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A PROJECT ON:

GEOTHERMAL ENERGY AND THE ENVIRONMENT

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ABSTRACT

This report explains the source of geothermal energy, the origin of the underground water the geysers and the process of heating. It also gives a brief account on how it is drilled, piped to turn the turbines which in turn generate electricity and the pollutant associated with it plus their effect on the environment. This report also discusses the major and minor geothermal pollutants considering their effect on the environment, human beings, land use, wild life and vegetation. It gives an accurate scientific analysis of the minor and major pollutants bringing forth good understanding to the effects of geothermal pollutants and nullifying some misleading assumptions and theories which were considered appropriate there before.

ACKNOWLEDGEMENT

I owe more to others than I find it more conformable to admit to my lecture Dr. C.M. Gichaba I do acknowledge with profound thanks his guidance support, invaluable suggestions and his constructive criticism throughout the course.

My cordial thanks go to the Department of Geology for allowing me to use their computer facilities to execute my data and availing relevant books for research.

Lastly and the greatest of all, I thank God for his blessings, sustenance and power in production of my report

DEDICATION

This report is dedicated to my beloved parents and my brothers and sisters who have worked tirelessly in support and encouragement at stages of my studies.

DECLARATION

I declare this work to be the original copy and have never been presented before for any other purpose. Source of information have been referenced at the back.

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ACRONYM AND ABBREVIATIONS

CAA	Clean Air Act
dBA	Units of Decibels A-Weighted
EA	Environmental Assessment
EIR	Environmental Impact Report
EIS	Environmental Impact Statement
EPRI	Electric Power Research Institute
EPA	Mental Protection Agency
GRC	Geothermal Resource Council
NAAQS	National Ambient Air Quality Standards
NEPA	National Environmental Policy Act
NO_X	Nitrogen Oxide
PM	Particulate Matter
PPB	Part per Billion
ROG	Reactive Organic GAS
RPM	Risk Management Program
SO_X	Sulfur Oxide
TOG	Total Organic Gases
WGC	World Geothermal Conference

CHAPTER 1

INTRODUCTION

There is rapid development and growth especially in the third world countries and the need for electricity as a source of energy is in high demand. Due to the high cost incurred in the production of electricity through other processes like nuclear production, and the risks and regulations attached to it hence it is convenient and easy to generate electricity through geothermal processes. Geothermal energy is renewable and efficient compared to fossil fuel. Potential places especially in volcanic zones have been identified all over the world.

Less has been addressed about the environmental impact of geothermal energy. The purpose of this project is to provide accurate and current information about the environmental aspect of geothermal energy. There is wide spread misconception about geothermal energy and the environment and this acts as a barrier to geothermal developers who have little knowledge on geology, hydrology and environmental impacts of geothermal energy.

OBJECTIVES

- To acquire knowledge on how to prepare a geological thesis.
- To provide accurate and current information about the environmental aspect of geothermal energy.
- To address some of the common misconceptions about geothermal energy.

PROJECT METHODOLOGY

Most of the data was collected from books and internet. This entailed intensive research on the topic in question. Questioners were also forwarded to respective lectures and relevant people in this field of study.

CHALLENGES AND LIMITATIONS

1. Detailed research could not be achieved due to financial constrains since this was a self sponsored project hence there was little or no technical or laboratory analysis that were carried out.
2. Some of the questioner came back unanswered due to the in availability of some colleagues and incompetence of some technicians.
3. There was in adequate resources like books since less has been done in this field of study.

CHAPTER 2

SOURCES OF GEOTHERMAL ENERGY

Geothermal power is power extracted from heat stored in the earth. This geothermal energy originates from the original formation of the planet from radioactive decay of minerals and from solar energy absorbed at the surface.

The heat emanating from the interior of the earth is essentially limitless flow of heat. The heat continuously flowing from the earth's interior is estimated to be equivalent to 42 million megawatts of power. 1 megawatt is equivalent to 1 million watt and can meet the power need of about 1000 homes.

The interior of the earth is expected to remain extremely hot for billions of years to come ensuring an essentially limitless flow of heat. Geothermal plants capture this heat and convert it to energy in the form of electricity. The picture below shows how temperature or heat increases with increase in depth.

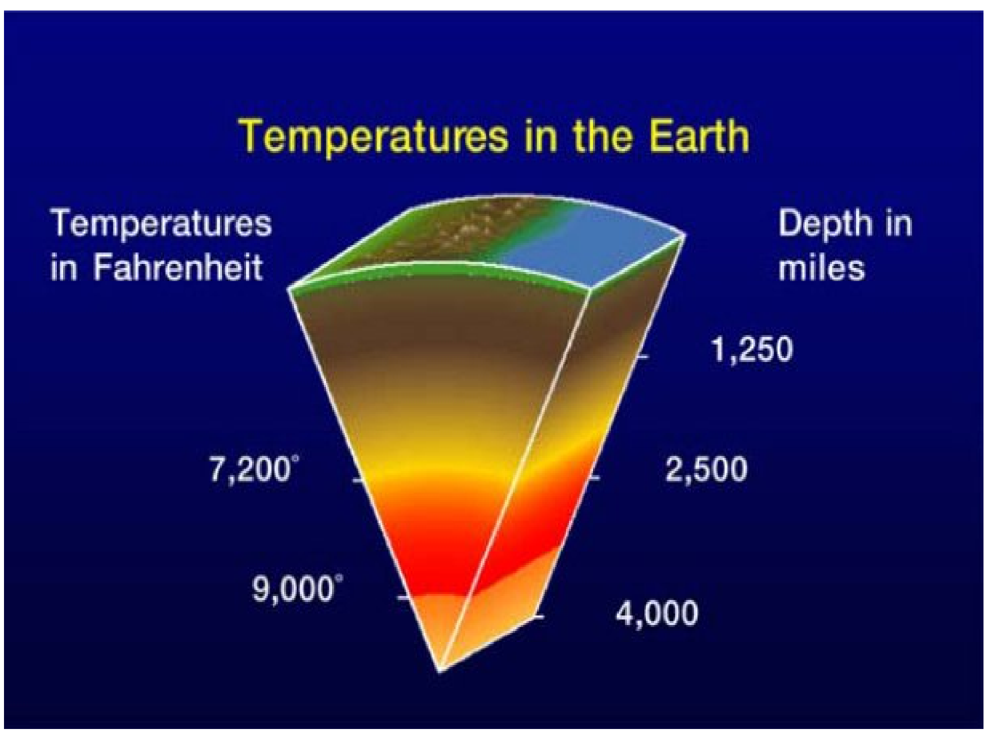

Fig 1 Temperature in earth (http://www.erec.org)

CONVERSION OF GEOTHERMAL ENERGY INTO ELECTRICITY

Heat emanating from the interior of the earth and crust generate magma or molten rock. Since magma is less dense than surrounding rock, it rises but generally does not reach the surface, heating the water contained in rock pores and fractures. Wells are drilled into this natural collection of hot water or steam called a geothermal reservoir in order to bring it to the surface and use it for electricity production.

