Journal of Physics: Conference Series

PAPER • OPEN ACCESS

Thermal characteristics of the X geothermal resources, and a recommendation on utilization possibility

To cite this article: K Pudyastuti *et al* 2019 *J. Phys.: Conf. Ser.* **1402** 022057

Thermal characteristics of the X geothermal resources, and a recommendation on utilization possibility

K Pudyastuti[1, *], H Harmen[2], M Djumantara[1] and S Fadhlurrahman[1]

[1] Petroleum Engineering, FTKE, Universitas Trisakti, Jakarta, Indonesia
[2] Mechanical Engineering, Universitas Lampung, Lampung, Indonesia

*krispudyastuti@trisakti.ac.id

Abstract. Like in petroleum, geothermal has a high cost and risk in exploration, development including drilling and utilization. This needs a clear definition and understanding of the nature and characteristic of the system in question, so the increasing of investment cost and risk could be mitigated. Un-like in the petroleum industry, reservoir engineering and geoscience are intricately intertwined in geothermal. Considering this issue, in this study the author has integrated the results of reservoir engineering analysis with geoscience concept, to determine the up-flow zone, is a zone with high thermal potential and high permeability, so it can develop as geothermal field. It was conducted at a geothermal prospect in Indonesia located at the average altitudes of about 1000 meter above sea level (m.a.s.l), where 26 wells have been drilled. The research focus in characterising of the system, using wellbore temperatures and pressures measured. This will conclude the reservoir temperature and pressure as well as enthalpy, and up-flow zone by deploying several methods and approach: namely Horner temperature, BPD curve and Pivot concept, and thermal conductivity or heat transfer concept which applied in geo-science. The research includes a literature review on heat energy conversion to electricity based on reservoir temperature and or enthalpy approach, which is used to recommend the conversion system that can extract the heat efficiently. In addition, the question on location of the up-flow zone has been answered by this study, i.e. in the southern part of the field.

1. Introduction

If we look at energy portfolios of any country recently, it appears that renewable energy is pursued to increase its share in primary energy supply. As well as Indonesia, is currently working to increase its geothermal energy share in the energy supply mix, to assure sustainable energy development while actively participating in strengthening the global response to the threat of climate change. The installed power generation capacity in Indonesia has reached 1,924.5 in the first quarter of 2018, which is still about 11.03% of the existing reserve [1]. It seems the geothermal development for electricity (indirect utilization) in Indonesia is quite low. Investor say that is happened due to the uncertainty of laws and regulations and the dilemma of decreasing geothermal electricity price to meet just and fair value for consumers and increasing electricity price to attract private investment and compensate for increasing investment cost and risk [2].

Indeed, geothermal has a high cost and risk in exploration, development including drilling and utilization. This needs a clear definition and understanding of the nature and characteristic of the system in question [3].The understanding will be achieved through the development of a conceptual model of the system, which is a descriptive or qualitative model incorporating, and unifying, the essential physical features of the system, which mainly based on analysis of geological and geophysical information, temperature and pressure data, information on reservoir properties as well as information on the chemical content of reservoir fluids. The models should explain the heat source for the reservoir in question and the location of recharge zones, the location of the main flow channels as called up-flow zone, the general flow patterns within the reservoir as well as reservoir temperature and pressure conditions.

There have been many research publications on this field, although there are still doubts about the up-flow zone - a high temperature zone and at the same time high permeability. This study will answer this question.

2. Methods

This paper describes the two main studies. First, thermal characteristic of the system based on wellbore temperature and pressure data. It was carried out by Horner methods using wellbore temperature measurements during heating-up, which also called as temperature build up. The formation temperatures are inferred from Horner, were then supplemented with additional information, i.e. geo-science research on the determination of up flow zone in a geothermal reservoir based on thermal conductivity concept that has been done by Sebastien 2013. The results are used to infer the up-flow zone. Furthermore, pivot pressure analysis based on wellbore pressures measured during heating-up, the study produces value of the thermodynamics properties namely pressure, as well as enthalpy at reservoir depth.

Second, the study also explains about simple approach in estimating the efficiency of the conversion from thermal energy to electricity. This recommend the best conversion technology which is match with the thermal characteristic namely temperature, pressure as well as enthalpy at reservoir depth.

