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UTILIZATION OF OFFSHORE GEOTHERMAL RESOURCES FOR POWER PRODUCTION

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ABSTRACT

Today geothermal energy has been utilized on land worldwide and the geothermal resources have a potential of being one of the greatest sustainable energy choices there is. Offshore geothermal energy has not been considered a feasible option, but with increasing energy prices and increasing knowledge of the utilization of this resource the choice becomes more attractive. The main objective for the project described in this paper was to analyze and compare a number of configurations for potential power production from offshore geothermal resources. The options were analyzed mainly with technical feasibility and estimated power output in mind. A rough estimation of the economic aspects was performed as well. The energy output was calculated and compared for different energy processes using data from the geothermal field in Reykjanes Iceland. The goal of this work was to establish a map of available options and opportunities within the offshore geothermal industry with Reykjanes ridge particularly in mind. The main disadvantage is the high cost compared to a traditional power plants located on land. The most feasible option is a single flash power plant located on land connected to a wellhead on the ocean bed. Thermoelectricity could be a favorable future power option but at this point the specific electricity production of the device is too small.

INTRODUCTION

The main focus of this project is offshore geothermal power plants utilizing offshore geothermal resources. The energy market in Iceland still has some potential to utilize energy on land, which is a less expensive option than an offshore power plant when it comes to investment cost and operation and maintenance cost per unit of energy produced. But if it was not for the concept of "*thinking outside the box*" Iceland would not be as advanced in geothermal technology as it is today. Utilization of offshore geothermal energy is not far away, the technology is already there. The project motivation is to extend the scope of geothermal energy utilization options by mapping available possibilities within the offshore geothermal industry. The advantages of offshore power plants as opposed to land utilization are several, e.g. no need for a detailed visual environmental assessment although it will need some general environmental assessment. No land space is required or an extension of the actual energy fields, which is a big factor as available energy fields are decreasing every year with wider utilization. On the other hand the disadvantages are the economical sides of it, the same goes for almost all sustainable energy systems available on the market today. The objective of this project is to analyze and compare a number of configurations for potential power production from offshore geothermal resources. These analyses are compared mainly with estimated power output feasibility in mind. A rough estimation of the economic aspects is performed as well. The position of the power plant is given a particular emphasis and there are several options available.

The options analyzed in this work are listed below along with a conceptual drawing showing how it could look like:

- Platform based power plant where the steam goes through a pipeline from the seabed to the platform

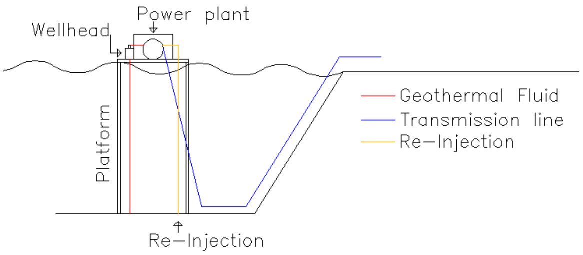

Figure 1: Platform based power plant

- Land based power plant separating the two phase fluid at the seabed then directing the pure steam onto land via pipeline

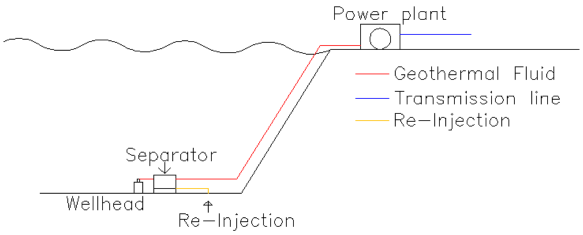

Figure 2: Land based power plant

- Underwater power plant producing electricity and transporting it to land

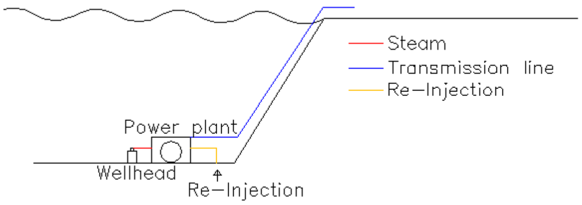

Figure 3: Underwater based power plant

- Binary power plant on land which uses a heat exchanger located at the seabed heating circulating working fluid.

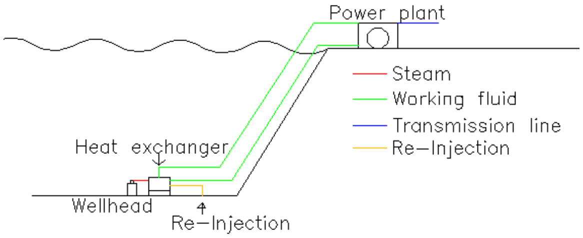

Figure 4: Binary power plant based on land

- A pipeline connected to a thermoelectric device using the temperature difference between the geothermal fluid and the ocean.

