001)

2.2. World Status of Geothermal Generator

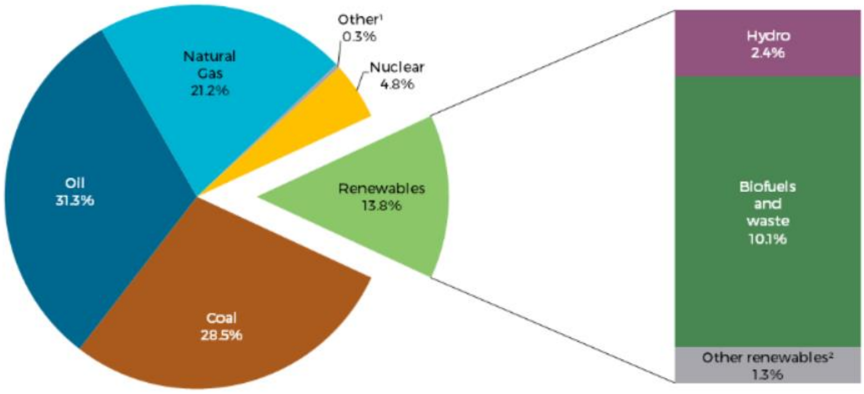

Figure 8, World Primary Energy Supply Mix (IEA, 2016)

According to the figure 8, most of the total world primary energy supply still counted on the fossil fuels. Mixture between natural gas, oil, and coal still be the main source of energy supply and generation, on the other hand the renewables still be the second place of the energy source ranking with the main domination of biofuels and hydro. The geothermal power energy supply classified as "other renewables" and only counted as big as 1.3% with other source of renewables.

Normally an area that holds promising massive geothermal potency often located on the high volcanic activity with a lot of surface geothermal manifestations. This kind of active volcanic area usually reserves a thermal potential who that can be used for not only direct heating activities but also can be optimized for geothermal electricity power plant.

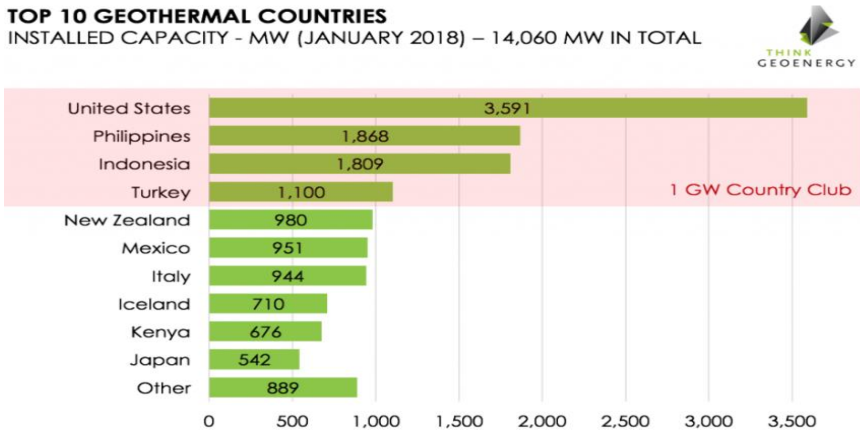

Figure 9, World Geothermal Generator Ranking (Think Geoenergy, 2018)

Referring to the figure 9 above, it can be seen that only 4 countries reached 1 GigaWatt (GW) in current installed geothermal energy source capacity. These top 10 country mostly utilizing the geothermal energy with both direct application and with purpose of power generating (except Indonesia and Philippines who using almost of their geothermal capability for electricity generation). Furthermore, most of the top 10 countries in generating geothermal energy are located in the area that has a volcanic activity ground such as Iceland, New Zealand, Indonesia, and Philippines whom famously located in the ring of fire (Worldatlas, 2018).

On the other hand, the huge ambitions in geothermal energy also influenced "flat" countries without high volcanic activity to develop and explore their capability of geothermal energy for instance, the Netherlands.

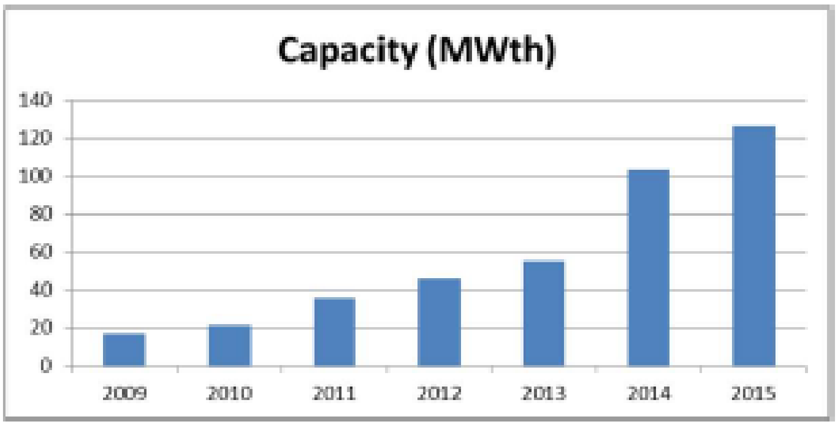

Figure 10, Netherlands Growth of Geothermal Capacity (Bakema & Schoof, 2016)

The figure developed by Bakema & Schoof above shown the Dutch geothermal capacity arises rapidly from below 20 MWth on 2009, to more than 120 MWth 6 years after.

Another source reported that the growth of the Netherlands geothermal power plant is growing 52% after 2011 and counted as the highest growth hence more than the other countries in the EU and Turkey (Think Geoenergy, 2016). Not only that, the Netherlands also set a high target in the future, as big as 32% gross electricity production have to come from geothermal energy in 2050 (Wees et al., 2013). This is the proof that hydrothermal energy system from geothermal energy can be explored with a variety of geological condition in certain different places.

Later, as it been mention before, the application of geothermal energy mostly depends on the enthalpy or level of temperature that the heat source has. While the high temperature (>220^{o}C) mostly used for electricity generation, the low to medium thermal (30^{o}C to 150^{o}C) commonly utilized for multipurpose of direct energy use (Mburu, 2013).

Direct use of hydrothermal also classified by two technological utilizations, with a heat pump or literally directs application without heat pump system. These two applications depend on the geological capability of the heat source in the reservoir below the surface.

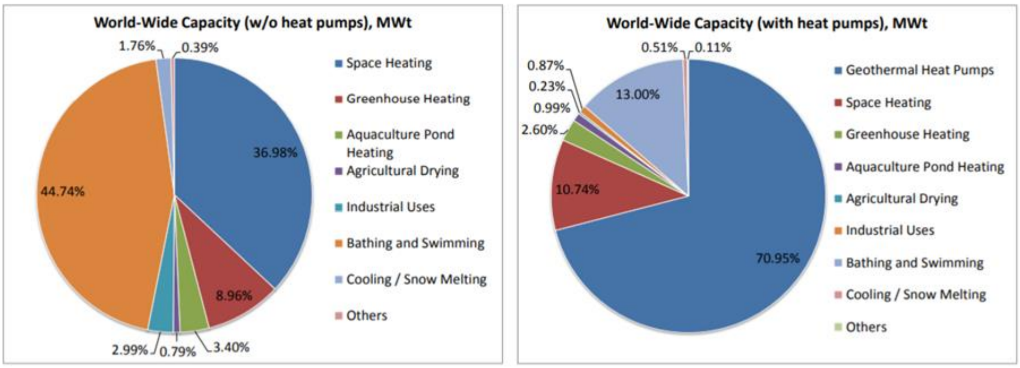

Figure 11, Global Direct Geothermal Capacity Mix Share 2015 (Lund and Boyd, 2015)

As it been mentioned in the figure of global direct geothermal capacity mix share above, the direct utilization without heat pumps mostly used for a commercial purpose such as bathing and swimming, greenhouse heating, and industrial purpose. While the heat pumps geothermal application dominated by the geothermal heat pumps whom mostly applied for several heating purposes like residential unit (5.5 KW) to commercial and institutional heating installations (250kW). These charts signify that geothermal energy plays a crucial role in a daily living for some countries that exploit the hydrothermal systems from geothermal energy.

2.3. Challenges on Geothermal Development

Developing geothermal energy is not only relying on the advantages of it. The most of challenges on geothermal development project are how to tackle the main issues regarding the contradictive fact of geothermal development itself.

In fact, the challenges of developing geothermal energy are not only limited by the physical challenge itself. The challenges of geothermal development also involving economical, technical and also social challenges also could be one of the problems in term of developing the hydrothermal systems.

Since the development of the geothermal energy especially in electricity power generator mostly implicating the upstream and downstream process, the involvement of stakeholders in this energy development (from external and internal) is also could be more complicated and bring the challenge into the next level.

Table 1, Summary of Geothermal Sustainability issues (Shortall, et al., 2015)

Theme	Positive impacts	Negative impacts
Poverty	– Increased per capita income – Increase in salaries – Social development initiatives – Affordable energy supply – Higher living standards – Improved food security – Access to drinking water	– Rising property prices – Community displacement
Health	– Improved sanitation – Improved medical facilities – Lower indoor air pollution – Therapeutic uses	– Odor nuisance – Toxic gas emissions – Water contamination risk – Noise pollution
Education	– Improved education facilities – Improved school attendance	– Sudden or unprecedented cultural change
Natural hazards		– Induced seismicity – Subsidence – Hydrothermal eruptions
Demographics	– Positive social change – Increased tourism	– Negative cultural impacts – Resettlement – Livelihood displacement
Atmosphere	– Displacement of greenhouse gas emissions from other energy sources	– Greenhouse gas emissions – H_2S pollution – Toxic gas emissions
Land	– Small land requirements relative to other energy sources	– Habitat loss – Soil compaction – Conflict with other land uses
Forests	– Replacement of traditional biomass	– Deforestation – Ecosystem loss
Freshwater	– Low lifecycle water consumption relative to other energy sources	– Conflict with other energy uses – Contamination of shallow aquifers and other water bodies
Biodiversity		– Habitat loss or disturbance – Loss of rare geothermal ecosystems
Economic development	– Increased energy security – Low climate dependence – High capacity factor – Direct, indirect and induced economic activity and employment	– Few direct long-term jobs
Consumption and production patterns	– Waste heat can be cascaded or recaptured	– Waste may cause environmental contamination – Risk of overexploitation – High cost of turbines may compromise efficiency

Referring from the table 1, there are 11 challenges or issues of geothermal development that could be classified in physical (natural hazards, atmosphere, land, forests, biodiversity, and freshwater), technical (consumption and production patterns), social (poverty, health, education, demographics) and economic challenges. Although not all of the listed impacts may occur in the all of geothermal energy user or generator, most of the big geothermal producer would face this challenges in developing the geothermal energy systems.

Furthermore, another report argues that the geothermal energy is an expensive energy. Since the exploration, especially in drilling activity for 1 MW capacity, usually end up with $2 – 7 million pricetags (Energy Invormative, 2018).

2.4. Conclusion

With the elaboration from the second chapter above, it can be seen that the geothermal energy is not the most developed renewable energy in this world that massly used, since the share of geothermal energy is still below 1.3% compared to another renewables and the USA is the biggest geothermal power generator in the world with more than 3.5 GW installed capacity. Later, from this chapter the researcher also learnt if the geothermal energy also would be sparated by 5 different earth thermal source, while the most massly utilized globally is hydrothermal energy and nowadays the "geothermal energy" words nowadays mostly reffered to hydrothermal energy. In addition, the heat that extracted from geothermal energy would also possibly to be utilized in the wide of range from direct usage to electricity generation with the minimum temperature.