3. The X geothermal resources

Geoscience surveys in the X geothermal field indicate at least 65 km2 of probable energy resource, and 26 wellbores have been drilled indicate a 25 km2 of proven energy resource [4]. The field is planned to supports the increasing targets of the energy sustainability and stable economic growth by installing the power plant of unit 1 and 2 also for units 3 and 4 [5].

3.1. Formation temperature of the X field

In this study, the formation temperature was estimated by through manual calculation which has been done by Syarif et al. [6]. It is an analytical method based on straight line relationship between measured wellbore temperature during drilling as called temperature buildup [7], at given depth, T, and the logarithm of relative time, τ , as called Horner time.

For detail purposes to figure the formation temperature distribution of entirely field of 25 km^2, the author has divided the X field into three clusters, namely cluster I which is represented by wellbore XA, cluster II which is represented by wellbore XB, and cluster III which is represented by wellbore XC.

3.2. Area cluster – I (Well XA)

Cluster I represent the middle part of the field. There are several temperature and pressure surveys have been done at well X A (after drilling with and without injection, during heat up, and after bleeding). Heating up temperatures measured were used to estimate static formation temperature (SFT) at each depth of well XA which represent thermal characteristics of cluster I. The SFT shows that well XA has a maximum temperature of 250^o C at depth around (-) 700m.a.s.l.

3.3. Area cluster – II (Well XB)

Cluster II represent the southern part of the field. There are several temperature and pressure surveys have been done at well X B (after drilling with and without injection, during heat up, after bleeding, and after vertical discharge).

Heating up temperatures measured were used to estimate static formation temperature (SFT) at each depth of well X B which represent thermal characteristics of cluster II. The SFT (figure 1) shows well

X B has an average temperature of 250°C at depth from (-) 200m.a.s.l. to (-)700m.a.s.l. It seems that SFT was overestimated by about 25° C when compared with temperature profiles after bleeding and after vertical discharge.

3.4. Area cluster III (Well XC)

Cluster III represent the northern part of the field. There are several temperature and pressure survey have been done at well XC (after drilling with and without injection, and during heat up). Heating up temperatures measured was used to estimate static formation temperature (SFT) at each depth of well XC which represent thermal characteristics of cluster III, as shown by figure 1. The SFT shows well X C has a maximum temperature of 250° C at depth from (-) 450m.a.s.l. to (-) 900m.a.s.l. It seems that the SFT matches the temperature profile during heat up 265 days and 339 days.