The steam or water is always under high pressure and it's tapped in that nature and the high pressure steam is used to turn the turbines which in turn generate electricity.

GEOTHERMAL PLANTS AND THEIR COOLING SYSTEMS

The most common type of power plant to date is flash power plant with a water cooling system where a mixture of water and steam is produced from the well. The steam is separated in a surface vessel called the steam separator and delivered to the turbines and the turbines power a generator.

In dry steam plant, steam directly from the geothermal reservoir run the turbine that power the generator in this case there is no separations because the well only produces steam.

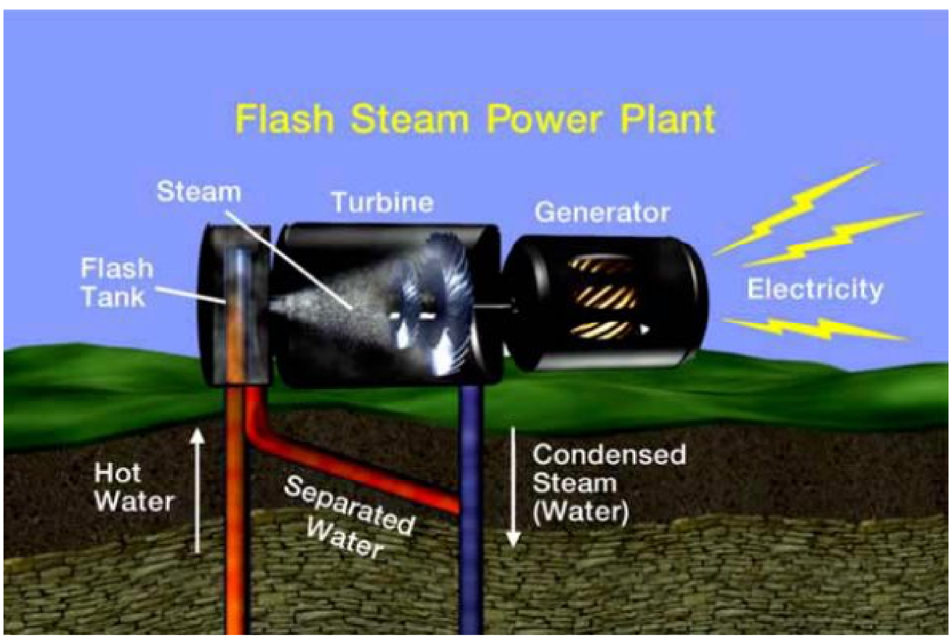

Fig 2 flash steam power plant (http://www.erec.org)

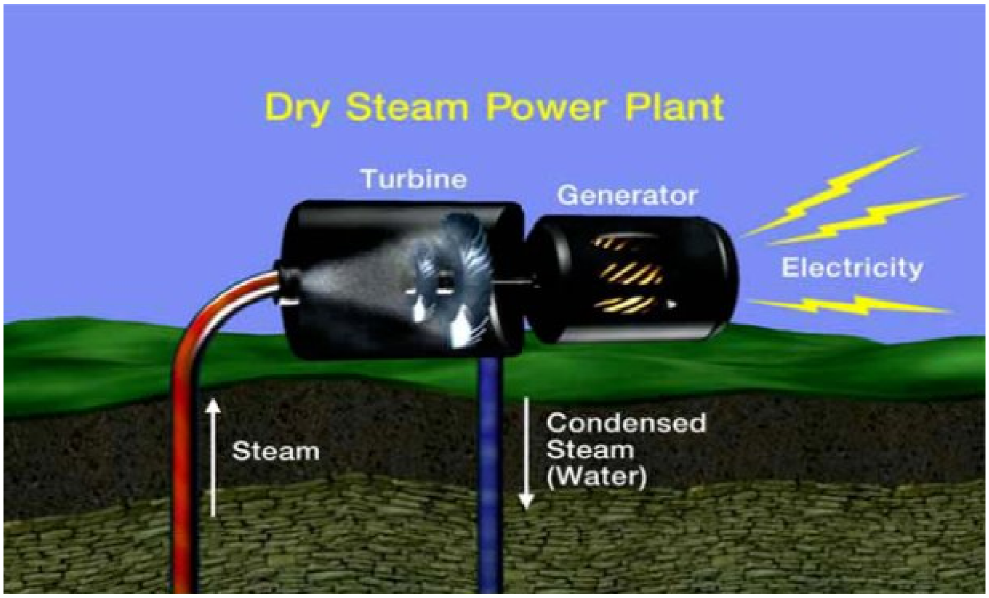

Fig 3 dry steam power plant (http://www.erec.org)

Recent advance in geothermal technology have made possible the economic production of electricity from lower temperature geothermal resource at 100 degrees Celsius to 150 degrees Celsius known as binary geothermal plant. These facilities reduce geothermal energy already low emissions rate to nearly zero.

In binary process the geothermal water heats another liquid such as isobutene that boils at lower temperatures than water. The two liquids are kept separate through use of a heat exchanger used to transfer the heat energy from the geothermal water to the working fluid. The secondary fluid vaporizes into gaseous vapor and like steam the force of the expanding vapors turns the turbines that power the generator.

If the power plant uses air cooling, the geothermal fluids never make contact with the atmosphere before they are pumped back into the underground geothermal reservoir effectively making the plant emission free.

The ability to use lower temperature resources increases the number of geothermal reservoir that can be used for power production.