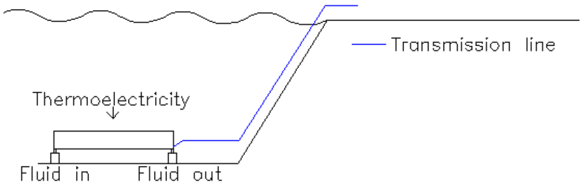

Figure 5: Conceptual drawing showing how the thermoelectricity power station could look like

The location of the potential offshore power plants that was studied within this project is the Reykjanes ridge. There is already a 2x50 MW_e power plant operating on the peninsula of Reykjanes, Reykjanes power plant, and studies indicate that there is energy capacity to produce at least 50 MW_e more (Þórólfsson 2012). The depth to the seabed along the ridge varies between 150-350 meters (Höskuldsson et al. 2007) and considered to be, at certain depths, shallow enough for controllable hydrostatic pressures for pipeline gathering system and underwater power plant. Figure 6 shows the actual depth to the seabed.

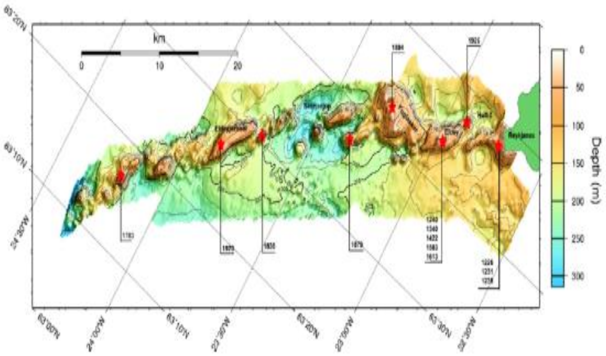

Figure 6: A map of Reykjanes ridge showing the actual depth to the seabed (Höskuldsson et al. 2007)

LITERATURE REVIEW

Not much has been done when it comes to the utilization of offshore geothermal energy. The main reason for this is that more economical options are on land than offshore. The development phase for offshore geothermal energy still has to go on so that future generations can benefit from earlier research phases. The research phases could e.g. be material choice for the pipe as well as which insulation material would fit pipes located underwater best and research on weather conditions for areas where offshore projects might be constructed.

There are two projects that have high potentials to become the next offshore geothermal projects. Those two projects are the only projects under development that could be found in the literature research performed in this work.
Those two projects are the Marsili project in Italy and the hydrothermal vent project in the Gulf of California. The Marsili project is currently underway in the ocean south of Italy, Marsili is an underwater volcano where the goal is to extract steam from the volcano to produce electricity (Eurobuilding 2012). The other project is a submarine with a binary station built inside. The goal of that project is to utilize

hydrothermal vents in the Gulf of California to produce electricity (Hiriart et al. 2010).

Possible Locations around Iceland

Possible locations for offshore geothermal utilization around Iceland are marked with colored dots on Figure 7. The red dot north of Iceland is the island Grímsey where hydrothermal vents are to be found (Atkins 2013). The depth to the hydrothermal vents is approximately 400 meters but the biggest disadvantage for utilizing that offshore steam field is the location, far out in the sea, and the fact that Grímsey is not connected to the electrical grid of Iceland. On the other hand it could be a good energy choice for the people living on the island Grímsey to utilize that source as they are producing electricity with diesel driven generators and heating their houses using oil.

In the southwest corner of Iceland dots are marked with green, yellow and blue colors, the green dot indicate evidence of gas bubbles from possible hydrothermal vent, the yellow dot indicates possible volcano eruption and the blue dots indicate measured seismic activities. The location of that area is close to land on the Reykjanes peninsula, connected to the national grid and has some information available to estimate the behavior of the geothermal field.

Reykjanes ridge

Figure 8 shows the Reykjanes peninsula extending into Reykjanes ridge. Scattering was detected on the ridge with sonar instruments (Benjamínsson 1988), this scattering could indicate that there are some hydrothermal vents in the area. Precise locations where the bubbles were found are shown on Figure 8 (Atkins 2013). It is now known that Reykjanes peninsula has a high capacity geothermal resource and with the information regarding the bubbles and the seismic activity along the ridge it is estimated that geothermal energy could be found on the Reykjanes ridge as well.