Chapter 3: Geothermal Energy Resources, Applications, and Technologies

3.1. Geothermal Energy Resources

Massive resource of geothermal energy mostly lies below the surface of the earth. The heat source that will be the crucial resource of the geothermal energy normally conducted into the reservoir fluids inside the matrix pore. The subsurface heat located in the shallow or even deep reservoir should be extracted in a proper economical manner, since the utilization of geothermal energy should not exceed the certain point of economic limit who usually refer to conventional energy like oil and coal based power plant. Beside the subsurface geothermal resource, in some high-activity volcanic area geothermal energy resources also can be found in the surface (also called geothermal manifests) such as warm ground and geyser.

Figure 12, Map of Global Geothermal Energy Power Plant (Think Geoenergy, 2018)

For the current time and with the application of current technology, geothermal energy generator electricity power plant effectively used in the mountainous and active volcanic area (as can be seen in figure 12 above). For example, with the benefit of areas that surrounded by mostly active volcanic mountain and also located in the ring of fire Indonesia has succeeded to build world biggest geothermal power plant called "Sarulla

Geothermal Project”. This geothermal project contains three different unit of power plant with estimated capacity of 110 MW in each power plant to produce electricity (Wolf & Gabbay, 2015). Furthermore, the geothermal energy in volcano active area is more easily possible to be exploited, since the sign of surface manifestation resource can be used and the thermal gradient is more high so the geothermal well may more shallow (<1000 meters) than the non-volcanic area (>2000 meters) to get the sufficient heat to be extracted.

3.1.1 Geothermal Energy Surface Manifestation Resources

The most obvious evidence occurs of geothermal reservoir is when the fluids arise from subsurface to the ground throughout fault via permeable rock pore. The appearance of the surface manifestations can be found in several forms such as it will be explained bellow:

1. Hot or Warm Spring
   This kind of surface manifestations is one of the indications of certain area hold a geothermal energy potential. The hot/warm spring formed by the stream of thermal fluids from subsurface who streamed from the stone matrix into the surface area. Classification of warm and hot are classed by the fluid temperature in the surface area, the warm spring normally hold a temperature less than 50^oC and otherwise the hot spring have more than 50^oC temperature. The spring also can indicate the dominating fluid inside the geothermal reservoir is steam or hot water dominates.

2. Fumarole
   The fumarole is a small hole on the surface ground with a dry or wet steam streaming through the hole. Furthermore, fumarole that streamed a high speed steam usually can be seen in the steam dominated hydrothermal reservoir system. This steam could also contain SO_2 who can only being stabilize at more than 500^oC or can be classified as ultra-high temperature. In the end, almost all of the fumarole in the surface streamed a hot-wet-steam and normally the temperature not exceeding 100^oC.

3.1.2 Geothermal Energy Subsurface Resources

Most of the geothermal energy resources located in the subsurface. The potential of geothermal energy located below the earth surface forecasted as more than 50.000 amount of energy that can be derived.

As it been mentioned before, there are several types of geothermal energy such as: earth energy, hydrothermal, hot dry rock, magma and also geopressured energy that potentially can be used in a mass extraction of energy (Saptadji, 2001). On the other hand, with the different variety of geothermal subsurface resources the most used as main energy source globally is hydrothermal energy, since the application of exploration and exploitation of hydrothermal systems is mostly applied with developed oil and gas technology.

Unlike the hydrothermal system, most of the rest of geothermal systems are still in the preliminary calculation and technological development. The hot dry rock energy systems for instance, currently the scientists from China are developing the potential resources of this geothermal system in China. The group of scientists has drilled a well with 3.705 meters depth and reached the sources of the hot dry rock with the estimated temperature of 236^{o}C, and with the current state of technology today engineered geothermal systems in the hot dry rock with estimated depth from 3000 to 10.000 meters could possibly recovered energy with a temperature more than 150^{o}C to be utilized for both power generation and heating source. Furthermore, a preliminary calculation forecasted that the potential reserve of hot dry rock systems in this world is equivalent with 10 times of oil, natural gas and coal combined (Think Geoenergy, 2017).

Same development path is currently happened in magma rock energy, the current state of development on this energy is still in R&D phase. One specific case from the scientific team from USA tried to drill an abandoned site of geothermal energy site in the Icelandic active volcanic mountain. The team drilled a well directly to the magmatic area and found a good quality of geothermal well. Furthermore, when the well tested by the team, the magma well can produce a dry steam with 400^{o}C thus the high temperature steam can produce a 25 MW power plant, higher than a normal geothermal well that usually has 5 to 8 MW capacity (Renewable Energy World, 2009).

Different with the other geothermal energy, the geopressured energy seems not to be really developed and most of energy that counts on geopressured is mixed with another energies such oil and gas or also hydrothermal energy, since most of the geopressured resources contains three energy forms: thermal, hydraulic, and methane gas (Lunis, 1990).

3.2. Geothermal Energy Applications

3.2.1 Electricity Generations

As it mentioned before, the geothermal energy applications (mostly hydrothermal energy) that sufficient to fulfill the amount of heat towards running the power plant is mostly located in mountainous and volcanic active area. The heat that coming from subsurface well (dry or wet steam or both) transported directly with pipe to the power generator who will produce electricity. Furthermore after the heat from the steam taken, the leftover water and also chemical from the subsurface are injected again with the injection well. This is why that geothermal energy classified as renewable, since the energy generations only use the heat from the subsurface thus the rest of water and the chemical from the steam are injected again to the subsurface.

Basically, there are three types of hydrothermal energy generation power plants that currently being used in the world: dry steam plants, flash steam plants, and binary steam plants (EIA. 2017). From those three types of the geothermal power plants, the flash steam energy generator plant is the most type that currently being used although the technology of flash steam is more complex than the dry steam, but the leftover water and any condensed steam are being injected again to the subsurface hence making the pressure and resource more sustainable to be maintained (Renewable Energy World. 2018).

Later, another sophisticated technology of geothermal energy had developed for the Sarulla geothermal energy project in Indonesia. The technology called Geothermal Combined-cycle Unites (GCCUs) claimed produce more efficient technology and sufficiently captures the steam from the subsurface then produce heat sustainably without any interference and eludes the reservoir system from the gas exhaustion (Power-Technology, 2018).

3.2.2 Direct Heating

The utilizations of direct heating geothermal energy are the simplest things that geothermal energy could apply. The purpose of direct heating can be fulfilled by the wide of scale, from the households to the multipurpose of commercial industries heating and drying activities.

According to the Lindal Diagram, the requirements of direct heating temperature geothermal are divided into three scales from the lowest 15°C to 200°C. From the bottom temperature around 15°C to 60°C most of the utilizations used for space heating with heat pumps in the fish farming to the air conditioning, the usage of this relatively low heat source used for small industries and also small community use. This low geothermal energy can be utilized in the most of sub-tropical and cold area, since the technology that being used is only simple and could applied with heat pump for the household and small community heating.

Furthermore, at the moderate temperature scale from 80°C to 150°C the binary fluid electricity generation technology applied for building and greenhouses heating to medium industries purpose such as drying agricultural product, stock fish, cement block, and also the top of the temperature (140 to 150°C) could be used for evaporation and canning food process. Later, the capability of moderate temperature that used for direct heating can produce a slight amount of electricity. The amount that being produced may not be used for mass use of commercial electricity generation, but the heat that extracted with current state of technology could be use full for the space heating and making the industries more sustainable in the energy consumptions.

The highest point of temperature normally used for direct heating in the geothermal energy is ranged from 140°C to 200°C. The conventional electric generation that used for direct heating mostly also capable for electricity power plant, the direct heat that utilized in this temperature is mostly joined with the steam that used for electricity generation in the electricity power plant.

At the geothermal energy country generation ranking, USA is the most country that using geothermal energy source for the direct heating and the electricity generation purpose. The country reaches the amount of more than 3.5 GW equivalent in electricity production in term of geothermal energy power generation in direct heating and electricity production.

3.2.2.1. Greenhouse Heating

The greenhouse heating is one of the most applicable direct heating uses of geothermal energy that support the agricultural industries towards mass using of renewable energy for the purpose of commercial use.

The utilization of greenhouse heating with geothermal energy ranked 3rd and 4th worldwide in global ranking of geothermal capacity without and with heat pumps application. According to the data the percentage of greenhouse heating without using heat pumps technology is ranked 3rd with 8.96% of global total share in worldwide capacity, while the heat pumps utilization in greenhouse only have 2.6% shares or ranked 4th in the total world ranking of heat pumps geothermal world capacity.

The utilization of the direct heating geothermal energy in this case is quite low in term of temperature requirement and also applicable in the cold situation when the plants cannot grow in this condition. The application of the green house heating with geothermal energy uses low enthalpy from the shallow to deep well with a help from pump and sometimes heat exchanger. The system from a single well could be applied not for only one greenhouse but also applicable for 2 or even more, depend on thermal gradient of an area.

For example, the low enthalpy of geothermal energy for greenhouse is already applied for more than a decade in Greece. The farmers utilize the heat from the geothermal fluid with the Heat Exchanger. The tools can help the farmer to produce approximately 95°C of hot water. The heat from the exchanger can be spread it to the plants in the greenhouse with the heavy duty steel pipes and the temperature reduced from 95°C to approximately 50°C to prevent over heating the plants. Overall, the heating system can maintain inner temperature of the greenhouse keep 20°C when the outer temperature 7°C, even when the outside temperature drop to 2°C the system can hold the thermal stable in 15°C. The low enthalpy geothermal energy mostly effective being used from October to April, when the temperature start to drop caused by the winter weather (Bakos, 1999).

Furthermore, currently not the only low enthalpy geothermal energy being utilized for the greenhouse heating, since the heat is promising for the farmer, lot of farmer in the sub-tropic area start to exploring their capability of geothermal energy to discontinue their addict in using conventional heat system with scarce resource such as fossil fuels.

3.2.2.2. Bathing and Swimming

The purpose of direct heating geothermal energy in bathing and swimming may not very popular or common to be heard. The geothermal application in this bathing and swimming mostly without utilizing the heat pump and ranked 1st among the other geothermal application in world ranking of worldwide geothermal capacity without heat pumps with 44.74% of the total share.

In this case, the resources can be exploited not only from the subsurface resources but also with the surface manifestations if it is possible. Most of the surface geothermal manifestations are in the fluid forms like geysers and hot pools, since that some surface manifestation could be possible directly used for bathing and swimming such as natural hot spring water in some area.

On the other hand, the subsurface resources of geothermal energy can also be utilized for bathing and swimming. The heat from the ground can be conducted with heat exchanger to make the swimming pool in friendly temperature to be used. Another application also possible to be utilized, the geothermal system also can be used with binary system to make the bathing purpose of households or also community. This system can be assured together with the heating purposes.

3.2.2.3. Heat Pumps and Space Heating

Most of the domination in the direct heating of geothermal utilizations is used for geothermal heat pumps that also may use for building and space heating. Around 70.95% the utilization of geothermal world-wide capacity with heat pumps is used for geothermal heat pumps with multiply utilization (mostly for building) and also 10.74% of total world share is specifically used for space heating. On the other hand, from other statistic of world-wide capacity geothermal utilization without heat pumps said that 36.98% percent of world utilization is used for space heating or placed 2nd under the bathing and swimming purpose who counted as big as 44.74% of total world share. Nowadays, the geothermal purpose of district heating could be found in 12 different states and provide energy for more than 44.772 TJ per year (Bloomquist, 2003).