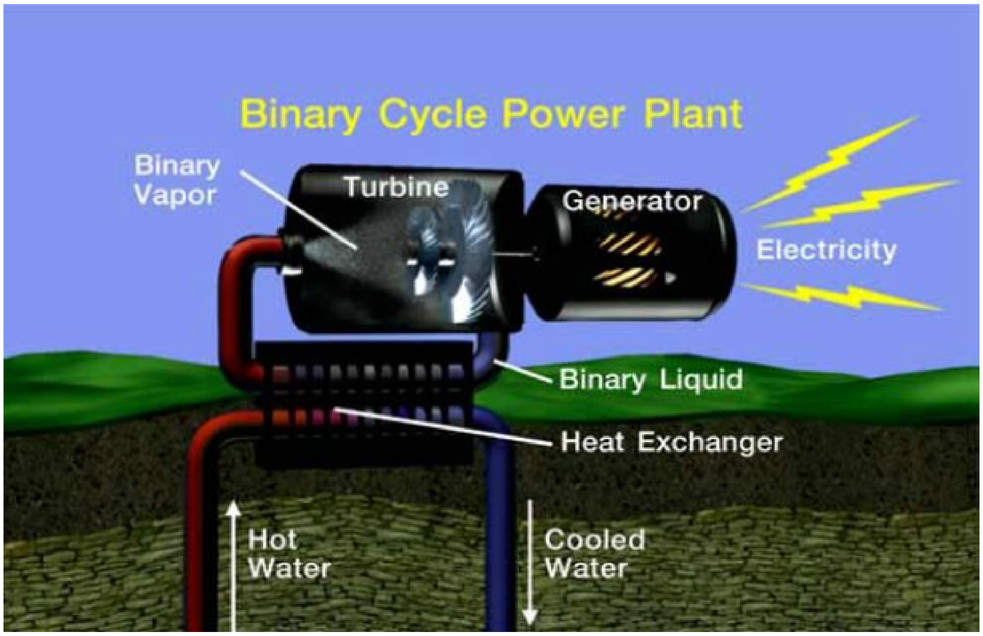

Fig 4 binary cycle power plant (http://www.erec.org)

COOLING SYSTEM

A cooling system is essential for the operation of any modern geothermal power plant. Cooling towers prevent turbines from overheating and prolong facility and efficiency life. Most power plants, including most geothermal plants use water cooling systems. The figure below shows a detailed geothermal power plant, complete with a water evaporate cooling system

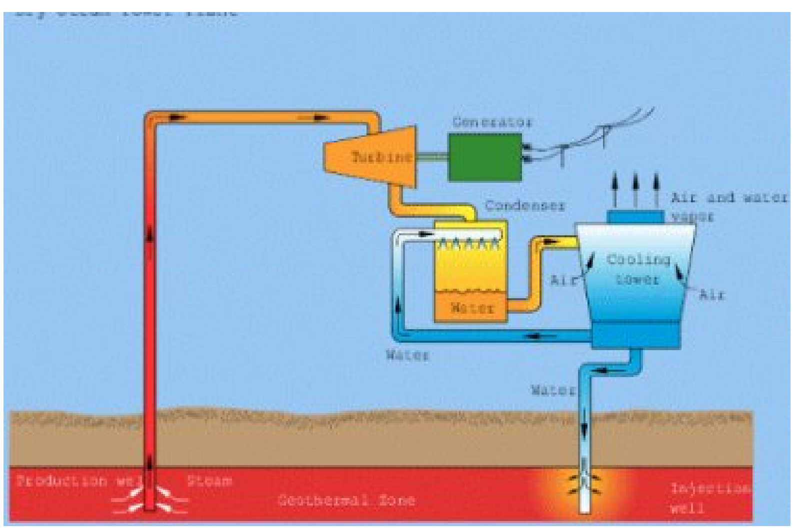

Fig 5 cooling system (http://www.erec.org)

Water cooled system generally require less land than air cooled system and are considered overall to be effective and efficient cooling system. However, require a continuous supply of cooling water and create vapor plumes. Usually some of the spent steam from the turbines (for flash and steam type plants) can be condensed for this purpose.

Air cooled system are beneficial where extremely low emissions are desired or in arid regions where water resource are limited since no fluid needs to be evaporated for the cooling process. Air cooled systems are also preferred in areas where the view shed is particularly sensitive to the effect of vapor plumes as vapor plumes are only emitted into the air by wet cooling tower and not air cooling towers. Most geothermal cooling is used in binary facilities.

A combination of flash and binary technology, known as the binary combined cycle, has been used effectively to take advantage of the benefits of both technologies. In this type of plant, the flashed steam is first converted to electricity with a back pressure steam turbine, and the low pressure steam exiting the back pressure turbine is condensed in a binary system. This allows for the effective use of air cooling towers with flash applications and takes advantage of the binary process.

The flash binary system has a higher efficiency where the well field produces high pressure steam, while the elimination of vacuum pumping of non condensable gasses allows for 100 percent injection.

RELIABILITY OF GEOTHERMAL POWER GENERATION

The source of geothermal energy, the earth’s heat is available 24 hours a day and 365 days a year compared to other sources of energy which are dictated by various factors. For this reasons electricity from geothermal energy is more consistently available, once the resource is tapped, than many other forms of electricity.

Geothermal plants characteristically have very low planned and unplanned outage rates. Geothermal power availability, measured as the number of hours that a power plant is available to produce power divided by the total hours in a set time period, usually a year, is about 95 percent. This means that geothermal electric power plants are available for generation 95% of any given time, based on decades of observation by plant operator.

While availability factor measures a plants potential for use, capacity factor measures the amount of real time during which is facility is used, and is therefore less than or equal to a plants availability factor. Capacity factor can be influenced by change in resource, equipment or transmission variability, power market fluctuation and other factors

The table below shows capacity factor information for four renewable energy sources,

Technology	**Capacity factor % range**
Geothermal	80-97
Biomass	80
Wind	26-40
Solar	22.5-32.2

Table 1

MANAGING GEOTHERMAL SYSTEM

In existing geothermal system, the heat from the earth is transferred into power using underground water or steam. In some cases there has been geothermal decline at geothermal decline at geothermal fields. Decline may be caused by well field problems with scaling by a loss of water/steam or by declining temperature in specific areas or wells with a geothermal resource. Heat may continue to be available indefinitely but the carrier medium (water) and reservoir must be properly managed. Managing the fluids used to generate power is an important part of development a sustainable geothermal plant.

The carrier medium either water or at higher temperature steam is stored in what is known as a geothermal reservoir. A geothermal reservoir in the entire system of fractured and permeable rocks, along with the hot water or steam circulating in that volume of rock. The success of a geothermal power plant depends upon how efficiently the geothermal reservoir is managed regardless of the temperature or type of the resource itself.