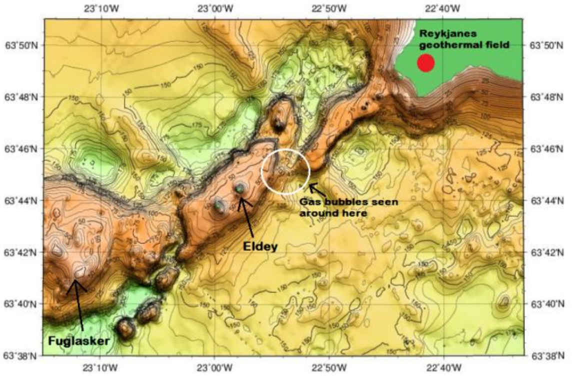

Figure 8: Location where the gas bubbles were found in the Reykjanes ridge (Höskuldsson and Kjartansson 2005)

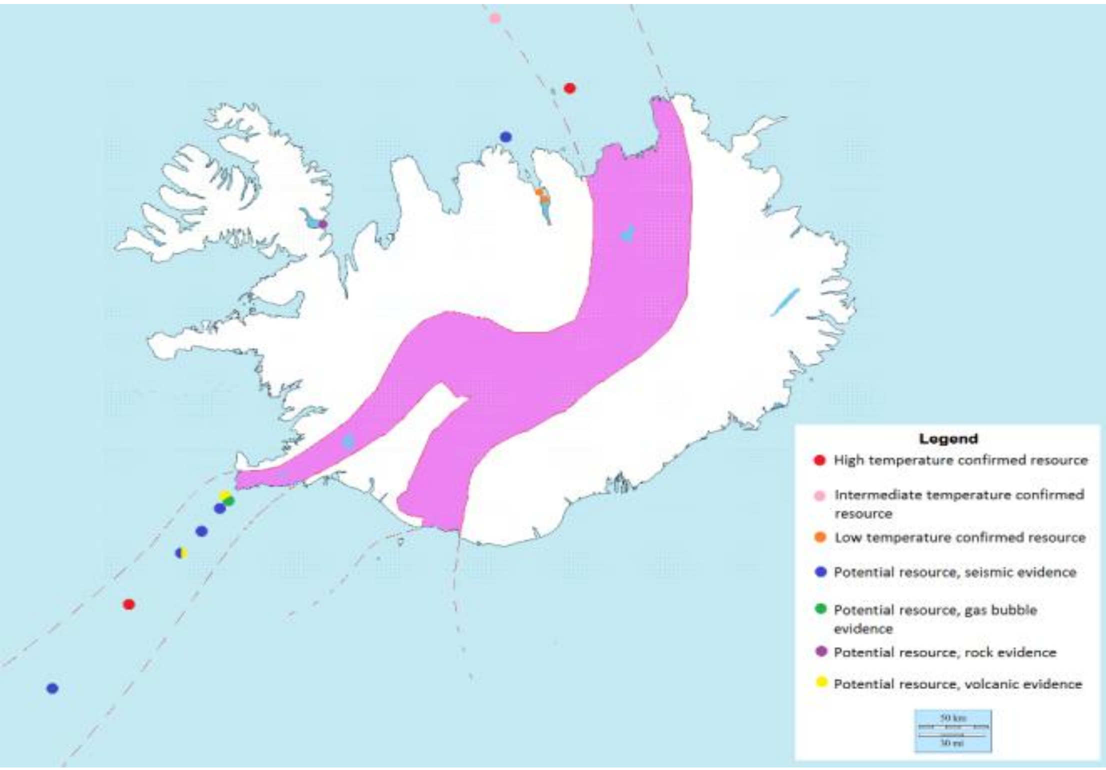

Figure 7: Map of Iceland showing known offshore geothermal areas (Atkins 2013)

Weather conditions at Reykjanes

The weather conditions at the ocean outside Reykjanes are not the optimal weather conditions for an offshore project and therefore it could be very difficult to operate offshore geothermal power plants there. The main reason for that are strong winds and high waves. Experience from the oil industry on the other hand has shown that the oil platforms have been operated at worse weather conditions than in Reykjanes. For that reason bad and windy weather in Reykjanes should not necessarily be an obstacle for future offshore projects. In Reykjanes the wind can go up to 40 m/s and the ocean current around Reykjanes is close to zero velocity at the surface and it is estimated to be around 2-3 m/s at 150 to 250 meters depth (Stefánsson and Ólafsson 1991). The waves can also be high on the Reykjanes coastline and that could affect the platforms structural calculation when it comes to choosing the foundation for the actual platform.