Space and district heating may also referred as one of the oldest application of geothermal direct uses application. The application started at the early of 14th century in the Chaudes-Aigues Cantal in the France and the district heating still be operated until today. Later, with the development of technologies and the rising of demand, the heat pumps and heat exchangers are used to boost the temperature to the certain levels. Even the general requirement of temperature is around 50°C, with the help of geothermal heat pumps the resources with lower temperature such low as 40°C can be used in some conditions even possibly lower.

3.2.2.4 Agriculture and Aquaculture Use

The shares of these applications in geothermal energy direct application are not as popular as the other purpose. With world total share below 4% the agriculture drying and aquaculture pond heating are currently not very common and popular to be use. Basically the drying of the agricultural is for avoiding the rotten process while storing, faster time in harvesting, and increase the price also the quality of agriculture products (Popovska, 2014), while the aquaculture pond heating wanted for upraising the freshwater or also marine living organisms in a manipulated environment to improve the production ratio (Boyd, 2003).

Principally, air is used as the heating medium for the purpose of draining. There are two options for heating the air as the medium, first the air could be heated by the fluid through the heat exchanger, and second the air can be circulated by the fluid in the heat exchanger with the more complex systems. Since the requirement of thermal for this purpose is relatively low (from 35 to 80°C), low hydrothermal temperature could be used as the heat source for the air that also being used to drying the crops.

On the other hand, the aqua culture process mostly used in colder climates where the usual heater is not economically could be used. The requirement of temperature from this application of pond heating is relatively low from 10 to 30°C. The geothermal heat fluid could also combine with fossil fuel heating system and used to manipulate the pond environment.

3.2.2.5. Industrial Uses

Industrial uses share in the direct use of geothermal energy hold the last rank with less than 3% of total world capacity, both in the with and without heat pumps global share (even in the with heat pumps total percentage, it counted less than 1%). The uses of this application can be applied to many industrial processes such as: process heating, industrial space air conditioning, food and fish drying, pulp and paper processing, textiles washing, even fuel production and oil enhancing.

The industrial uses only need a heat source that low to medium geothermal fields can be supplied. Mostly the heat can be used form 10 to 149°C, and it can be supplied from geothermal, while most of the industries currently using the conventional heat source such as gas and coal (Jóhannesson et al., 2014).

Since 54% of energy use is consumed by industrial sector and mostly still not using the renewables as their main source of energy (EIA, 2016), geothermal can be one of the alternative source that can be used by the industries, with the wide application can be uses.

3.3. Geothermal Energy Technologies

3.3.1. Exploration Technologies

The exploration phase tool of the geothermal mostly adapted from oil and gas exploration technologies. There are 5 different phase in term of exploring the thermal potentials; geochemistry, drilling, remote sensing, geology/stress analysis and modeling, potential field geophysics, and seismic activity. Most of the exploration activities in the searching the potentials of geothermal energy are on the geology and geophysics (GnG) activities (Garchar et al., 2016)

Since the variety of geothermal type and utilization of this energy is volatile, the exploration survey especially GnG mapping can be useful and mostly in the upstream area of geothermal energy, with the map from the survey, the specific types of exploration and utilization can be predicted and adjusted with the needs of utilizations. The process of GnG can also include seismic survey, mapping, remote sensing, geology/stress analysis and modeling, geophysics, and also geochemistry may include as GnG activities. The tools that used in this GnG phase mostly are the tools with the mapping purpose like seismic tools, except the geochemical activities. The geochemical activities in the exploration phase mostly analyzing the fluid contents from the surface and also steam who come from subsurface.

Beside the GnG process, the most risky, crucial and expensive in the exploration phase are the drilling process. The process of making a borehole for extracting the heat from subsurface can spend millions of dollars without a certainty of finding the exact reservoir in one drilling activity. Most of the drilling application is adapting from oil and gas drilling phase, the only different of the geothermal drilling process is the size of the borehole and pipe. Geothermal well size may vary from micro size (<2” well) to the large diameter hole (>8.5”). The micro size hole of the geothermal mostly used for the exploration hole to find the estimated temperature in the reservoir below the surface, while the larger hole effectively use for the purpose of efficiency in the geothermal energy heat extraction (Garchar et al., 2016)

3.3.2. Production and Utilizations Technologies

The production technologies of geothermal energy may divide by two different activities, direct utilizations and electricity power plant utilizations. As it been mentioned before, the direct utilizations mostly used while the capability of the geothermal energy in certain area not big as the electricity power plant requirements.

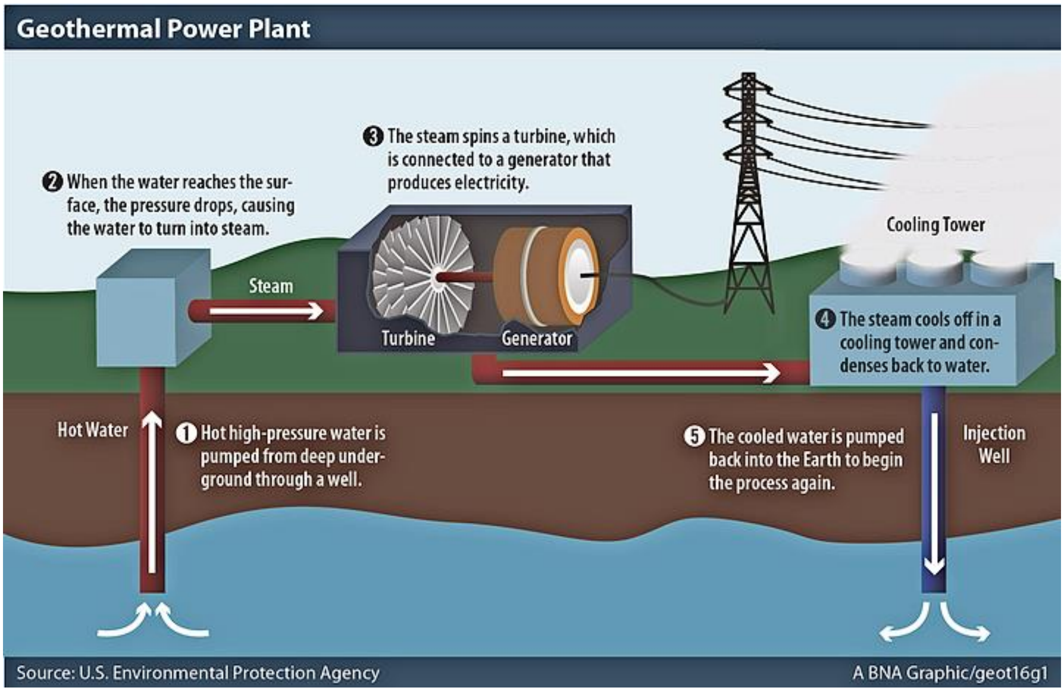

Figure 13, Geothermal Electricity Power Plant (Bloomberg BNA, 2016)

Basically the geothermal electricity power plant can be explained in the figure 13 above. The thermal extraction of this type of geothermal energy is coming from the steam that flowing through the production well. Produced steam in the surface used to spinning the turbine that connected to a power generator to produce electricity. After the heat from fluids extracted, the fluids and steam run into the cooling tower and thus the cooled water being injected back into the reservoir via injecting well, and also as it been also mentioned in the sub chapter of electricity generation above (3.2.1.) above, dry steam plants, flash steam plants, and binary steam plants are the most technologies that used in the electricity generation of geothermal energy.

Later, different with the power plant application, the direct heating uses more volatile and variant of technology in it applications. Firstly, the most direct heat utilization is known as the application of ground-source heat pumps. This geothermal heat pump relies on the constant temperature below the ground. The sub-surface temperature relatively warmer during the winter and also colder in the summer thus the heat sources from the ground can be used for the winter and also can transfer the thermal from the building when the summer time, since the geothermal heat pumps does not a extra ordinary geological conditions such as hot springs to be applied in daily usage. The ground-source heat pumps (GSHP) is also an environmental friendly technology that can reduce emissions 66% cleaner compared with the normal thermal systems that fossil fuels sourced (Omer, 2006).

The GSHP also consists of three different types of systems; open systems, closed systems, and other systems. The systems itself can be chosen by regarding several factors review; geology, hydrology, area and utilization, existence heat sources, and also characteristic of the heated or cooled areas.

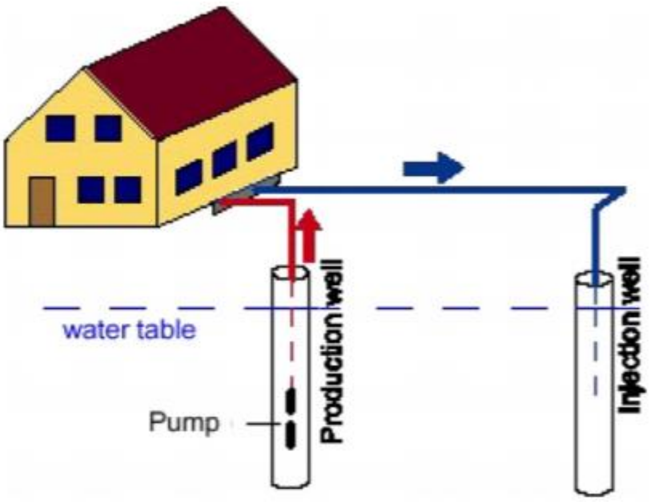

Figure 14, Open Loop Groundwater Heat Pump Doublete (Omer, 2006).

The open loop systems use groundwater or surface water as the thermal exchange media. The systems composed of extraction wells, reinjection wells, and also possibly surface water systems. Later, the water quality and availability of water are the two crucial factors, since the quality of water can add some corrosion, fouling and also blocking the pipe while the minimum 1.5 to 3.0 gallons of water per minute should be pumped between the heat exchanger and refrigerant.

On the other hand, the closed systems of direct heat geothermal utilization mostly using the ground heat exchanger. The pipes who work also as a ground heat collectors or heat exchanger. These pipes are settled up horizontally underground below the soil top layer, but due to restriction in some smaller countries such as Western and Central Europe area, the heat exchanger is connected in the series or parallel for land efficiency, while an American style use more space in a larger area.

Finally, for the systems that classified as “other systems” are the kind of systems that not exactly has a same principle with both of the open or closed systems. Other systems may referred as a systems that may existed already before and could be used as a thermal source such as mine water, tunnel water or also standing column wells. The system may also described as system that happen when there is a differentiation among the subsurface water with the heat bearer liquid without true delimiter.

3.4. Conclusion

From the explanation of this chapter 3, it can be conclude that the geothermal resources may be classified by the surface and subsurface resource. The surface resource of geothermal energy could indicate the massive heat potential of geothermal energy in the subsurface is stored under the ground and could be used for electricity generation and other multifunctional usage. Secondly, the electricity power plant is the most wanted utilization of geothermal energy during the daily use of geothermal energy, since the electricity power plant need a minimum heat to be extracted into electricity, while the direct use of heat extraction from geothermal energy may not only use for house hold heating but would also possibly to support the needs of commercial utilization like drying and agriculture business. Finally, the technological aspect of geothermal energy is mostly adapted by the modified tools of oil and gas exploration and production applications. The exploration phase especially in the geothermal well drilling mostly used the petroleum drilling technology with the special high temperature and high pressure anticipation.

Chapter 4: Determining Current Geothermal Energy Problems

Since the geothermal is not currently applied and used everywhere in a large scale as fossil fuels does, the development and application may lead to several pros and cons that could be separated in three dimensions: physical, technical and also social problems. According to Shortall et al (2015), there are more than ten major issues and problem of geothermal development and utilizations, while the writer also mentioning the positive side of impacts while elaborating the negative impacts itself.