The geysers are expected to be economically profitable for several decades more. The improvement in technology and additional injections could increase the projected economically profitable lifespan even further. Unlike most other geothermal systems no water flows naturally into the geysers geothermal system. The geyser is airfare dry steam field while most other geothermal reservoirs are liquid dominated and recharge naturally.

CHAPTER 3

GEOTHERMAL ENERGY AND THE ENVIRONMENT

To understand geothermal energy and its impact on the environment, a brief overview of applicable regulations is necessary. Many regulations such as the clean air act apply to all sources of emission, including emissions from renewable technologies such as geothermal. These environmental regulations dictate specific levels of allowable air emissions, how permits can be issued, what sort of environmental review must take place, and what land type may be approved for development. Development of any kind will impact the environment, and this must follow specific regulations.

AIR EMISSION

Geothermal power plants release very few air emissions because they do not burn fuel like fossil fuel plants. Geothermal plants avoid both environmental impact associated with burning fuel as well as those associated with transporting and processing fuel sources. Geothermal plants only emit trace amount of nitrogen oxides, almost no sulfur dioxide or particulate matter, and small amount of carbon dioxide. The primary pollutant some geothermal plants must sometimes abate is hydrogen sulphide, which is naturally present in many subsurface geothermal reservoirs with the use of advanced abatement equipment, however, emission of hydrogen sulphide are regularly maintained.

NITROGEN OXIDE

Nitrogen oxide is often colorless and odorless or reddish brown as nitrogen dioxide. Nitrogen oxide form during high temperature combustion process from the oxidation of nitrogen in the air.

Nitrogen oxide contribute to smog formation, acid rain, water quality deterioration global warming and visibility impairment, health effects include itchy irritation and respiratory ailments such as infectious coughing, chest pain and breathing difficulty.

Geothermal energy produced in the word, when compared to coal offsets approximately 32 thousand to of nitrogen oxides emission each year. This is substantial considering that even brief exposure to high level of nitrogen oxide may cause human respiratory problems. Levels above the established EPA rules may damage the ecosystem.

Since geothermal power plants do not burn fuel, they emit very low levels of nitrogen oxides, in most cases geothermal facilities emit no nitrogen oxide at all. The small amount of nitrogen oxide released by some geothermal facilities results from the combustion of hydrogen sulfide.

Geothermal plants are generally required by law to maintain hydrogen sulfide abatement systems that capture hydrogen sulfide emission and either burn the gas or convert it to element sulfur. During combustion small amounts of nitrogen oxides are formed.

HYDROGEN SULPHIDE

Hydrogen sulphide (H_2S) is a colorless gas that is harmless in small quantities, but is often regarded as an “annoyance” due to the destructive “rotten egg smell. Hydrogen sulphide can be lethal in high doses. Natural sources of hydrogen sulphide include volcanic gases, petroleum deposits; natural sources of hydrogen sulphide may also form decomposition of sewage and animal manure and can be emitted from sewage treatment refineries, compositing facilities, dairies and animal feedlot operation.

Anthropogenic man made source of hydrogen sulfide account for approximately 50% of total hydrogen sulphide emission. Health impacts from high coal include nausea, headache and eye irritation, extremely high levels can result in death hydrogen sulphide remains in the atmosphere for about 18 hours. Though hydrogen sulphide is not criteria pollutant it is listed as a regulated air pollutant.

Hydrogen sulphide remains the pollutant generally considered to be of greatest concern for the geothermal community. However, it is now routinely abated at geothermal power plants; the two most common used vent gas hydrogen sulphide abatement systems are the Stratford and Co-CAT. Both systems convert over 99.9% of the hydrogen sulphide from geothermal non condensable gases to element sulfur, which can be then used as soil amendment and fertilizer feedstock.

SULFUR DIOXIDE (SO_2)

Sulfur dioxide to the family SO_x gases that form when fuel containing sulfur is burned at power plant.

Fossil fuel-fired power plants are responsible for 67% of the world's sulfur dioxide emission. High concentration of SO_2 can produce temporary breathing impairments' for asthmatic children and adults who are active outdoor. Health impact from short exposure include wheezing, chest tightness shortness or breath, aggravation of existing cardiovascular disease and respiratory illness SO_2 emission injure vegetation damage freshwater lake and stream ecosystems decrease species variety and abundance and create hazy conditions.

There are both short and long term primary NAAQS for SO_2 the short term (24hours) and second any (3hours) standards are not to be exceeded more than once per year.

While geothermal plant do not emit sulfurs dioxide directly once hydrogen sulfide is released as a gas into the atmosphere, it spread into the air and eventually changes into SO_2 and H_2SO_4, therefore any SO_2 emission associated with geothermal energy derive from H_2S emissions.

CARBON DIOXIDE (CO_2)

Carbon dioxide is a colorless, odorless gas released into the atmosphere as a byproduct of burning fuel. Increased atmospheric carbon dioxide concentrations are caused by human fossil fuel burning. The increase in carbon dioxide concentration is typically attributed to power plants emissions. About 37% of incremental CO_2 accumulation is caused by electric power generation, mainly from fossil fuel and secondary to deforestation and land-use change according to energy information administration (EIA)

CO_2 accounts for 83% of the worlds green house gas emission while CO_2 does not pose any direct human health effects human exhale carbon dioxide with every breath experts generally agree that global warming poses significant environmental and health impacts including flood risks, glacial melting problems, forest fire, increase in sea level and loss of biodiversity.

Geothermal plants do emit CO_2 but in quantities that are small compared to fossil fuel fired emissions. Some geothermal reservoir fluids contain varying amounts of certain non condensable gases including carbon dioxide.

Geothermal steam is generally condensed after passing through the turbine. However the carbon dioxide does not condense and passes through the turbine to the exhaust system where it is then release into the atmosphere. Carbon dioxide found in geothermal fluid can vary depending on location and the amount of carbon dioxide actually released into the atmosphere can vary also depending on plant design.

This makes it difficult to generalize about the amount of carbon dioxide emitted by an average geothermal power plant. In Binary plants with air cooling are in a closed loop system and emit no carbon dioxide because in this system the geothermal fluids are never exposed to the atmosphere non condensable gases such as carbon dioxide make up less than 5 percent by weight of the stream phase of most geothermal systems.