Drilling on Reykjanes

Drilling at the ocean crust is not an unknown procedure; in fact it has been done for decades within the oil industry as well as for geological explorations. The average ocean depth outside Reykjanes coast is 200 meters down to the ocean bed. The ridge area is known to be highly active with a heat flow into the ocean (Höskuldsson et al. 2007). As shown on Figure 9 the seismic areas are very close to land and at feasible depth when it comes to drilling and operation. The red dots on Figure 9 show seismic activity. The activity is most intense around Fuglasker, but even closer to land it looks promising as well as seismic measurements indicate that there could be heat stored beneath (Höskuldsson et al. 2007).

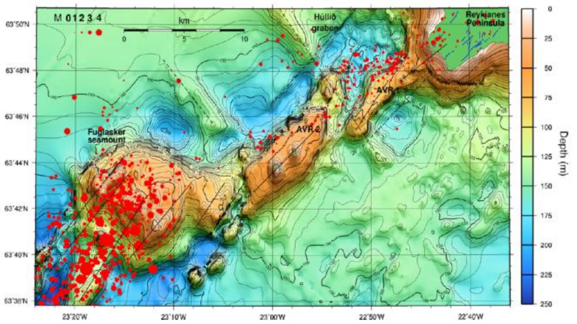

Figure 9: Map showing the Reykjanes ridge seismic activities between 1990 and 2004 (Höskuldsson et al. 2007)

REYKJANES GEOTHERMAL FIELD

The Reykjanes geothermal steam field is mostly covered with lava and is one of the most studied geothermal fields in Iceland (Sæmundsson 2012). The foundation for these researches reaches back to the years before 1970 as seismic activities occurred frequently in the area (Sæmundsson 2012). Reykjanes steam field has the highest temperature of steam fields in Iceland, and it has been used for power production for several years without significant impact on the reservoir (Sæmundsson 2012). The liquid that is available and is used for energy production consist mainly of salt water (Sæmundsson 2012).

For the Reykjanes steam field, wells have been drilled and monitored. For many years data has been collected; e.g. measurements of mass flow, pressure and enthalpy. The production wells are shown on Figure 10.

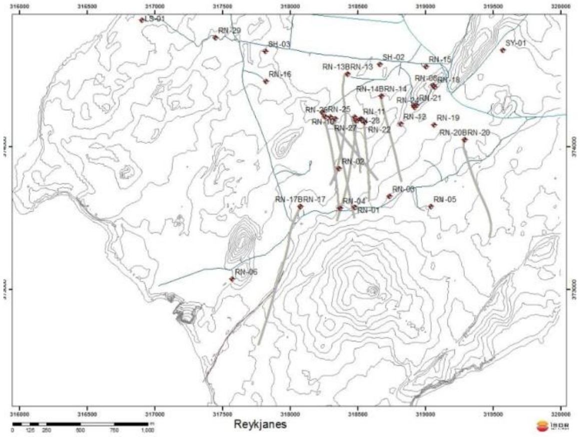

Figure 10: The location of the production wells on the Reykjanes peninsula (Jónsson and Björnsson 2011).

Data Analyzed

To get an idea of how much the offshore wells outside Reykjanes would produce, the boreholes used by the Reykjanes power plant were analyzed, as those boreholes are close to the Reykjanes ridge area and therefore may be assumed to have similar properties. Information gathered from the Reykjanes boreholes was therefore used for further analysis. The actual data for the boreholes located on the Reykjanes peninsula were collected from two companies; ISOR (Icelandic Geosurvey) and HS-Orka (the owner of the steam field). From ISOR, information about the productivity curves for the boreholes was collected and analyzed. Power production and enthalpy information was collected form HS-Orka. The well productivity curves are shown in Figure 11. The productivity curve used in this research was simulated from all the production curves available from the Reykjanes power plant data bank. The production curve for each borehole was plotted from the data and they are shown in Figure 11. Those data are actual measurements from the boreholes.

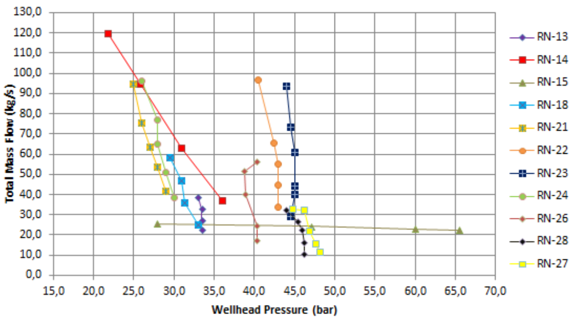

Figure 11: Plotted production curves from Reykjanes steam field

With information from all the individual production curves a simulation was performed with the calculation software MATLAB. MATLAB was used to make a hypothetical productivity curve resembling the most realistic productivity curve from all the wells. The actual power output was calculated using this hypothetical average production curve. To calculate the average production curve, calculations of the mean and standard deviation for the well parameters were needed, those calculations are shown in Table 1.