4.1 Physical Problems

The physical problems of geothermal development are the biggest issues regarding the impact, since the geothermal energy located in the beneath the earth surface and the exploitation to the exploration process may affecting the surface with the probability of high risk and bad impact to the nature and also surrounding area of the proposed locations. Natural hazards, atmosphere, land, freshwater, forests, and biodiversity is the main issues that currently the physical problems of geothermal energy development faced.

4.1.1. Natural Hazards

Negative impacts that could be happened in the geothermal energy development are the seismicity induction, landslide and hydrothermal eruption. The risks of these negative impacts mostly possible to be happened in the phase of geothermal explorations and also minor possibility accident in the exploitation phase.

Firstly, induced seismicity and micro-seismicity are one of controversial issue that associated in the Enchanted Geothermal Systems (EGS). At least two projects of EGS are canceled worldwide caused by this problem. Even though in the reality and application of EGS development the micro-seismicity has less effect and even no proven physical hazards for the communities, the seismicity issues still be the public concern when there is a geothermal project in the certain area for isntance Soultz Geothermal Development Project in France. Since the induced seismicity is an crucial tool of reservoir management that very important in the phase of proving the capability of geothermal area in some areas, the further improvement of technology need to be done to increasing the public acceptance of geothermal energy (Majer et al., 2007).

Secondly, Landslide or subsidence is also one of the issues that mostly happened in the geothermal explorations and production phase that majorly happened in the volcanic geothermal areas. As it been mentioned before, most of the geothermal energy (especially hydrothermal) potential is located in the mountain with high inclination areas. Although most of the subsidence happened by the mass use of subsurface water for the irrigation and community utilizations, the large scale geothermal development could also causing a hazardous subsidence. For instance, Wairakei geothermal project in New Zealand caused a subsidence around 15 M, although the minor effect caused by this geothermal project, the systemic disaster is possibly happened with the surrounding areas, thus the specialized technical surveying systems mandatory to prevent the bigger disaster happened (Bloomer & Currie, 2001).

Lastly, although the hydrothermal eruptions is commonly happened in the both of geothermal areas (exploited and unexploited), exploitation activity of geothermal in certain of scale could stimulate the eruption when the pressures exceeding lithostatic, accumulation of steam and/or gas, progressive flashing, and rare condition of addition magmatic heat or gas (Lawless & Browne, 2001). Later, although the condition is relatively rare, preventing hydrothermal eruptions is one of the hazard assessments that should be done by the company/organizations while they developing the geothermal fields (Bromley & Mongillo, 1994).

4.1.2. Atmosphere

Furthermore, atmospheric problems also classified as air pollution that caused by geothermal exploration and extraction activities. The activities can cause greenhouse gas emissions, H_2S pollution, and other toxic gas emissions.

First of all, most of energy and even renewable energy extraction activities can induce a certain amount of distracting greenhouse gas, while avoiding the dependency on fossil fuels utilizations can minimize the unwanted impact causing by the CO_2 gas.

Table 2, Environmental Impact of Energy Sources (Li, 2015)

	CF(%)	Efficiency(%)	CO_2 ①	Water ②	Land ③
PV	8-20	4-22	90	10	28-64
Wind	20-30	24-54	25	1	72
Hydro	20-70	>90	41	36	750
Geoth	90+	10-20	170	12-300	18-74
Coal		32-45	1004	78	
Gas		45-53	543	78	

Referring to the table 2 above, although the greenhouse gas that produced by geothermal energy not as big as the fossil fuels sources (coal and gas), the level of CO_2 is still the biggest among the other renewable energy (PV, wind, and hydro). Later, with the efficiency and water use also the main unbeneficial things from geothermal energy activities, the land efficiency is the main profit that geothermal have according to the table above.

Hydrogen sulfide or H_2S gas is also one of the biggest threats that unwanted in the geothermal energy heat extraction. The H_2S gas could be produced together with the CO_2 and this corrosive gas is dangerous especially if the geothermal source and power plant located on the communal area. For example, most of the geothermal power plants in Iceland are located in nearby the cities or towns, thus the level of hydrogen sulfide in these areas such as the City of Bjarnarflag are engineered in certain model to distribute and predict the concentration of H_2S to avoid disadvantageous and even life threat condition (Juliusson et al., 2015).

Another gas could also being produced in the geothermal heat extraction. The other gases who usually being produced with geothermal fluid and steam beside CO_2 and H_2S are H_2, N_2, CH_4, and Ar. Luckily, in some condition the content of H_2 gas in the geothermal gas could be utilized for another source of energy and utilization. Through some chemical processes the hydrogen can be extracted directly from the geothermal fluids (Flovenz, 2006). Furthermore the excess gasses in minor amount of geothermal fluid such as N_2, Ar, and CH_4, normally are being injected again to the subsurface within the injection well, since a gas like CH_4 is flammable and could endangering the surface if there is a fire contact.

4.1.3. Land

Although according to some another renewable energy sources like solar panel and wind energy the geothermal energy only need fewer place or land to be used, there are some issue regarding the land impact in geothermal energy development and utilization such as habitat loss, soil compaction and also conflict with other land uses.

Since some of geothermal energy resources are located in the conservation areas, the development of this energy could endanger some local species. A case from the geothermal energy development in the Kenya for instance, while the Olkaria geothermal power plant project can increase the electricity rate in the Kenya, the existing geothermal area need to be conserved too. The Olkaria project are located within the Hells Gate National Park in Kenya, with the endangered ecosystem the government need to be aware regarding both of developing the renewable energy and conserving the fragile natural ecosystem in the national park (Mutia, 2010).

Case of soil compaction also could be happened beside the soil erosion. The compaction of the soil normally can be occur while the pre-lease exploration and even can be increased in the post-lease exploration, phase of development and the production activity. In short, while the developments of geothermal site the soil in those areas could become impacted with the heavy equipment to drill the site. Furthermore, these processes even could destroy the soil structure and it would compact the land in some areas and it could loosen in others (US Department of Interior, 1977).

The last common problems is conflict with another land uses. The uses of the land before geothermal power plants being built are very vary. For instance, in some volcanic area the land could be used for tourism, nature and forest conservation, community and local use, and even a local housing area. Since the development area of geothermal energy need to be “clear” in certain scale, the conflict with the other purpose of land use may could still be a problem in the future of geothermal energy, because the subsurface resources of geothermal cannot be moved like the surface condition.

4.1.4. Fresh Water

These days the availability of fresh water is one of the critical issues that being discussed in lot of scientific and governmental forum. One of weakest points in geothermal energy application is some type of geothermal power plants are consuming a lot amount of fresh water to be operated. The geothermal power plant may consume more water than other type of fossil and nuclear power plants. It is estimated the power plant need more than 300.000 acre feet of water to keep the electricity production in 5.500 MWe on the case of Imperial Valey geothermal power plant (Butler, 2012).

Furthermore, the contamination of water also being a problem in geothermal energy development and production phase. The interaction while drilling process and also the steam that used to generating the power plant could also pollute the surface and subsurface water in every chance of interactions (Kerina, 2017).

4.1.5. Forests

Although the geothermal energy use can save the forests and it biodiversity by replacing the traditional biomass, the development of this thermal energy could make such of complicated problem like deforestation and ecosystem loss while developing the energy.

The deforestation of geothermal energy is an old issue. While the geothermal also famously known as green energy with all of its advantage, in some case of geothermal development the opening phase of this thermal energy may need to destroy a ‘little part’ of forest, since some of place that hold this energy would be located in the middle of forests like in Indonesia. The Kamojang geothermal project is one of dozens geothermal power plants that located in the forests and mountains. Since the needs of energy the deforestation cannot be avoided, although the Kamojang project located within the protected conservation forest, and since the beginning of the power plant being build more than 200 ha forests had been destroyed to ensure the electricity project running smoothly (Dachlan et al., 2016).

Same as deforestation problem, the problem of ecosystem loss would maneuver the geothermal development into more complicated especially if the mass use of thermal reserves is located in the remote and fragile ecosystem area. Once again, the deforestation problem would lead to the next complicated stage like ecosystem loss. The wildlife ecosystem in the certain area inside the forest could be endangered with the development, while the impacts by the range of non-condensable gas also other element like arsenic, mercury, etc. would possibly affect and intervene the ecosystem in long and systemic way (Mutia, 2016).

4.1.6. Biodiversity

While conserving biodiversity and increasing the share of renewable energy are part of the Sustainable Development Goals (SDG's), some project development of geothermal energy could lead the biodiversity into endanger by stimulating the habitat loss and disturbing the rare ecosystems in the geothermal potential areas. The disturbance of habitat in some geothermal area is now currently one of concerned issues that faced by some government, Indonesia for instance. The Indonesian Government has to lease the conservation of "virgin" forest in Slamet Mountain to ensure the development of geothermal field, while the Slamet Volcano also known as the habitat of Javanese Puma an endangered species who lived in the local areas.

4.2 Technical Problems

The technical problem of geothermal energy mostly based the aspect of technology and engineering dimension, since the perfectionism in technical aspect would lead a geothermal energy project into a certain goals of success while the weak performance of engineering could follow the project into technical failures who also lead into other problems in physical and social dimensions.

According to the issues of geothermal sustainability aspect who developed by Shortall et al. (2015), most technical problem is in the theme of consumption and production patterns. Failed waste management, overproduction and exploitation, also cost of geothermal power plant turbine can make the energy project even more complicated.

Firstly, a failure waste management in the case of geothermal energy production could contaminate the environmental who possibly lead the problem into another account. As it been mentioned in the physical problems, steam who coming from the subsurface could contain dangerous chemical materials and corrosive gases that could endanger the surrounding nature and even the local community who live near the site of geothermal project.

Secondly, since most of the geothermal projects are forecasted for a long period, the aspect of hydrothermal reservoir should be maintained and monitored carefully because the loss of pressure in the geothermal reservoir could reduce the performance of electricity production.

Thirdly, the utilization of steam to produce electricity is very dependent on the turbines itself. The steam turbines who convert the steam into electricity are the one of the most expensive in the initial investment regarding on geothermal energy development. The dilemma of choosing the right options between concerning on capital efficiency or focusing on maximizing the engineering design who will directly affect the performance of the power station for an extensive period, since focusing on the reducing geothermal operation capital and initial cost is currently the issues that faced in the plan of development geothermal energy (Morris & Robinson, 2015).

In addition, the maintenance challenge of geothermal power station in extent to keeping the electricity production performance in a certain limit also currently the issues that every most geothermal power plant operations being faced. For instance, after producing electricity for two consecutive years the production capacity on the Olkaria II power plant in Kenya reduced from 35.0 MWe to 34.3 MWe. This is a proven evidence that the geothermal power station need a periodic treatment to keeping the productions in a specific level, since a loss of MWe productions can lead into a major financial disadvantages (Ndege, 2006).

4.3 Social Problems

At the last dimensions of geothermal energy problems, the social aspect is the most complicated parts beside the physical and technical part. The social problems may extent to poverty, health, education, demographic, and economic development, since the aspect of economical side also being the important part of the social context in this elaboration of society issues of geothermal energy development.