PARTICULATE MATTERS

A particulate matter (PM) is abroad term for a range of substances that exists as discrete particles. Particulate matter includes liquid droplets or particles from smoke dust or fly ash “primary” particles such as soot or smoke come from a variety of sources where fuels burned “secondary” particles form when gases of burned fuels react with water vapor and sunlight. Secondary particulates in the form of soot or smoke (VOCs). Large particulates in the form of soot or smoke can be detected by the naked eye, while small particulates (PM.2.5) require a microscope for viewing PM 90 refer to all particulates less than or equal to 10 microns in diameter of particulate mass per volume of air.

Particulate matter is emitted through the full process of fossil fuel electricity production particularly coal mining. Health effects from particulate matter include eye irritation, asthma bronchitis, lung damage, cancer, heavy metal poisoning and cardiovascular complication, particulate matter contributes to atmospheric deposition, visibility impairment and aesthetic damage.

Water cooled geothermal plants do emit small amount of articulate matter from the cooling tower when stream condensate is evaporated as part of the cooling cycle.

However, the amount of particulate matter given of from the cooling tower is quite small when compared to coal or oil plants which have burning processes in combination with cooling towers.

MERCURY

The majority of mercury emissions derive from natural sources, mercury occurs naturally in soils, groundwater and streams, but human and soil coal fired power plants are the largest source of additional mercury of any energy source because the mercury naturally contained in coal is released during combustion.

Mercury emissions from coal vary both day to day and from plant to plant. According to a recent EPRI study, mercury emission vary significantly over a month period, snapshot mercury emission information takes over a 1-2 hours period does not always accurately reflect long term mercury emission hourly averages can vary by almost an order of magnitude in addition mercury emissions from certain types of coal plants such as bituminous plant tend to be greater than from other types of coal plants. It is estimated that bituminous plants emit 52% of coal mercury emissions while lignite coal plant emit 9%. Those plants with emission technologies reduction (SCR) and wet fine gas desulphurization (FGD), tend to emit the lowest level of mercury.

Mercury emission from power plants pose a significant risk to human health when mercury enters water, biological processes transform it to a highly toxic forms, methyl mercury, which build up in fish and animals that eat fish. People are exposed to mercury primarily by eating fish or by drinking contaminated water mercury contamination in the blood could lead to reduced IQ and motor skill in human off springs, mercury and mercury compounds are considered one of the 188 hazardous air pollutants (HAP) and one of 33 urban HAPs.

Mercury is not present in every geothermal resources however if mercury is present in a geothermal resource using that resource for power production could result in mercury emission depending upon the technology used because binary plant pass geothermal fluid through a heat exchange and then return all of it to the reservoir, binary plants do not emit any mercury, the geysers is the main geothermal fields known to emit small quantities of mercury in the atmosphere.

Measures to reduce mercury emissions are put in place. The abatement measures that reduce mercury also reduce the emission or sulfur generated as a byproduct of hydrogen sulphide abatement. After hydrogen sulphide is removed from geothermal stream the gas is run through a mercury filter that absorbs mercury from the gas. In removing mercury the sulfur that is created from the abatement process can then be used as an agricultural product.

TOGS AND ROGS

Geothermal power plants may emit small amount of naturally occurring hydrocarbon such as methane (CH4). Methane is reported in total organic gases (TOG). Ten percent of TOGs are assumed to be reactive organic gas (ROG) emissions. TOGS contain of all compounds containing hydrogen and carbon, while ROG consists of organics with low rates of reactivity. Methane is the primary TOG emitted by geothermal plants followed by ethane and propane. Methane emission estimates are uncertain however, because they are usually accidental or incidental to biological processes and they are not always present in geothermal systems.

Other ROGS, such as benzene a known carcinogen are generally not of concern to the geothermal Community as they are injected back into the system. Benzene emissions released at most geothermal facilities have never been high enough to trigger a risk. Benzene comprises less than 9% of cooling tower gases.

AMMONIA.

Naturally occurring ammonic (NH_3) is emitted at low levels by geothermal facilities with more concentrated amount emitted by certain plants at the geysers while livestock is responsible for almost half of ammonia emission, geothermal accounts for only a fraction of ammonia emission as substantially lower than 9%. Additional sources include fertilizer, crops and biomass burning. Emitted Ammonia can combine with waters to form ammonium hydroxide. If it lasts long enough in the environment, ammonia may combine with nitrogen oxide to form particulate (ammonic nitrate) or if there are no acid gasses present in the atmosphere it will be absorbed into the soil and taken up by green plants.

Experts generally concur that ammonia is released as hydrated ammonia and depending upon the environment is absorbed in soil to become part of the nitrogen cycles.

BORON

Boron an element found in volcanic spring water does not exist naturally in its elemental form but is commonly found as mineral salt borax in dry lake evaporate.

In geothermal steam system borax is present in the streams. Highly soluble boric acid when combined with ammonia, it often forms white crystalline salt deposit or equipments exposed to geothermal stream. Because of its high solubility nearing all borate entering a geothermal plant will dissolve in the steam condensate where it exits the plant through cooling tower blow down and is injected back into the steam reservoir. New geothermal plants are now required to install high efficiency drift elimination for particulate control regardless of boron content in the water and these eliminations reduce boron emission. Boron salt compounds may be emitted in cooling tower drift but boron emissions are generally not regulated. Boron has no negative impact on plant as assumed by many.

SOLID AND LIQUID WASTE

In most geothermal facilities, air emission is the most significant environmental issue of concern. Solid waste discharged from geothermal power plants. The non hazardous are produced in low quantities. The substances listed in the list are typically either too low to cause any concern or are recycled through system or do not make any contact with water hand or air. Solid and liquid waste substances are included in this report to provide as comprehensive as possible a review of the environmental aspect of geothermal energy.

ARSENIC

Arsenic, in its pure form: is a gray, crystalline solid, but can be found in various forms in the natural environment in combination with other elements, arsenic is produced naturally in the earth’s crust and can be emitted during volcanic eruption. It is also produced in fossils fuel; processing and in the production of pesticides, wood preservatives, glass and other materials. It is a known human carcinogen. Additional health effects include sore throat, irritated lungs, nausea vomiting, decreases production or red and white blood cells, abnormal heart rhythm, damage to blood vessel and skin pigmentation abnormalities.

Like all HAPs, monitoring of arsenic from its source is not required under the clean air act. However, the safe drinking water Act currently mandate that arsenic not exceed 50ppb (part per belief) in drinking water legislation is presently under review that would reduce the number of 10ppbas per the recommendation of government sponsored study by the nonprofit organization. Academic press limits exposure to arsenic in industrial facilities but power plants remain unregulated. Individual countries can have specific regulations for arsenic production standards.