Table 1: The mean and the standard deviation of the cutoff pressure, enthalpy and the mass flow from the production curves shown on Figure 11

Parameter	Mean, μ	Standard deviation , σ
Pressure [bar]	36.2	8.4
Mass Flow [kg/s]	48.1	25.35
Enthalpy [kJ/kg]	1,570	364.5

The equation to find the mean is expressed with Eq. (1):

$$\mu = {\sum x}/{n} \tag{1}$$

Where μ is the mean, $\sum x$ is the sum of all fixed numbers gathered from the data collected and n is the quantity of the fixed numbers.
The equation to find the standard deviation is expressed with Eq. (2):

$$\sigma = \sqrt{[\sum(x_i - \mu)/n]} \tag{2}$$

Where σ is the standard deviation, x_i is each fixed number gathered from the data collected, μ is the mean calculated using Eq. (1) and n is the quantity of the fixed numbers.

The average productivity curve

The average production curve was calculated and simulated by generating one hundred wells, where the probability follows the normal distribution parameters from Table 1. The average well flow for these 100 wells is then plotted against wellhead pressure, and a regression curve fitted. This process was then repeated a few times, with similar results. The regression curve is shown on Figure 12 together with a sample of the 100 well average generated. The regression curve was then used in the software EES (Engineering Equation Solver) to determine the optimal pressure and flow rate that will enter the turbine for the power production options used for the power calculations. This was done to resemble the most realistic power output for the Reykjanes area.

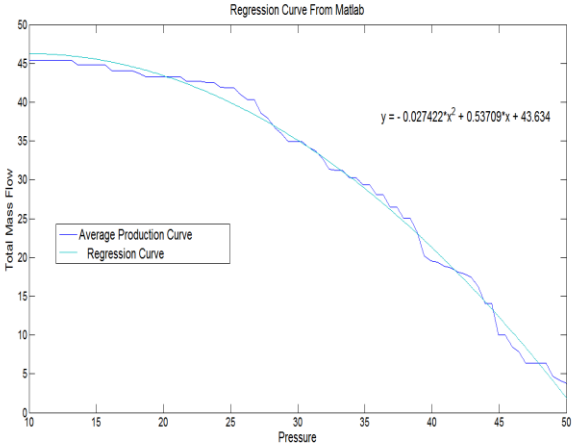

Figure 12: Regression curve used as the average productivity curve

The regression curve in Figure 12 is expressed with Eq. (3):

$$\dot{m}_{geo\ fluid} = A * P_1^2 + B * P_1 + C \tag{3}$$

Where $\dot{m}_{geo\ fluid}$ is the total mass flow of the geothermal fluid, P_1 is the wellhead pressure and A, B and C are constants calculated for the regression curve fits the given input data.

RESULTS

As previously stated, the following energy processes and power cycles were analyzed and calculated:

- Single flash power plants on a platform at the ocean
- Land based power plant with a separator at the ocean bed
- Underwater power plant located on the ocean bed
- Binary power plant located on land with a heat exchanger on the ocean bed

- Thermoelectricity device producing electricity using temperature difference between the ocean and the geothermal fluid

Single Flash Power Plant

The properties needed to calculate the power output from a single flash power plant is the enthalpy, pressure and mass flow at each state. The pressure along with the corresponding mass flow from the regression curve on Figure 12 is optimized to maximize the power output of the cycle. The enthalpy used in this case is the average enthalpy from the production wells at the Reykjanes power plant and can be seen in Table 1. Table 2 summarizes the optimal pressure and mass flow from all the single flash cycles. Thermal losses as well as changes in kinetic and potential energy are neglected in the power calculations

Table 2: Power plant´s optimal pressure and mass flow

Power Plants	Platform	Under-water	On Land
Average Enthalpy [kJ/kg]	1570	1570	1570
Optimal Pressure at Turbine Inlet [bar-a]	12.06	12.06	12.06
Optimal Pressure at Wellhead [bar-a]	12.1	12.06	14.26
Optimal Total Mass Flow [kg/s]	46.12	46.12	45.72
Optimal Steam Mass Flow [kg/s]	17.89	17.89	17.2

Power plant on a platform

This power plant option is based on the idea of locating the power plant on a platform. A pipeline is needed to direct the fluid from the seabed to the platform for the fluid flowing from the reservoir to the separator. It is estimated that the pipeline is like an extension of the well so there is no two phase flow in the pipeline concerned. The approximated depth between the platform and ocean bed was set to be 300 meters. The depth in that area is shown on Figure 6.