4.3.1. Poverty

Since the massive geothermal potential mostly located in the remote and undeveloped areas, poverty is a common problem that developer faced especially for the local community who lived in the areas for a long period. While the increasing aspect of income, salaries and higher living standards may be the positive aspect while tackling the poverty in the geothermal development surrounding areas and community, the developed site of geothermal power plant areas also would rising up the property prices that would affect a certain kind of people who can afford to buy a property in the surrounding areas. Meanwhile, a case of community displacement in the surrounding development areas of geothermal energy also possibly leads into poverty. As it been mentioned, a massive potential of geothermal areas mostly located in the rural and some of residence may not legally owned the land that they are staying at, since the geothermal developer company could enforcing the local communities to leave with the legal permit that they have to developing the site like what happened in the relocation of Maasai families caused by Kenya Electricity Expansion Project (KEEP) geothermal operations (The World Bank, 2013).

4.3.2. Health

Furthermore, with the bad impacts coming from air smell disturbance, poisonous gas, water contamination, and also pollution that come from noise would causing a complicated health problems to the society. Mixture between odor nuisance and poisonous gas emissions could come from geothermal wells problem like the hydrogen sulfide in a small amount, even the bigger amount of this gas could endanger the peoples nearby the geothermal power plant. A case of hydrogen sulfide poisoned a man who once collapsed while he wanted to cleaned unused oil inside a vacuum pump of geothermal turbine. The man instantly died after he cleaned the leftover oil thus the hydrogen sulfide poisoning was suspected since the amount of H_2S gas was detected over the certain limit and from the toxicological analysis some content of sulfide was founded in the man blood (Kage et al., 1998). Later, to ensure and minimize the risk of another H_2S gas leak an air quality, impact assessment with AERMOD (Atmospheric Dispersion Modeling System) needed before the geothermal power plant being built, especially in the populated areas (Hosseinzadeh, 2014). Another assessment regarding the noise level also needed to prevent disruption of the loudness in geothermal production activity, since high level of noise disturbance could affect the loss of hearing or even a hearing breakdown (Ndetei, 2010)

Same with air pollutions from toxic gas, ground and surface water contamination from geothermal exploration and production waste can be harmful for the human life. Since geothermal fluids could possibly containing dangerous materials such as arsenic, mercury, and also boron who could invade the ground water reservoir that mostly used for daily life (Baba & Tayfur, 2011).

4.3.3. Education

While educational especially in formal sectors in geothermal energy activity area most likely improved with possibly allocated CSR allowance in education facilities, an advance explanation according the geothermal energy business with the advantages to the surrounding area should be promoted to educate the local people about the energy itself and also increase the social acceptance regarding the geothermal energy.

Education level in the remote and rural area mostly not as high as urban area, while as it mentioned before, the high geothermal energy potency mostly located in the volcanic mountain and not developed neighborhood.

A minimum stage of understanding and communication problem leads the geothermal development a public rejection in some rural area. Lack of information regarding the energy and its technology from the company, then also low involvement of local community would make the trust and acceptance from the local stakeholders away (Payera, 2018), thus the educational approach (formal and non-formal) is the key to increasing local acceptance, while another important points like communications and public involvement also needed.

4.3.4. Demographics

Demographic factors in the geothermal energy also play an important role, not only for the positive social change in the manner of using green energy, another application also could be utilized to boost the local economy like eco-tourism.

Despite the goods side of demographic factors, the geothermal further development may disrupt the conservative practice by the local inhabitant. Some physical disturbance during the post-explorations activity like construction and extraction process may cause several pollutions such as sound and dust. Furthermore, assimilation between the site workers could also involving the culture and the way of thinking from local people in the surrounding areas. Later, another factor like a steady supply of electricity could also change the local community manner in the daily live since in this part involvement of education is also a crucial point to be included.

Another point that also played important role in this demographic elaboration like livelihood displacement and resettlement also could not be thrown away. As it mentioned in the poverty parts, the resettlement could also be a problematic case. The community displacement who caused by resettlement once happened in Kenya and could possibly to be happens again in the other part of the world while developing this energy.

A Livelihood displacement could also be a good and negative impact. From positive point of view, a new job could be settled and the people could be stimulated for another way to produce money and be creative. From another side, the old livelihood who also trademarked as their cultural identity could be disappear with the new job that created by the geothermal energy activities, since the local may more focused into the new sources such as retail, food services, and providing accommodation (Kurgat & Omwenga, 2016).

4.3.5. Economic

Last factor who may also possibly nominated as the most important beside all of the mentioned factors above is the economic factor. Energy and economic growth are two related aspects that substantially affect the development target in certain scale. According to the energy trilemma principle the energy security, equity in social aspects, and environmentally sustainable is the keys towards reducing the conflict in the energy production.

While the development of geothermal energy in some area may also boost the area development with the availability and security of electricity, the job differentiation between the high skilled worker and the local inhabitant would increase the gap between the locals and the comers, since most of project in general not always involve and recruit the local people in their surrounding site with the lack of skill problem, hence the direct long-term jobs would predispose the socio-economic factor and denounce the energy trilemma conceptual especially in the equity of social aspects.

4.4. Conclusion

There are three dimensions of problem that mostly faced during the development and extraction of geothermal energy: social, physical and technical. These three controversial aspects are coming from both of internal and external factors. Firstly, the social problems from the utilizations of geothermal energy mostly caused by the equity who demanded by the surrounding geothermal energy areas of development. These factor mostly faced by the development of power plant utilization on geothermal energy, since the direct utilization like direct heating etc. are only require smaller areas than the electricity power plant, in addition the most of social problems can be classified as an external factor of geothermal energy development. Secondly, the physical problems of geothermal energy are mostly the environmental hazard that coming from the subsurface that can caused problems like odor, noise, and poisonous gas leak. This internal aspect of problems would be tackled up by the engineering solution. Finally, the technical problems of geothermal energy utilization are mostly about the internal factors like the heat capability, pressure depletions, and the other initial factors from the capability of geothermal field that possibly overcome by an initial planning and also engineering solution.

In other words, the first two dimensions like technical and physical problems of geothermal energy could be tackled up by an engineering and planning approach that could be finished by adding more approach of technical knowledge and investment in the engineering solutions. Different with the two problems before, the social problems are more complicated since this problems are involves lot of people with the different interest that needed a compact solution to satisfy the society and the other involved stakeholders.

Chapter 5: Geothermal Energy Situation and Applications in the Netherlands

The position of chapter 5 in this thesis is intent to show an illustrative case of geothermal energy potential and it possibility of mass utilizations and applications in the Netherlands.

Geothermal energy in The Netherlands is currently not utilized and developed very well in both of the direct use and electricity production. Since most sources of energy that the country nowadays use are based on fossil fuels like gas and coal (IEA, 2017), thus the Netherlands start to increases the share of renewable energy from around 5% into 14% in the 2020 (below the EU average target within 20%) and with an optimist target of 20% on the 2030 (The Netherlands Government, 2018).

Furthermore, with the 4 different seasons the country need a different amount of energy in every season, while it mostly peaked during the end of autumn to the end of winter thus the constant source of energy like geothermal is needed in order of fulfilling energy needs to the society.

The cores of this chapter is to elaborate on the findings from the previous chapters, to ensure what kind of resources that the Netherlands have, typical applications that suitable for the country and its society, problems could be faced while the development and extraction processes, and what are the targets of the Netherlands to develop the geothermal energy in the future.

5.1 Netherlands Potential Capability of Geothermal Energy

From the geographical perspective, the Netherlands can be called as a relatively flat country with 322.7 meters above sea levels is nominated as the highest point that the country has (WorldAtlas, 2018), although there is some part of the Kingdom of the Netherlands that located in the Caribbean who has some ground elevation more than 322.7 meters.

With the flat ground level that the Netherlands have, there is unlikely any volcanic activity and mountain to be found around the surrounding areas of the country since the exploration activity in order to find the potential reserve of geothermal energy need to be more advanced as there is probably no strong evidence regarding geothermal energy surface manifestations and also high geothermal gradient. So it can be assumed that to generate electricity from geothermal energy, more effort is needed since the possible heat would be stored under the kilometers deep under the ground.

On the other hand, there are still other geothermal applications that could be explored and exploited from this typical flat and low volcanic activity country. Direct utilizations like space heating, factory processes, also agriculture and aqua culture are more suitable with the possibility of very low to low temperature of reservoir that the Netherlands has in the current economic and technological capability.

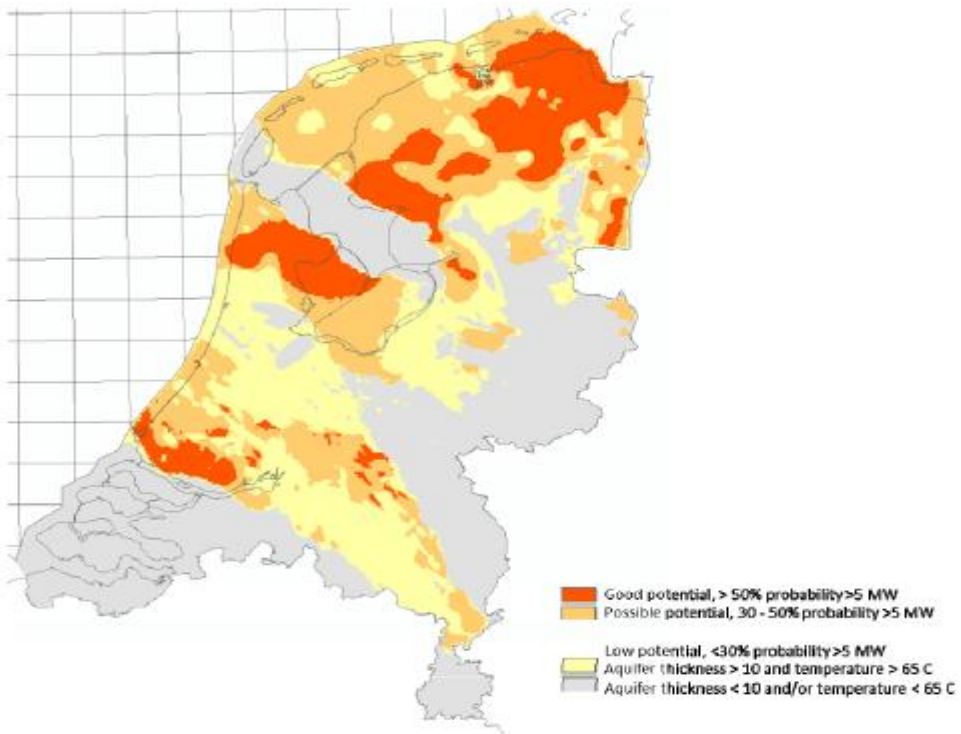

Figure 15, The Netherlands Map of Geothermal Potential (Pluymaekers et al., 2014)

According to the figure 15 above, who was made by the scientist group of the Netherlands Organization for Applied Scientific Research (TNO), the Netherlands holds some good and possible potentials of hydrothermal aquifer that could possibly utilized for the direct heating geothermal application.

In order to classify the reserve that the Netherlands has, TNO classified the three different classification of the heat from the subsurface heat content with Heat in Place (HIP), thermal that could be extracted with the more advance technology or Potential Recovery Heat (PRH), and the economically reasonable to be utilized on the subsurface application with Recoverable Heat (RH).

Firstly, the TNO found the total of initial heat of reservoir fluid approximately as big as 820.000 PJ, the estimation of this hydrothermal initial reservoir heat is increased significantly from the early study that reported the HIP hold 90.000 PJ of heat. Later, the

Dutch organization also considered the amount of recoverable heat hydrothermal reserve from the geological mapping perspective could supply 85.000 PJ of heat or would be compared with 70% amount of recoverable energy that can be derived from the gas field of Slochteren in the Groningen Province (Pluymaekers et al., 2014), while the amount of RH would be increased in the meantime with the development of geothermal extraction technology.