Arsenic takes its final form in sediment soil, water sources, shellfish or fish and is most harmful in the inorganic as opposed to organic form.

Geothermal plants are not considered to be high arsenic emitters even though arsenic is common to volcanic systems, when arsenic is present in a geothermal system it typically ends up in the solid form in the sludge and scale associated with production and hydrogen sulfate abatement study show arsenic levels from geothermal power plants to be very low.

SILICA AND OTHER WASTE PRODUCTS

Silica, an abundant element that is the primary component of sand it’s a byproduct of geothermal power production from certain brine reservoirs. Silica is typically dewatered and the silica sludge is disposed of offsite. Silica is only considered a potential hazard when found in high concentrations in the workplace, but it poses no environmental risks. Silica is found in the effluent or treated wastewaters that are the byproducts of drilling operations. In some resources, concentrations of silica are low enough in geothermal facilities that workers are not at risk. Silica is unregulated. Other geothermal effluents are generally considered to be harmless and even at times beneficial to the environment.

The primary “waste” in geothermal operation is drilling cuttings comprised primary of bentonite naturally occurring clay. Waste from drilling activities, mud and cuttings are stored in what is known as “sumps” for disposal according to state and federal regulations, sumps provide secure storage for drilling mud and cuttings. They are typically lined with impervious material to prevent leaching.

NOISE POLLUSION

There are various local and international noise pollution regulations for geothermal power plants with which geothermal developers must comply. Noise at ½ mile, or at the lease boundary, if closer from major geothermal operation shall not exceed 65 units of decibels. A weighted, or dBA, sound is measured in units’ decibels (dB), but for environmental purposes is usually measured in decibels A-weighted (dBA). A-weighting refers to an electronic technique which simulates the various frequencies comprising all sounds.

However geothermal power plant can operate in compliance with the applicable regulations and are not considered a noise nuisance in surrounding residential communities. All power facilities must meet local noise ordinances according to the phase of construction and operation.

- Noise pollution from geothermal plants is typically considered during three phases, the well drilling and testing phase, the construction phase and the plant operation phase. During the construction phase noise may be generated from construction of the well pad. Transmission tower and power plant.
- During the operation phase the majority of noise is generated from the cooling tower the transformer and turbine generator building.

Construction is the one of the noisiest phase of geothermal development but even construction noise generally remains below the 65 dBA regulation established by the BLM. Noise pollution associated. With the construction phase of geothermal development, as with most construction, it is a temporary impact that ends when construction ends. Well pad construction can take anywhere from a week or months to a few years depending upon the depth of the well. In addition construction noise pollution is generally only an issue during the daytime hours and is not a concern at night.

The well drilling and testing phase of geothermal development generally does not exceed the federal BLM noise regulation. Much like the construction phase of development well drilling and testing are temporary and the noise pollution they produce is not permanent.

However unlike the construction phase of development well drilling operation typically take place 24hours per day, seven days a week.

This temporary noise pollution can last anywhere from 45 to 90 days per well.

Noise from normal power plant operation generally comes from the three component of the power plant. The cooling tower, the transformer and the turbine-generator building.

Several noise muffling techniques and equipment are available for geothermal facilities. During drilling temporary noise shields can be constructed around portion of drilling rigs. Noise controls can also be used on standard construction equipment, impact tools can be shielded and exhaust muffling equipment can be installed where appropriate.

WATER QUALITY AND USE

Geothermal water is a not often salty mineral rich liquid withdrawn from a deep underground reservoir. The steam that is “flashed” from the hot water is used to turn turbines and generate electricity. The remaining water along with the condensed steam is then injected back into the geothermal reservoir to be reheated in water cooled system 50% or more of the liquid is lost to the atmosphere in form of steam and the remainder is injected back into the system. Because the geothermal water in a binary air cooled plant is contained in a closed system binary power plants hence do not consume any water. In a geothermal facility, geothermal water is isolated during production, injected back into the geothermal reservoir and separated from ground water by thickly encased pipes, making the facility virtually free of water pollutants.

Most geothermal reservoirs are found deep underground well, below groundwater reservoirs. As a result these deep reservoirs pose almost not negative impact on water quality and use while no record of water use problems exist, portable groundwater and clean surface water are important resources that require continued attention as the use of geothermal domestic resources grow.

INJECTION OF GEOTHERMAL FLUID

Geothermal steam and hot water can reach the surface in two ways, through naturally occurring surface features such as geysers and fumaroles, or through manmade wells that are drilled down into the reservoir to capture the Earths energy for electricity. In either case these natural geothermal fluids contain varying concentration of potentially toxic mineral and other elements and are extremely hot when they reach the surface of the earth. For these reasons, geothermal water can be dangerous to humans and surrounding ecosystems. This is just one of the reasons, that geothermal fluids used for electricity are injected back into geothermal reservoirs and are not allowed to be released into surface waterways. Injection of spent geothermal fluids is regulated by the EPA to coincide with the underground injection control program requirements and the BLA and state well construction requirement o ensure that ground water is protected, where geothermal fluids are injected back into a geothermal system to fluids are isolated from shallow groundwater by thick well casing injection typically takes place in separate wells that are designed to properly handled the chemistry of the injection fluids. In addition geothermal developers manage geothermal fluids in order to minimize potential impact. Benefits of injection include enhanced recovery of geothermal fluids reduced subsidence and safe disposal of geothermal fluids.

Occasionally geothermal effluent if stored rather that injected back into the system deliver beneficial environmental effects for example injection was banned at the Amedee geothermal field in Northeastern California because the effluent stored in a holding tank, produced a diverse thriving wetland, in other case an evaporative pond at a Mexican geothermal facility was found to be occupied by 34 species of birds, finally few people realized that the Icelandic tourist attraction, the blue lagoon (a turquoise body of mineral rich water) was actually created by geothermal water discharge from a power plant. Although injection is the most environmentally beneficial method of disposing of geothermal fluids these are instance where other beneficial approaches have been taken.

WASTE WATER INJECTION SUCCESS AT THE GEYSERS

Geothermal plant have the potential to improve local water quality so called "waste water injector" projects serve the dual purpose of eliminating wastewater, which would otherwise be dumped into local water ways and rejuvenating geothermal reservoirs with new water sources.

The additional water being pumped into the geothermal reservoir has helped recharge the resource to make full use of the heat still trapped in the earth's rock and has slowed the decline of the resource. This reduces surface water pollution and help to improve the sustainability of the geothermal reservoir.