The turbine power output was calculated with regard to optimal pressure and is 10,946 kW_e. The generator was estimated to have the efficiency of 0.95 and the cooling water pump needs 406 kW_e to be able to provide the necessary flow into the condenser. The net power output for the single flash power process is then calculated to be 9,993 kW_e.

Land based power plant

This power plant option is based on the idea of having the power station located on land. To be able to situate the power plant on land a separator shall be located at the seabed as a two phase flow coming from the reservoir cannot flow upwards. If the two phase flow is to flow upwards an unstable flow pattern could occur like slug flow (DiPippo 2008). Slug flow can cause excessive vibration in the pipes (DiPippo 2008). The pipeline from the separator to the power plant is the main difference in calculations between the platform based power plant and the land based power plant described in this section. Thermal losses are neglected and therefore it is estimated that the quality in the pipe line between the separator and the power plant is 100% steam.

The turbine power output was calculated to be 10,523 kW_e. The cooling water pump needs 390.3 kW_e to be able to provide the necessary flow into the condenser. The net power output for the single flash power plant based on land was therefore calculated to be 9,607 kW_e.

Underwater power plant

This power plant option is based on the idea of having all of the power plant components completely underwater. A transmission line is needed to transport the electricity to land. Calculations regarding the power output are almost the same as for platform based power plant except for the pump work for the cooling. The total required pump head calculated is 0 meters when using underwater power plant compared to 50 meters in head for platform based power plant. The biggest difference between the power plant options is the actual cost.

The turbine power output was then calculated with regard to optimal pressure being 10,946 kW_e. The generator was estimated to have the efficiency of 0.95 and the cooling water pump needs 129.2 kW_e to be able to provide the necessary flow into the condenser. The net power output for the underwater single flash plant was then calculated to be 10,269 kW_e.

Binary Cycle Power Plant

This power plant option is based on the idea of having a binary cycle power plant located on land. There are two options available for utilizing the energy of the geothermal fluid coming from the wellhead. A) Transporting the geothermal fluid to land in liquid form without flashing as a two phase flow cannot flow upstream. Doing that the pipeline would be at reservoir pressure and reservoir temperature. B) To have a heat exchanger located at the seabed transferring the working fluid from land based plant to the heat exchanger located on the seabed. Option B was chosen for the calculations performed in this research as the reservoir pressure was considered to be too high for the pipeline and theoretically it would be impossible to keep the pipeline without thermal and pressure loss all the way to land, such losses could cause the liquid to boil and transform it into a two phase flow. The heat exchanger at the seabed will heat up the working fluid to the turbine inlet state. The pipeline gathering system for the binary power plant is twice the length of the pipeline for the single flash plant because the pipeline goes both ways to and from the exchanger. Thermal losses as well as changes in kinetic and potential energy are neglected and therefore it is estimated that the working fluid in the pipeline coming from the heat exchanger to the power plant will be superheated steam.

Properties for the binary power plant

The properties used to calculate the binary cycle power plant are the enthalpy of the geothermal fluid, optimal pressure and the optimal mass flow for the geothermal fluid. The enthalpy of the geothermal fluid is the calculated average enthalpy from Table 1, or 1,570 kJ/kg. The pressure and mass flow of the geothermal fluid were optimized to give the maximal power output for the binary cycle. In this case the optimal pressure was calculated to be 19.14 bars and the total mass flow was calculated with the regression curve formula to be 43.87 kg/s.

A calculation regarding the best fitting working fluid was done in EES. The selected binary fluid used is methanol, it was chosen from calculations of several different fluids. Methanol gives the highest net power output and has a small specific volume compared to other binary fluids. There is one disadvantage though and that is the high 45 bar pressure inside the binary cycle.

The calculated turbine power output was 16,449 kW$_e$. The generator was estimated to have the efficiency of 0.95 which leads the power output to go down to 15,626 kW$_e$. The pumps was estimated to have the efficiency of 0.65 and the power needed for the feed pump is 412.5 kW$_e$ and for the cooling water pump 1,127 kW$_e$. Then the net power output will become 14,086 kW$_e$.