These good and possible hydrothermal that located in the province of North Holland, Friesland, Zeeland, Groningen, Drenthe, some part of Utrecht and Flevoland would give another options of energy source, since the good potential have a big percentage with more than 50% possibility and hold estimated temperature more than 65^{o}C, the possible hydrothermal potentials could be used for range of options such as cold storage, space heating, drying of agricultural products and stock fish, also possibility of cement block drying, while the 'Possible Potential' have a moderate percentage in the range of 30-50% and same aquifer temperature in more than 50^{o}C.

On the other hand, with more than 470 gas and 40 oil fields that the Netherlands has, potency of geothermal energy extraction from existing oil and gas wells also should be counted. A case study shown that the accidentally produced water from the abandoned gas well at Texas could produce a net power generation as big as 340 kW from a single well, hence with the numerous well from hundreds of the Netherlands oil and gas fields could also be considered as a potency of geothermal energy that the country hold (Soldo & Alimonti, 2015).

The Netherland potency of geothermal not only limited in the hydrothermal aquifer and thermal gradient in the oil and gas wells. The country also could also use the existing shallow geothermal energy heat closed system with utilize the ground heat exchanger in the parallel for the land use efficiency, meanwhile the utilization of shallow water reservoir also could be used for the application of cooler system in the summer.

5.2 Netherlands Geothermal Energy Resources

Since there is no volcanic activity in the Netherlands, there also no strong evidence found regarding the surface geothermal manifestations like geyser, hot pool, and warm soil in the surrounding areas of the country. In different circumstances, the Netherland hold aquifer of hydrothermal systems with a classification of low to possibly middle temperature reservoir in the subsurface.

In addition, the Netherlands also possible to use the surface water also shallow geothermal resources like water reservoir and application of ground heat exchanger as heat medium that could be derived during the winter (Zeiler, 2017).

To sum up, the resources of geothermal energy in the Netherlands are mostly located in the subsurface area, since there are no manifestations of geothermal found the surface water like stored sea water is the only media that could be used for thermal options.

5.3 Netherlands Geothermal Energy Applications

Historically, the application of geothermal energy in the Netherlands was started during the start of 80's. The utilization of the energy was initiated with the superficial geothermal use, with the purpose of cooler and winter heating energy storage. Later, the research during the 80's was focused for the purpose of community space heating like building and medium community areas, then since the shallow subsurface water could be found in most of any location in the Netherlands, during these time lot of fresh edifices were applying the water as their media to reserve the heat and energy.

Later, during the next 20 years after the first application of geothermal energy in the Netherlands, the Dutch started drill a deep geothermal well with 1.600 meters total depth to explore their potential of deep geothermal energy in the North Brabant. Unluckily, the deep geothermal that was purposed for agricultural activity was failed since the project was not economically feasible and the water production was not enough to fulfill the needs of the agricultural purpose thus the next deep geothermal well in the North Brabant was terminated due to these reasons.

With the experience from the failure of their first attempt of deep hydrothermal wells, massive cost estimations, and the low price of oil and gas, the second proposed deep geothermal well exploration in the Nalldwijk who located at the South Holland province was rejected by the Dutch Government. At least during the period of 1975 until the year of 2000 more than 20 million euro was spent without any massive progress in term of energy and heat generation from the geothermal source (Heekeren & Bakema, 2015).

Another turning back point was happened during the period of 2000's. The factors of gas price rose, technological development in thermal and cold storage utilizations, and also the societal market demand of clean energy rising up. These reasons encouraged the stakeholders from different point of view and created a legal platform that called *The Stichting Platform Geothermie* (SPG). The SPG member consists of energy companies, multilevel authorities, R&D organizations, etc. and purposed to promote the national deep geothermal energy expansion then also educating the Dutch society regarding this kilometers deeply thermal energy. As a result, the involvement of the SPG affords the initial success of the Dutch deep geothermal project that mostly used for the greenhouse purpose.

Although the thermal storage already called as not relatively new technology, until 2014 the Netherlands geothermal is not still utilized and developed very well, it could be seen from the figure 16 bellow even if the number of deep wells are rose from 2 into 13 wells from 2008 to the year of 2014 all of these geothermal wells are used for direct purpose of heating.

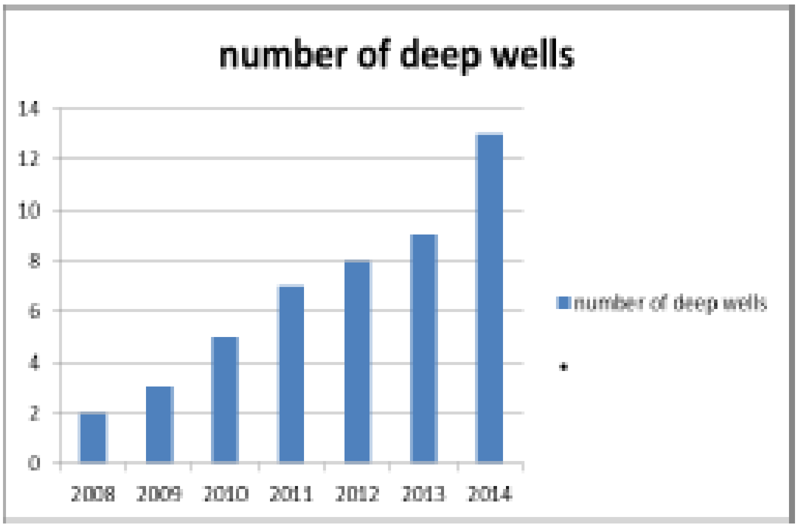

Figure 16, The Netherlands Deep Geothermal Wells Growth (Heekeren & Bakema, 2015)

Since the Netherlands are world 2nd largest agriculture exporter in the world ((The Netherlands Government, 2015), at least during the 2014 most of deep geothermal wells are owned by the horticulture companies: 6 wells are owned privately and 5 wells operated by the joint ventures between horticultural and neighboring, while the 2 others owned by municipalities and joint venture between the energy provider.

During the period of 2015 to 2016, there were 8 additional deep geothermal wells completed (3 in 2015 and 5 in 2016). Although the drilling process of geothermal wells were successful, there were several issues regarding a technical problem that caused a production delay, for instance the CAL-GT-1 & 2 wells of Californie Lipzig Gielen installation and PLD-GT-1 & 2 of Poeldijk Installation were unable to start the operation in the earlier of 2017 (the Netherlands Ministry of Economic Affairs, 2017). In other words, there are 16 installed geothermal installations on earlier 2017 at least, but only 12 of them that being operated.

Regarding the figure x below, more than 2.681 tera joules (TJ) cumulated from the 12 operated geothermal energy installations in the Netherlands. This amount of energy and the geothermal wells are always increasing since the year of 2011, and even the heat production would improve significantly with the other geothermal installations that are still in the progress to be utilized.

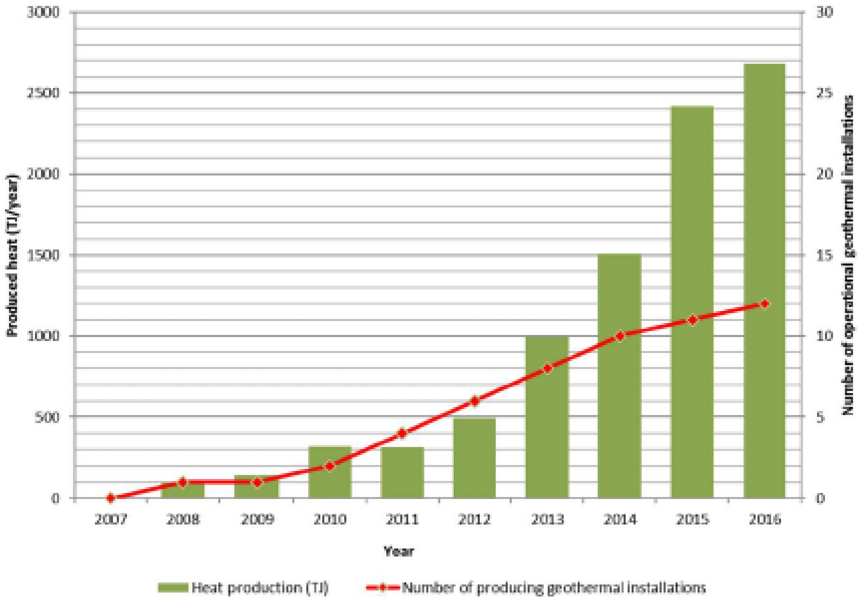

Figure 17, Geothermal Heat Production and Installations in the Netherlands (the Netherlands Ministry of Economic Affairs, 2017)

Another report from the Ministry of Economic Affairs in the Netherlands (2017) said there are also some oil and gas also produced from the geothermal wells, at least more than 7.500.000 normal cubic meters gas and 130 standard cubic meters of oil are co-produced in the Dutch geothermal Installations (see table 3 below).

Table 3, Produced Energy from the Netherlands Geothermal Installations (the Netherlands Ministry of Economic Affairs, 2017

Year	Energy produced (TJ)	Co-produced gas (x1000Nm^3)	Co-produced oil (Sm^3)
2008	96*	-	-
2009	142*	-	-
2010	318*	-	-
2011	316*	-	-
2012	495*	-	-
2013	993*	-	-
2014	1509	3267	429
2015	2417	4378	186
2016	2681	7670	130

From another perspective, the utilization of geothermal in the Netherlands could also help the crude oil production in the country. Since the hydrothermal reservoir in the Netherlands is come from the same characterization and rocks like the hydrocarbon does, the injection of hot water that produced during the geothermal operations to the oil wells would reduce the viscosity of crude oil then improve the productivity of mature petroleum wells and reservoir ((Ziabakhsh-Ganji, et al., 2018).

5.4 The Netherlands Possible Geothermal Energy Problems

As it been elaborated in the previous chapter, there are 3 dimensions of geothermal energy problems that mostly happen nowadays. The matters of social, technical, and physical problems are currently happened globally during the development and extraction of the geothermal energy.

Since the mass utilization of geothermal energy in the Netherlands is still on the early phase development stage, there is a possibility of problems that could possibly happened during the further development of this thermal energy.

5.4.1. Possibility of Social Problems

Firstly, the Dutch society currently faced with the problem of several earthquakes that mostly happened in the gas extraction areas in the province of Groningen. The province hold a big reserve of gas that exploited massively by the NAM Corporation to fulfill the energy needs of the society. Later, since the geothermal exploitation mostly adopt the petroleum exploration technology especially during the well drilling phase and the huge potential of the Dutch hydrothermal energy is located at more than 1.600 meters depth, there is a public worries regarding the safety and risks of this deep thermal energy (Think Geoenergy, 2017).

Furthermore, the public apprehensive of this energy also could lead into a demographic, health and also economic problems, thus the Dutch Government need to prevent the possibility of disaster that concerned by the public while the extraction and development of this energy.

5.4.2. Possibility of Technical Problems

Secondly, the technical aspects of geothermal energy may always be a concern while developing the energy. As the sufficient heat and pressure are needed to extract the thermal into the electricity, the Netherlands may need to search for deeper reservoirs that contain a hotter temperature that could be extracted into electricity. For instance, a single well with 2212 meters depth from volcanic areas in Indonesia can produce up to 19 MW thus the installed capacity of an geothermal area could produce more than 200 MW of electricity (Think Geoenergy, 2018), while heat that the Netherlands have with the current application could only supply the direct utilizations for heating and mostly used for green house.

Other technical issues like corrosion, safer drilling technologies, and gas prevention leak technologies would be suitable to be concerned in the development of geothermal energy In the Netherlands.