Geothermal brines are injected back into geothermal reservoirs using wells with thick casing to prevent cross contamination of brines with groundwater system. A well casing in composed of thick specialized pipe surrounding by cement in order to prevent any contamination as the geothermal fluids are put back into the reservoir. Once the brines are returned to the geothermal reservoir they are re-heated by the Earths rocks and can be used over and over again to produce electricity.

Although geothermal development does not contaminate groundwater, like any form of development it has some impact on local water use. For geothermal development water impacts occur during construction and are only temporary. However, regardless of the nature of degree of water use impacts geothermal development that benefits geothermal operations and practices and preventatively minimize potential impact.

Geothermal power plants do use surface or groundwater during the construction and operation of the power plant as well as during well drilling to sustain operation. These uses, are typically not a significant concern as they do not decrease the amount of ground and surface water available for portable development of geothermal resources.

During normal operation liquid wastes from drilling activities are stored in lined sumps before being properly disposed of in accordance with environmental regulation. Accidental spills of geothermal water may occur due to well blowouts during drilling leaking pipes or well heads or overflow from well sumps. These effects are rare and only occur accidentally.

LAND USE

Geothermal power plants can be designed to blend-in to their surrounding more so than many other types electricity-producing facilities. Binary and flash binary power plants normally emit no visible steam or water vapor plumes and flash and steam plants produce minimal visual impacts the picture below shows the flesh/binary Puna geo venture facility, located in Hawaii. This plant blends into its surrounding and produces no steam plumes while still utilizing high temp resource.

Fig 6 land use in geothermal power plants (http://www.erec.org)

Geothermal facilities are often located on land that have multiple use capabilities consider a case study at the geothermal facilities of ken gen Naivasha which is located in a National park. The ecosystem of the area is not affected also the geothermal resource influence the state of the hot environment. They also reduce deforestation and air emissions.

While some fossil fuel energy source such as coal use up large swath of land in the mining of their fuel, geothermal plant minimize the total amount of land use by only building the plant along with number of well pads needed to support operation. It is important to keep in mind that the land impact of renewable energy development and use coal mining require the transportation of huge amounts of dirt and rock sometimes into streams and cause disruption of water system through acidic drainage, deforestation and damage to ecosystem. Geothermal power plant uses less land than many other sources. Geothermal power plant impose minimal visual impact on their surrounding when compared to typical fossil-fuel plants some of the key visual quality effect related to geothermal development are the pressure of steam plumes, night lighting on the well field and power plant and visibility of the transmission line. The majority of geothermal visual impact can be modified to reduce their effects. Detailed site planning facility design materials selection vegetation programs and adjustment to transmission like routing are all key aspects of geothermal operations that can reduce the visual impact of the facility. Today many geothermal plants operators already employ these mitigation techniques to reduce their facilities visual impact for example, one large geothermal company reduced the visual impact of their power plant by painting all of the piping on the plant forest green so that it blended into the surrounding landscape.

Additionally some companies utilize non specula conductor which reduce reflection and glare of transmission lines other visual impacts are only of concern on a vehicles drill rigs and other heavy equipment would have a negative impact on the visual quality of the area or limited amount of time.

SUBSIDENCE

Subsidence is most commonly thought of as the slow downward sinking of the land surface. Other types of ground deformation include upward motion (inflation) and horizontal movement is some cases, subsidence can damage facilities such as rocks building and irrigation systems or even cause tracts of land to become submerged by nearby water bodies.

Although it can occur naturally, subsidence can also occur as a result of the extraction of subsurface fluids in these cases a reduction in reservoir pore pressure reduces the support for the reservoir rock itself and of the rock outscoring the reservoir potentially leading to a slow downward deformation of the land surface. In most areas where subsidence has been attributed to geothermal operation the region of earth deformation has been confined to the welfare area itself and has not disturbed anything off-site.

While subsidence can be included by thermal construction of the reservoir due to extraction and natural recharge, property placed injection reduces the potential for subsidence by maintaining reservoir pressure. At fields produced from sedimentary rocks where the porosity and permeability is primarily between rock grains injection can successfully mitigate for subsidence. At the Geysers where subsidence may be caused more by temperature decline (thermo elastic contractions) than pressure (poro elastic contraction) decline. Injection is not necessarily an effective mitigation tool for subsidence. However, long term monitoring at the Geysers demonstrates a very slow rate of subsidence that has no direct environmental impact.

Naturally occurring subsidence most frequently takes place in areas that are tectonically active such as volcanic regions and fault zones. Subsidence can also typically occur in areas where sedimentary basins are filled with unconsolidated sand, silt, clay and gravels. Most known geothermal resources are located in areas that are tectonically active and may experience natural subsidence, because geothermal operation occurs at tectonically active sites. It is sometimes difficult to distinguish between included and naturally occurring subsidence, subsidence related geothermal development is more likely in area where the geothermal reservoir occurs in weak porous sedimentary or pyroclastic formation.

In cases where subsidence may be linked to geothermal reservoir pressure decline injection is an effective mitigating technique. By injecting spent geothermal brines back into the reservoir from which they came from reservoir pressure is stabilized. The approach has helped to maintain the pressure of geothermal reservoirs and can prevent or mitigate for subsidence at geothermal development sites.

INDUCED SEISMICITY

Earthquake activity or seismicity is generally caused by displacement across active faults in tectonically active ones. An earthquake occurs where a body of rock is ruptured and radiates seismic waves that shake the ground. Although it typically occurs naturally seismicity has at times been induced by human activity including the development of geothermal fields, through both production and injection operations in these cases the resulting seismicity has been low magnitude events known as “micro earthquakes”. Earthquakes with Richter magnitudes below 2 or 3 which are generally not felt by humans are called micro earthquakes. These micro earthquakes sometimes occur when geothermal fluids are injected back into the system and are centered on the injection site.

The micro earthquakes sometimes associated with geothermal development are not considered to be a hazard to the geothermal power plants or the surrounding communities and will usually go unnoticed unless sensitive seismometers are located nearby. However around some geothermal fields particularly the geysers, there have been complaints about increased seismicity in nearby communities.