Thermoelectricity

Thermoelectricity has been a known method for a long time for power production (Ferrotec 2012). The method used is often called the Seebeck effect. It is named after a German physicist named Thomas Seebeck (Ferrotec 2012). Thermoelectricity can be produced from temperature difference (ΔT) between two fluids. When one side of equipment is at different temperature than the other side, an electric current can flow in a circuit between the two sides producing electricity. The greater the temperature difference is the more current can flow in the circuit and therefore more electricity can be produced. Figure 13 describes the process more visually as used in this research.

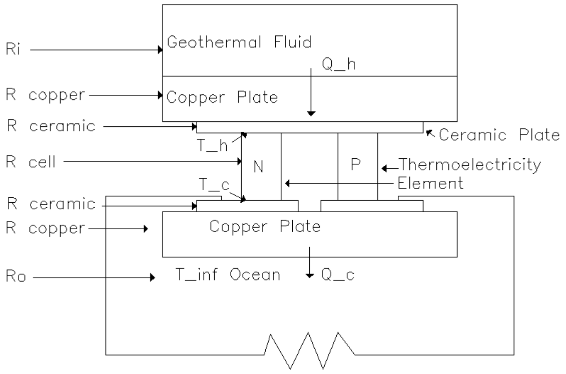

Figure 13: Single thermoelectric couple

Where Q_$_h$ is the thermal heat going through the cell, Q_$_c$ is the thermal heat rejected after going through the cell, T_$_h$ and T_$_c$ are the temperatures on each side of the cell and N and P are the crystals in the cells, utilizing the temperature difference from the fluids to produce electricity. When the two conductors N and P have electric contact, the electrons from one concoctor flow into the other conductor producing electricity.

The materials used around the cells are different, all depending on the situation but in this calculations copper is used as the metal between the fluids in the cell because of high thermal conductivity although detailed analysis are needed to see what metal fits the geothermal fluid best. The material used between the copper and the cell are ceramic plates and they are used as an electrical insulator.

Thermoelectric power calculations

To calculate the power output for the situation described, information for some parameters is needed. Those parameters are the depth down to the seabed where the thermoelectricity equipment is located and is set to be 150 meters, the inlet temperature of the geothermal fluid which is considered to be 180 °C and the ocean temperature considered to be 5 °C down at 150 meters.

The convection heat transfer coefficient for the geothermal fluid is estimated to be 5000 W/m^{2}K and the convection heat transfer coefficient for the cold ocean side is variable with regard to temperature and length shown on Figure 13 and Figure 14. Therefore calculations with different ΔT are performed; those calculations were done with MATLAB. One square meter of the thermoelectric device used in this calculation is shown in Figure 14.

The area of one square meter was divided into 10 equal areas which all have different ΔT which is the temperature difference between the geothermal fluid and the ocean temperature on the other side of the equipment. The geothermal fluid going in the device is two phase flow at the temperature of 180°C. The mass flow is not calculated as the device is consider to have enough flow to have the device at constant temperature of 180°C. It was calculated that for every area with the geometry of 0.1 meter times 1 meter, 59 cells could be fitted in that area. Calculations with regard to that are shown in Table 3.

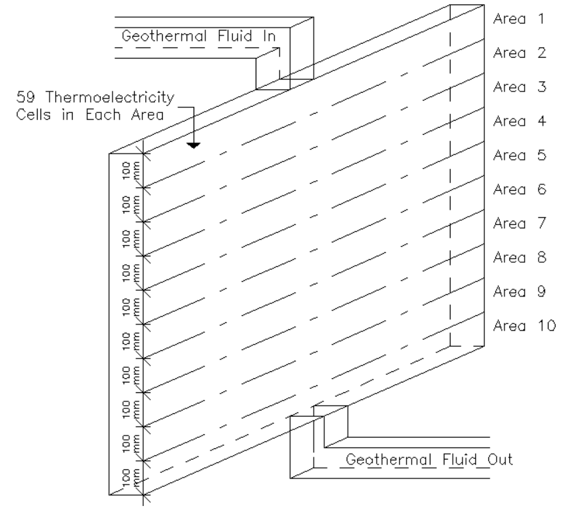

Figure 14 Drawing describing the geometry for one square meter of thermoelectricity device

Table 3: Power calculations for thermoelectricity

Area	ΔT [°C]	Power for One Cell in [W]	Number of Cells [10cm x100cm]	Power per Area [W]
1	67.2	6.70	59	395.3
2	66.5	6.63	59	391.2
3	65.8	6.56	59	387.1
4	64.9	6.47	59	381.8
5	63.9	6.37	59	375.9
6	62.15	6.20	59	365.6
7	61.15	6.10	59	359.7
8	59.3	5.91	59	348.9
9	56.6	5.64	59	333.0
10	52.2	5.20	59	307.1
Total Power Output [W]				3645.7

Calculations of the total power output for the thermoelectricity device shown on Figure 14 are approximately 3.6 kW.