5.4.3. Possibility of Physical Problems

In the Netherlands physical aspect of geothermal activity would be a big concern that may induce another social and also technical problem. Physical problems that consist of natural hazard and atmospheric problems would be a major obstacle for the geothermal energy development, while the other physical issues like biodiversity, land, deforestation, and fresh water would only be minor issues compared to the issues before, as the Netherlands currently only use the geothermal energy for direct heating.

As it been mention before, the most concerned issues during the development and utilization of geothermal energy in the Netherland is natural hazard or more specifically to be mentioned is earthquake. Since geological mitigation like earthquake is one of major problem during the wells sourced energy like oil and gas extraction, the geothermal exploitation would also inducing earthquake. Even more, the exploration processes like geophysical seismicity and drilling can also causing natural hazard incidents like gas leak and even a disruptive major blowout.

Furthermore, atmosphere problems such as H_2S gas leak and the other gas emission would be an aspect that also giving bad impact to the surrounding areas of geothermal activities. While the H_2S gas leak is a global concerned issues that currently faced by the most of the geothermal operator, the other gas and chemical pollution could also be a threat that disrupting the areas if it not prevented before.

In addition, some minor caution like fresh water (both of ground and surface water) contamination would possibly be a greater problem, since the demographical society are using both of the water during the daily life for crops, transportation, household etc., while the deforestation would not massively be a threat since the geothermal installation of direct use is not as big as the electricity power plant.

5.4 Further Development of Geothermal Energy in the Netherlands

Geothermal energy in the Netherlands is entering the new phase, since the Dutch trying to improve their share of renewable energy and the depletion of gas production in the Groningen gas field urge the Netherlands Government to improve their capability of other source in energy, especially renewable energy.

As a supporting scheme and subsidy, the Dutch Government trying to stimulate the market energy player to invest in hydrothermal energy with the SDE+ (Stimulation of Sustainable Energy Production or *Stimulering Duurzame Energieproductie* in Dutch). The SDE+ started in 2013 as an financial subsidy or incentive for the operator who generate renewable energy. As some renewable energy project not eternally profitable, the SDE+

stimulating the renewable energy operator with some incentives for the unfavorable gap in number of period for renewable electricity, gas and heat or mix between renewable heat and electricity (The Netherlands Enterprise Agency, 2018).

Table 4, Phasing and Rates for Geothermal in SDE+ (The Netherlands Enterprise Agency, 2018)

2018	Phase 1 From 9 am 13 March	Phase 2 From 5 pm 19 March	Phase 3 From 5 pm 26 March to 5 pm 5 April	Base energy price	Provisional correction amount 2018	Maximum full load hours per annum	Maximum subsidy period (years)	Operation must start at the latest within (years)
Geothermal	Maximum base amount / phase amount (€/kWh)			(€/kWh)				
Geothermal heat								
• ≥ 500 m deep	0.053	0.053	0.053	0.016	0.017	6,000	15	4
• Conversion of existing oil and/or gas wells, ≥ 500 m deep	0.053	0.053	0.053	0.016	0.017	6,000	15	4
• Expansion of production installation with at least one extra well, ≥ 500 m deep	0.034	0.034	0.034	0.016	0.017	6,000	15	4
• ≥ 3,500 m deep	0.060	0.060	0.060	0.016	0.017	7,000	15	4

As it can be seen from the table x above regarding the phasing and rates for the geothermal energy criteria, the SDE+ subsidy can last until 15 years long with 4 years of construction since the scheme granted to the contractors. There are 4 options and criterias that suitable for the subsidy scheme: geothermal with more than 500 meters depth, oil and gas conversion wells within deeper than 500 meters, installation expansion with additional wells with more than 500 meters deep, and lastly is ultra deep geothermal with more than 3.500 meters deep. In addition, another administrative requirement such as geological model that suitable with TNO (Dutch Applied Science Organizations) and geothermal exploration permit from the Dutch Mining Act (or *Mijnbouwwet* in Dutch) also required before applying the SDE+ scheme.

Later, at least during the autumn round of 2017 SDE+ application who was announced in the middle of May, there were 5 new geothermal projects that accepted for this subsidy scheme. The Amerlaan geothermal, ECW Geo Andijk, Hoogweg Aardwarmte, Ennatuurlijk B.V., Agriport Warmte, are 5 chosen project that granted the SDE+ scheme with total estimated 149.5 MW capacity (Think Geo Energy, 2018).

Moreover, according to the figure 18 below, the geothermal (or *geothermie* in Dutch) energy ranked 3rd in the Dutch SDE scheme after onshore wind energy (or *wind op land* in Dutch) and solar energy (or *zon PV* in Dutch). This rank of SDE+ subsidy granted indicate that the geothermal energy is not a main renewable energy that cosen by the energy companies or market player in dutch for certain kind of reasons, since the wind energy and solar panel morelikely to be improves year by year, although the subsidy may rise and improve the number of geothermal instalations in the Netherlands.

Figure 18, Subsidized Energies by SDE+ on Autumn 2017 (The Netherlands Enterprise Agency, 2018)

In the mean time, the country also have a long term target about the number that can be seen in the table below. At least 32% of gross electricity production of the Netherlands is come from the geothermal with the projected electricity consumption exceeding 50 TWh in 2050, while the country currently does not have a geothermal power plant that sufficiently could produce electricity.

Table 5, The Netherlands Long Term Target and Economic Potentials (Van Wees et al., 2013)

Gross Geothermal Electricity Generation (TWh)	Geothermal Electricity Target in the NREAP (TWh)	Geothermal Economic Potential (TWh)	Geothermal Economic Potential (TWh)	% of geothermal in gross electricity production	Geothermal Economic Potential – Installed Capacity (MWe)
2010	2020	2030	2050		
0	0	0.23	51.76	32%	6 565

Another possible added option, the Netherlands could also convert their mature oil and gas wells or also use the oil and gas existing wells to produce heat while producing the crudes. Since the hybrid utilization are applied globally the Dutch would also implement and improve their unproductive wells into renewable energy sourced energy wells like geothermal energy (Soldo & Alimonti, 2015).

5.5 Conclusions

Same like the other place in the world, the most suitable geothermal energy that could be massly used in the Netherlands is the hydrothermal energy. This energy could be utilized for multi direct utilizations not only to support and supply the heating needs of the society but also could be used for the industrial purposes. Later, the Netherlands also could utilize hydrothermal energy in a short term for direct heating and a possibility of electricity generations in the medium to long term.

In addition, the development of geothermal energy in the Netherlands could also inducing physical problem like an earthquake who also similar like the oil and gas extractions problem in the province of Groningen.

In the end, the Netherlands has a sufficient supporting scheme and optimist long term target in order to stimulate the share of renewable energy, especially geothermal. Although the geological and geophysical conditions of the Netherland unlikely to hold big potentials of geothermal energy compared to countries like Iceland and Indonesia, the Dutch Government still make geothermal energy as their important options for generating heat and electricity from renewable energies.

Chapter 6: Conclusions

Finally, in order to acknowledge the main research question and 2 other sub-questions, the elaboration from the previous chapters would be concluded in these 7 points of answers:

1. Geothermal energy could be described as every heat or energy that coming from the surface to the subsurface of the earth and classified in the 5 different types: earth energy, hydrothermal energy, hot dry rock energy, geopressured energy and magma energy, while the most used type of geothermal energy is hydrothermal energy.
2. The geothermal energy resources could be elaborated by 2 aspects: surface and subsurface resource. The surface resource may know as geothermal subsurface manifestations that induced by the heat conduction from the heat source below the ground or possibly transferred by a rock properties friction while the subsurface resources are the heat source that placed below the ground such as heat reservoir, magma, etc.
3. Geothermal energy is a multifunctional energy that can be used in several ways for the society from household heating, manufactory purpose, agricultural and aquaculture needs, drying utilizations, electricity productions, and even the hot water from geothermal energy could possibly use for stimulating heavy oil production in the old oil well.
4. Nowadays geothermal energy utilizations mostly used by two different applications: direct heating and electricity production. The applications of direct heating is a utilization who uses constant or/and higher temperature compared from the surface in shallow or deep subsurface, while the electricity production of geothermal energy required a high temperature steam to generate turbines that enable producing electricity.
5. The problems of geothermal energy could be separated in three different characterizations. Firstly, the geothermal main physical problems is about H_2S gas that normally produced while the heat extraction process running, since the gas is poisonous and could endangering the surrounding peoples life and even communities. Secondly, technical main problem in geothermal energy is how to make the heat sufficient for supplying heat and electricity in the same time, since the electricity is needed in every society daily life and high temperature reservoir is needed in the electricity production. Lastly, demographics problem like livelihood displacement are the main social problems, since most of huge reserve of geothermal energy located in the remote areas with indigenous society, the development of geothermal energy in these kind of area may disrupt the local people daily activity or even dispossess the local indigenous land and their conservative way of life.

6. Although the Netherlands reserve a possible recovery heat (PRH) as big as 85.000 PJ the applications of geothermal energy in the Netherlands are still at the development stage. Although the Dutch government have a subsidy scheme that could stimulate it development, the geothermal energy is not main options for renewable energy, while the country have optimist 32% of gross electricity production, until 2017 there are only 12 geothermal heat installations without electricity productions.
7. From the elaborations in the several chapters before, geothermal energy hold very huge potentials to be used in the middle to long term future for multiply usage in different places around the world, even though geothermal energy cannot 100% replace the fossil-based energy, the energy would be a good replacement for heating and electricity productions.

To conclude, the geothermal energy is not the main options of renewable energy that being chosen globally in the meantime. From all of the geothermal generator nations, there are only three countries that touch the minimum 1 GW installed capacity, with the USA as the world biggest player with the 3.5 GW capacities, with the most type of geothermal utilized is the hydrothermal energy with the subsurface hot aquifer reservoir resources.

Later, the geothermal energy could be used globally especially with the simple direct heating utilizations while the most wanted form of geothermal energy application is the electricity power plants. Since, this type needed a higher steam temperature than the direct heat utilizations, the electricity production by the geothermal power plant are currently not being utilized massively in the current time all over the world. There are only some places in this world that known as a big player of electricity production by geothermal energy like Iceland, Indonesia, and also Filipina. These countries located in the high volcanic activity areas since the finding of subsurface heat reservoir shallower than the non-volcanic areas.

In a short to medium term, the researcher found that the geothermal energy would not be able to be a 100% alternative for the fossil energy, since the most precious energy that the geothermal energy could be produce is electricity and it could not be utilized globally in every areas. On the other hand, the geothermal energy could be substitutions for heating options globally and improve the renewables electrification ratio in the current time, and also the development of other type of geothermal energy beside hydrothermal like magma and earth energy would also boost the future utilizations of geothermal energy into the next level.

In the end, during the development and utilization of geothermal energy there are three most problems that currently faced all over the world: social, technical and physical problems. The social aspect of this problem mostly tackled with the complex resolutions, since the conflict of different interest by multi stakeholders usually happened during the development of geothermal energy especially in the electricity power plant areas, while the technical and physical problems only need an advance engineering solutions to be neglected.