Much like subsidence discussed in the previous section seismicity typically takes place in area with high levels of tectonic activity such as volcanic regions and fault zones. Because geothermal operations usually take place in areas that are also tectonically active it is often difficult to distinguish between geothermal induced and naturally occurring events. Many regions where geothermal development has occurred or has been planned are known as areas with high levels of fault activity,

LANDSLIDES

The extend to which geothermal development induced landslide is unclear as landslides which occur naturally in certain areas of geothermal activity such as volcanic zones are produced by a combination of events or circumstances rather than by any single specific action. While field construction operations can trigger landslides local geothermal preconditions must already exist in order for landslides to occur. Though landslides are rare when they occur they are small enough to be confined actively to the well field are of a geothermal facility. Geothermal areas with landslide hazards can be properly managed through detailed hazard mapping groundwater assessment and deformation monitoring among other management techniques. Because landslides always present warning signs such technique ensures that landslide can be avoided on geothermal lands.

GEYSERS, FURMAROLES AND GEOTHERMAL RESOURCES

Geothermal resources are often discovered under certain land features such as geysers fumaroles hot springs, mud pools, streaming ground, sinter and travertine Geysers are not springs where hot water stream or gas periodically erupts, while fumaroles vent gas and stream the word “geysers” derivers from the Icelandic word geyser which means the gusher. The picture below highlights some of these surface features.

Some individuals have expressed concern that such land features will be drastically altered or destroyed as a result of geothermal development. In some cases both during past geothermal development and geothermal development overseas. It is true that land features have been altered by geothermal development. However though the edition of

Fig 7 fumaroles and geysers(http://www.erec.org)

Geothermal development, developers have come to understand the best management produces that reduce surface feature impact and have employed preventive mitigation measures that reduce potential impact to surface features before they arise. The current status of geothermal development shows that a little alteration of land features has occurred in recent years as a result of sound geothermal management practices and law.

It is important to note in addition that geyser and fumaroles can both arise and diappear naturally without any human interference. In some developed geothermal fields, it is difficult to distinguish such natural ephemeral behavior from changes induced by geothermal or portable water resource development over time pressure. Increases in hot springs can cause geyser to erupt continuously and become narrower in shape. if increased pressure causes a geyser to explode it often resumes its previous shape and pressure as a hot spring. Moreover, the fluid pathways that feed a surface manifestation can be altered due to natural processes such as deposition and dissolution of mineral, interaction with meteoric water and seismicity, any of these factors can cause dramatic changes in the location appearance of existence of manifestation.

At times weather patterns such as drought have been shown to affect the activity of geothermal surface features. So natural, phenomenon and geothermal development have the potential to – but do not always alter geothermal land features.

IMPACT ON WILDLIFE AND VEGETATION

Geothermal development poses only minimal impact to wildlife and vegetation in the surrounding area when compared with alternatives such as coal. It should be noted that geothermal facilities must sometimes be built in more sensitive areas than coal plants. However, increased sensitivity leads to increased mitigation and surveillance in these areas. Before geothermal construction can even begin an environmental review may be required to categorize potential effects upon plants and animals. While any disruption of land that results from power plant construction has the potential to disturb habitat, geothermal plants like any type of power plant must comply with a host of regulations that protect areas set for development.

Geothermal plants are designed to minimize the potential effect upon wildlife and vegetation. Pipes are insulated to prevent thermal losses, power plants are fenced so as to prevent wildlife access, spill containment systems with potential to hold 150% of the potential maximum spill are put in place, and areas with a high population of wildlife or vegetation specific to an area are avoided. The construction of a geothermal plant reduces the overall impact on wildlife and vegetation species from energy.

CHAPTER 4

SUMMARY AND CONCLUSION

Although a geothermal power plant is renewable it is important to note that all power generation impacts the environment. Impacts such as land use for example cannot be avoided no matter what level of mitigation is employed. The goal instead of eliminating all impact, should be to minimize impacts because we cannot feasibly shut down all electricity producers, we must look to alternative sources.

Abundant geothermal resources throughout the world can provide an environmentally friendly source of energy. Data compiled from a variety of sources point to geothermal energy of an environmental option for new power generation that is far better than other energy sources such as fossil fuels.

In addition geothermal remain as environmentally friendly as most other renewable sources, while simultaneously offering reliable and a source of base load power that is unique among most other renewable option available. Research should be carried out on the basis to improve the already minimal environment impact of geothermal energy and to decrease the associated cost.

While currently used at only a fraction of its potential geothermal energy can substantially contribute to the energy needs of the twenty first century. With increased research and development funding in conjunction with supportive renewable energy policies scientist estimate that renewable source of energy can meet a higher percent of the world electricity needs 2020.

With continued technological development geothermal can be expanded from the western countries to third world country and the already negligible environmental geothermal impacts can be reduced to nearly zero. Though geothermal can provide the clean reliable and plentiful renewable energy resource for the world its pollutants should not be neglected.

SUMMARIZED ENVIRONMENTAL BENEFITS OF GEOTHERMAL ENERGY

In light of the inevitable impact and use of energy it is important to consider the environmental benefits of geothermal energy. Although geothermal provides environmentally sound electricity to millions, it supplies only a small percentage of total domestic electricity. In highlighting some of the most important environmental benefits of geothermal energy, the bullet below support the expanded development of geothermal power production.

- **Geothermal energy is reliable**

Because geothermal resource are available 24 hrs a day regardless of changing weather, geothermal energy is reliable as any fossil fuel facility. Geothermal is a renewable energy technology that can offer base load or intermediate power is dispatch able and can achieve high capacity factors. Geothermal represents a plentiful resource that has not been utilized to its full potential.

- **Geothermal energy is renewable**

Geothermal resources are sustainable because of the heat from the earth and water injection and thus will not diminish like fossil fuel reservoir.

As time progresses and technology improved our ability to extract geothermal resources with ease will increase not decrease.

- **Geothermal energy can offset other environmental impacts**

Waste water that would otherwise damage surface water is being used to recharge. The Geysers geothermal system and irrigate local land. In addition electricity generation from geothermal resources eliminates the mining, processing and transportation required for electricity generation from fossil fuel resources use of extraction technology would allow for the production of minerals without environmental impact of mining.

- **Geothermal energy is combustion free**

No smoke is emitted from geothermal power plants because no burning takes place, only steams emitted from geothermal facilities.

- **Geothermal energy minimally impacts land**

Geothermal energy uses less land than other energy sources. No transportation of geothermal resources is necessary because the resource is tapped directly at its source.

- **Geothermal energy is competitive with other energy technologies when environmental costs are considered.**

Study estimates that cost of power generation would increase 17% for natural gas and 25% for coal. If environmental cost were included. The cost induced and degradation potentially toxic emissions, environment forced extinction and destruction of animal and plant and health impacts to humans.

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