If thermoelectricity should be equal to the highest power output calculated for the options described earlier, which is the binary cycle producing 14,086 kW, the size of the thermoelectricity would need to be 3,863 square meters. That could e.g. be a plate 100 meter wide and 1 meter high. Approximately such 39 plates would be needed to for production of the same power output for the binary plant.

POWER OUTPUT COMPARISON

After analyzing each utilization option a comparison table between their power output and cost was made. That way it can be seen which power option fits Reykjanes area best for offshore utilization according to the calculations performed in this research.

Table 4: Comparison of net power options

Power option	Net power output kWe
Single Flash (Platform)	9,993
Single Flash (Land Based)	9,607
Single Flash (Underwater)	10,269
Binary Cycle (Land Based)	14,086

COST ANALYSIS

Order of magnitude cost assumptions was carried out for all the scenarios. The cost for each component was calculated as shown in Table 5

Table 5: Cost versus net power ratio

Power option	Net power output kWe	Total Cost $\$ *10^3$	Cost kW_e
Single Flash (Platform)	9,993	88,189	8,057
Single Flash (Land Based)	9,607	61,042	5,801
Single Flash (Underwater)	10,269	106,500	9,725
Binary Cycle (Land Based)	14,086	102,298	6,219
Thermoelectricity device with drilling, exploration and O&M cost (3 wells are considered)	14,086	110,270	7,828

DISCUSSION AND CONCLUSION

Data shows that the area around Reykjanes peninsula has seismic activity and could possibly be a feasible choice for offshore geothermal utilization. In this paper several power processes and configurations were analyzed and calculations made for the net power output and cost of each option. The results show that regarding the net power output only the binary power plant would be the most feasible option. On the other hand with respect to $/kW ratio, the single flash power plant located on land turns out to be the most realistic choice. Although the single flash located on land has the best $/kW ratio it could turn out to be too expensive. Factors like increased distances from land based plant to the source or wellhead will automatically change the cost calculations for the land based power plants, as land based power plant cost increases with longer pipelines.

Thermoelectricity could be a favorable future power option and calculations show that one square meter of thermoelectricity device shown on Figure 14 could produce approximately 3.6 kW. More analyses are needed to estimate how many square meters of thermoelectric device one geothermal well can provide. After such analyses the real total cost per kW can be calculated. Further cost calculations are needed to evaluate more realistic economic feasibility for thermoelectric power.

It is considered that offshore power plants are technically possible although many questions are still unanswered when it comes to detailed design of offshore power plant. Economically it is not feasible at least not when there is still geothermal energy to be utilized on land. The energy price has a big effect on the future development for offshore projects i.e. if the energy prices increase dramatically then development of projects like the offshore geothermal might be faster. The thermoelectric power option is not comparable with other power cycles as more detailed cost analyses are needed.

FUTURE WORK

In this paper, a number of configurations and energy processes for offshore power utilization were analyzed and compared, regarding power output and economical aspects. There are still many questions unanswered on offshore power utilization and those questions need further study. Some of the further studies necessary could be;

A) A detailed offshore power plant design taking into account all the components needed in a fully designed power plant. Those components would include transmission lines, separator, demister, turbine, condenser and other important components needed for detailed design.

B) Making detailed environmental assessment for the process of offshore geothermal utilization. That could be for the power plant location and the offshore drilling part. The offshore drilling could cause some disturbance to the wild sea life and for that reason there is need for an environmental assessment.

C) To conduct a more detailed cost analysis for all the configurations analyzed in the paper, the cost analyzed here is an order of magnitude assumption and for that reason it may be considered as a rough estimation.

D) A detailed scaling analysis for the pipeline gathering system, as the wellhead pressure for each scenario was selected with regard to the maximal power output instead of selecting it with regard to scaling effect. In real situations problems could occur with scaling at a given pressure. In those cases the pressure needs to be adjusted to the pressure where there is less effect of scaling in the pipeline gathering system. Then the power output might be even lower than the actual power output calculated before.

E) The amount of non-condensable gases coming with the geothermal fluid will need to be accounted for as it lowers the mass flow of steam entering the turbine and increases the parasitic load.

F) A detailed analyze for the underwater material, that could be e.g. for the metals used for the power options and the insulation for the pipelines located on the ocean bed. The metals have to withstand the corrosion that occurs when in contact with the ocean. The insulation on the pipelines has to withstand as little thermal loss as possible as more thermal loss in pipes will automatically change the power output for the power options.

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