References

1. Stober, I., & Bucher, K. (2016). Geothermal Energy From Theoretical Models to Exploration and Development. Berlin: Springer Berlin.
2. International Geothermal Association. (2004). What is Geothermal Energy? Retrieved March 25, 2018, from https://www.geothermal-energy.org/what_is_geothermal_energy.html#c347
3. Institut Cartografic I Geologic de Catalunya. (2018). What is a Geothermal Reservoir and Type of Geothermal Reservoirs. Retrieved March 27, 2018, from http://www.icgc.cat/en/Citizens/Learn/Geological-resources/Geothermics/What-is-a-geothermal-reservoir-Types-of-geothermal-reservoirs
4. Kiruja, J. (2011). Direct Utilization of Geothermal Energy. Shot Course on Exploration for Geothermal Resources. Nairobi: United Nations University.
5. Eliasson, T.E., Þórhallsson, S., Steingrímsson, B. (2008). Geothermal Power Plants. Geothermal Project Management and Development. Entebbe: United Nations University
6. Lund and Boyd (2015). Direct Utilization of Geothermal Energy 2015 Worldwide Review. World Geothermal Congress 2015. Melbourne Australia.
7. Popovski, K. (1999). Direct utilization of geothermal energy. Klamath Falls, Or.: Geo-Heat Center. Oregon Institute of Technology.
8. Saptadji, N. M. (2001). Geothermal Energy Engineering. Bandung: Bandung Institute of Technology Press.
9. Bakema, S. & Schoof, F. (2016). Geothermal Energy Use, Country Update for The Netherlands. Strasbourg: European Geothermal Congress 2016.
10. Wees, V.D.J., et al. (2013). A Prospective Study on The Geothermal Potential in The EU. Intelligent Energy Europe Programme of the European Union.
11. Mburu, M. (2013). Geothermal Energy Utilization. United Nations University. Short Course on Exploration for Geothermal Resource. Nairobi: United Nations University.
12. Think Geoenergy. (2018). Top 10 Geothermal Countries Based on Installed Capacity. Retrieved May 20, 2018, from http://www.thinkgeoenergy.com/top-10-geothermal-countries-based-on-installed-capacity-year-end-2017/

13. Think Geoenergy. (2016) The Rapid Development of Geothermal Energy in The Netherlands. Retrieved May 20, 2018, from http://www.thinkgeoenergy.com/the-rapid-development-of-geothermal-energy-in-the-netherlands/
14. British Petroleum. (2016). Geothermal Power. Retrieved May 19, 2018, From https://www.bp.com/en/global/corporate/energy-economics/statistical-review-of-world-energy/renewable-energy/geothermal-power.html
15. International Energy Agency. (2016). Renewable Energy Continuing to Increase Market Share. Retrieved May 15, 2018, from https://www.iea.org/newsroom/news/2016/july/renewable-energy-continuing-to-increase-market-share.html
16. Worldatlas. (2018). What is a Ring of Fire? Retrieved May 16, 2018, from https://www.worldatlas.com/aatlas/infopage/ringfire.htm
17. Shortall, R., Davidsdottir, B., & Axelsson, G. (2015). Geothermal energy for sustainable development: A review of sustainability impacts and assessment frameworks. Renewable and Sustainable Energy Reviews, 44, 391-406. doi:10.1016/j.rser.2014.12.020
18. Energy Invormative. (2018). Geothermal Energy Pros and Cons. Retrived May 19, 2018, from http://energyinformative.org/geothermal-energy-pros-and-cons/
19. Wohletz, K., & Heiken, G. (1992). Volcanology and geothermal energy. Berkeley: University of California Press.
20. Wolf, N., & Gabbay, A. (2015). Sarulla 330 MW Geothermal Project Key Success Factors in Development. Melbourne: World Geothermal Congress 2015 Paper.
21. Think Geoenergy. (2018). World Geothermal Power Plant Maps. Retrieved June 2, 2018, from http://www.thinkgeoenergy.com/map/
22. Lunis, B. (1990). Geopressured-Geothermal Direct Use Potentials Are Significant. Idaho: GHC Bulletin.
23. Renewable Energy World. (N.D.) Geothermal Power and Electricity Productions. Retrieved June 4, 2018, from https://www.renewableenergyworld.com/geothermal-energy/tech/geoelectricity.html

24. EIA. (2017). Geothermal Power Plants. Retrieved June, 5, 2018, from https://www.eia.gov/energyexplained/index.php?page=geothermal_power_plants
25. Power Technology. (2018). Sarulla Geothermal Power Plant. Retrieved June, 5, 2018, from https://www.power-technology.com/projects/sarullgeothermalpowe/
26. Bakos, G. C., Fidanidis, D., & Tsagas, N. F. (1999). Greenhouse heating using geothermal energy. Geothermics, 28(6), 759-765. doi:10.1016/s0375-6505(99)00041-3
27. Bloomberg BNA. (2016). Geothermal Sectors Begins Heating Up in Mexico. Retrieved June, 7, 2018, from https://www.bna.com/geothermal-sector-begins-n57982069025/
28. Kage, S., Ito, S., Kishida, T., Kudo, K., & Ikeda, N. (1998). A Fatal Case of Hydrogen Sulfide Poisoning in a Geothermal Power Plant. Journal of Forensic Sciences, 43(4). doi:10.1520/jfs14329j
29. Environmental assessment record and technical examination on proposed geothermal resource leasing in the Socorro Peak area. (1977). U.S. Dept. of the Interior, Bureau of Land Management, Jornada Resource Area, Socorro District.
30. Butler, E. W. (2012). Geothermal energy development: Problems and prospects in the imperial valley of california. Place of publication not identified: Springer.
31. Kerina, Joseph. (2017). Investigation into the Possibility of Ground Water Contamination and Possible Effects of Olkaria Geothermal Developments to Lake Naivasha. 42nd Workshop on Geothermal Reservoir Engineering Stanford University. California.
32. Dahlan, E. N., Putiksari, V., & Prasetyo, L. B. (2016). Geothermal Energy Utilization in the Kamojang Nature Reserve, West Java, Indonesia. Forum Geografi, 29(2), 129. doi:10.23917/forgeo.v29i2.999
33. Mutia, T. M. (2016). Do Geothermal Power Plants Affect Ecosystems? A Review of Bio-Indicators, Data Acquisition and Processing Protocols. African Rift Geothermal Conference. Addis Ababa, Eithopia.

34. Hosseinzadeh, Ali. (2014). Air Quality Impact Assessment: H2S Dispersion Modelling for The Sabalan Geothermal Power Plant, NW-Iran. United Nations University. Reykjavik, Iceland.
35. Ndetei, J. C. (2010). Noise Assessment and H2S Dispersion at Olkaria Geothermal Power Plant, Kenya. United Nations University. Reykjavik, Iceland
36. World Bank. (2013). World Bank Statement on Olkaria Maasai Evictions. Retrieved June, 9, 2018, from http://www.worldbank.org/en/news/press-release/2013/09/26/world-bank-statement-on-olkaria-maasai-evictions
37. Baba, A., & Tayfur, G. (2011). Groundwater contamination and its effect on health in Turkey. Environmental Monitoring and Assessment, 183(1-4), 77-94. doi:10.1007/s10661-011-1907-z
38. Payera, S. V. (2018). Understanding social acceptance of geothermal energy: Case study for Araucanía region, Chile. Geothermics, 72, 138-144. doi:10.1016/j.geothermics.2017.10.014
39. Kurgat, I., & Omwenga, J. (2016). Impact of Power Generation Project on the Livelihoods of Adjacent Communities in Kenya: A Case Study of Menengai Geothermal Power Project. International Journal Of Scientific Research And Publication, 6(10), 610-624
40. Ziabakhsh-Ganji, Z., Nick, H. M., Donselaar, M. E., & Bruhn, D. F. (2018). Synergy potential for oil and geothermal energy exploitation. Applied Energy, 212, 1433-1447. doi:10.1016/j.apenergy.2017.12.113
41. Think Geoenergy. (2017). Give Geothermal Energy a Fair Chance in the Netherlands – a Recent Opinion Piece. Retrieved July, 1, 2018, from http://www.thinkgeoenergy.com/give-geothermal-energy-a-fair-chance-in-the-netherlands-a-recent-opinion-piece/
42. Think Geoenergy. (2018). Five Geothermal Projects Under Renewable Funding Program, Netherlands. Retrieved July, 3, 2018, from http://www.thinkgeoenergy.com/five-geothermal-projects-under-renewable-energy-funding-program-netherlands/
43. Think Geoenergy. (2018). Successful Well Test of 18.9 MW Well Drilled by Pertamina at Ulubelu, Lampung. Retrieved August, 1, 2018, from

http://www.thinkgeoenergy.com/successful-well-tests-of-18-9-mw-well-drilled-by-pertamina-at-ulubelu-lampung/

44. The Netherlands Government. (N.D.). Central Government Encourages Sustainable Energy. Retrieved July, 15, 2018, from https://www.government.nl/topics/renewable-energy/central-government-encourages-sustainable-energy
45. World Atlas. (2017). Highest Points in The Netherlands by Elevation. Retrieved July, 14, 2018, from https://www.worldatlas.com/articles/highest-points-in-the-netherlands-by-elevation.html
46. IEA. (2016). The Netherlands – Energy System Overview. Retrieved July, 19, 2018, from https://www.iea.org/media/countries/Netherlands.pdf
47. Pluymaekers et al. 2014. ThermoGIS – Unlocking the Geothermal Potential of The Netherlands. 76th EAGE Conference & Exhibition 2014. Amsterdam, The Netherlands.
48. Soldo, E., Alimonti, C. 2015. From an Oilfield to a Geothermal One: Use of a Selection Matrix to Choose Between Two Extraction Technologies. World Geothermal Congress. Melbourne, Australia.
49. Zeiler, W. 2017. Heat Pumps: The Dutch Way. 12th IEA Heat Pump Conference. Rotterdam, The Netherlands.
50. Heekereen, V. V., Bakema, G. 2015. The Netherlands Country Update on Geothermal Energy. World Geothermal Congress. Melbourne, Australia.
51. Van Wees, J., et al. 2013. A Prospective Study on the Geothermal Potential in the EU. European Union.
52. Gupta, H. K. (2008). *Geothermal energy: An alternative resource for the 21st century*. Amsterdam: Elsevier.
53. Kömürcü, M. I., & Akpınar, A. (2009). Importance of geothermal energy and its environmental effects in Turkey. Renewable Energy, 34(6), 1611-1615. doi:10.1016/j.renene.2008.11.012
54. Knoema. (2017). BP World Reserve of Fossil Fuels. Retrieved March 23, 2018, from https://knoema.com/infographics/smsfgud/bp-world-reserves-of-fossil-fuels

55. International Energy Agency. (2016). Coal Reserves. Retrieved March 23, 2018, from https://www.eia.gov/energyexplained/index.cfm?page=coal_reserves
56. Golusin, M., Popov, S., & Dodic, S. (2013). *Sustainable energy management*. Oxford: Academic. Pages 288-293.
57. Geothermal Energy Agency. (2014). Geothermal basics. Retrieved March 25, 2018, from http://geo-energy.org/Basics.aspx
58. International Geothermal Association. (2004). What is Geothermal Energy? Retrieved March 25, 2018, from https://www.geothermal-energy.org/what_is_geothermal_energy.html#c347
59. Environmental Protection Agency. (2018). Geothermal Heating and Cooling Technologies. Retrieved March 27, 2018, from https://www.epa.gov/rhc/geothermal-heating-and-cooling-technologies
60. Pennsylvania State University. (2018). What is Renewable Energy. Retrieved March 28, 2018, from https://extension.psu.edu/what-is-renewable-energy
61. Geothermal Research Council. (2014). Geothermal Reservoir Engineering. Retrieved March 30, 2018, from https://geothermal.org/Annual_Meeting/PDFs/Garg%20GRC_ReservoirEngineering_Sep t2014.pdf