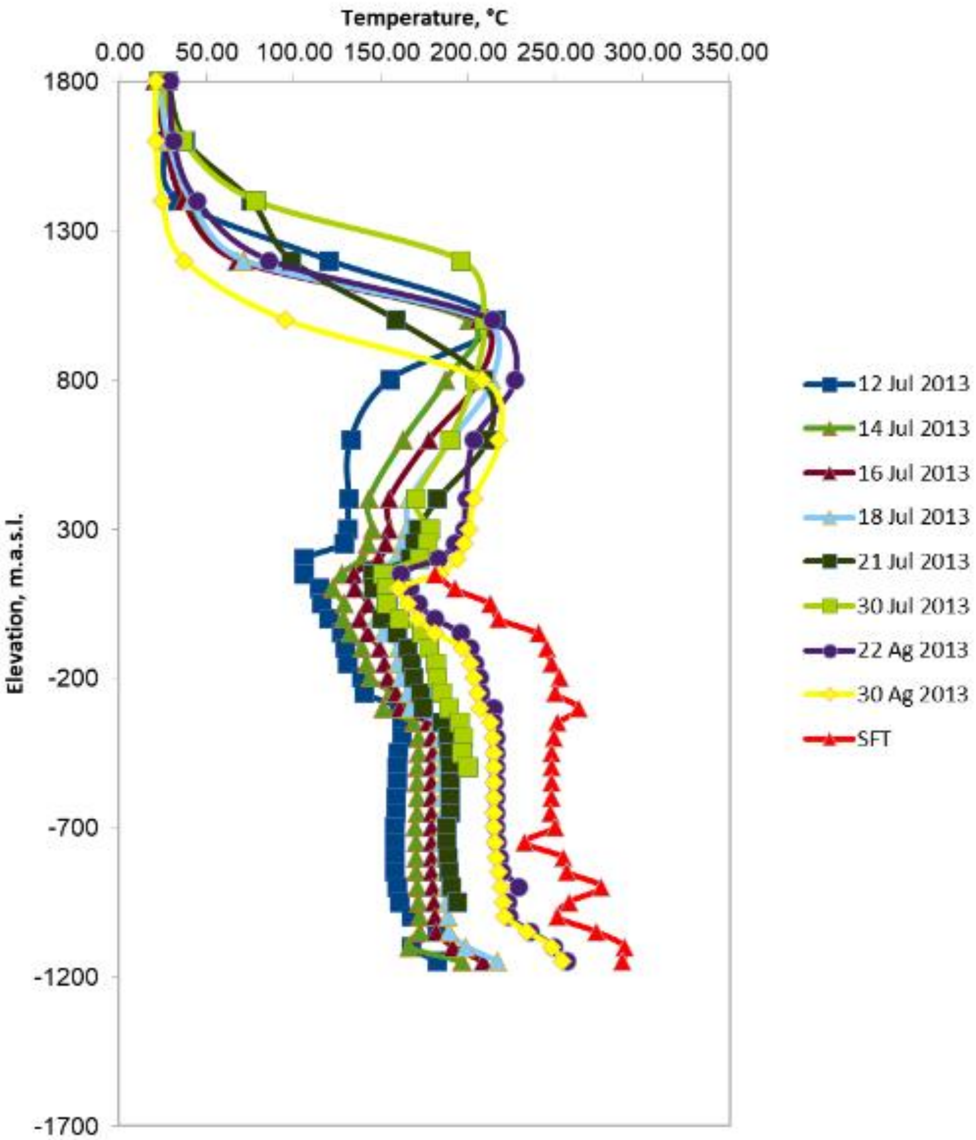

Figure 1. The Wellbore X B temperatures measured profile. The static Formation Temperature (SFT) based on Horner method calculation (red line), which represents temperature distribution at Cluster II [6].

3.5. Up-flow zone

In order to identify the flow-zones, Sebastien et al. compared the theoretical thermal gradients induced by the conductive flux against measured thermal gradients induced by conductive and convective heat transfer [8]. In this study, the author compared the calculated and measured thermal gradient profiles of wells X A, X C and X B, which revealed two cases. The first case of wellbore XC shows that the measured gradient gave higher values than the calculated gradient which was obtained by Homer method which then leads one to suspect the presence of hot fluid circulation or convection. Next, wells X A and X B show that the values in the calculated and measured gradients are equal, thereby indicating that the heat transfer is governed mainly by conduction and there is no significant occurrence of hot fluid flow.

3.6. Feed zone and the concept of pivot point

The feed zone has inferred from pivot point of pressure analysis. The concept of pressure pivot or pressure control point concept is crucial to understanding well behaviour during the heat-up period. As the wellbore fluid changes temperature during the heating period, the fluid density of fluid also changes but pressure at the feed zone is fixed by the formation pressure, so the pressure profile observed in the well pivots about the feed depth [9]. For the well with the single feed zone, the pivot uniquely identifies the depth. In short word the pivot point is the depth in the well where the pressure remains stable during well recovery because it approximates reservoir pressure. This concept was later made clear by Menzies [10]; as the well heat-up, the pressure gradient changes as a result of a decrease in fluid density. The pressure profile can then be rotated ("pivot") around the pressure control points. Location depends on the relative permeability of the zone in the well, and this is the only point at which the measured pressure is not affected by the temperature change.

Figure 2 shows heating profiles in well represent cluster I (middle part of the field). The pressures form pivot at depth between (+) 400m.a.s.l. and (+) 300m.a.s.l. In the southern part (cluster II), the pressures form pivot at depth between (+) 300m.a.s.l. and (+) 200m.a.s.l. The main feed zone seems located in the northern part of the field (cluster III) at depth between (-)350m.a.s.l. and (-) 450m.a.s.l. With regards to the conclusions in the chapter 3.5. that the up-flow zone is located in cluster III, the author concludes that pivot pressure at wellbore XC is a reservoir pressure of the X geothermal field.

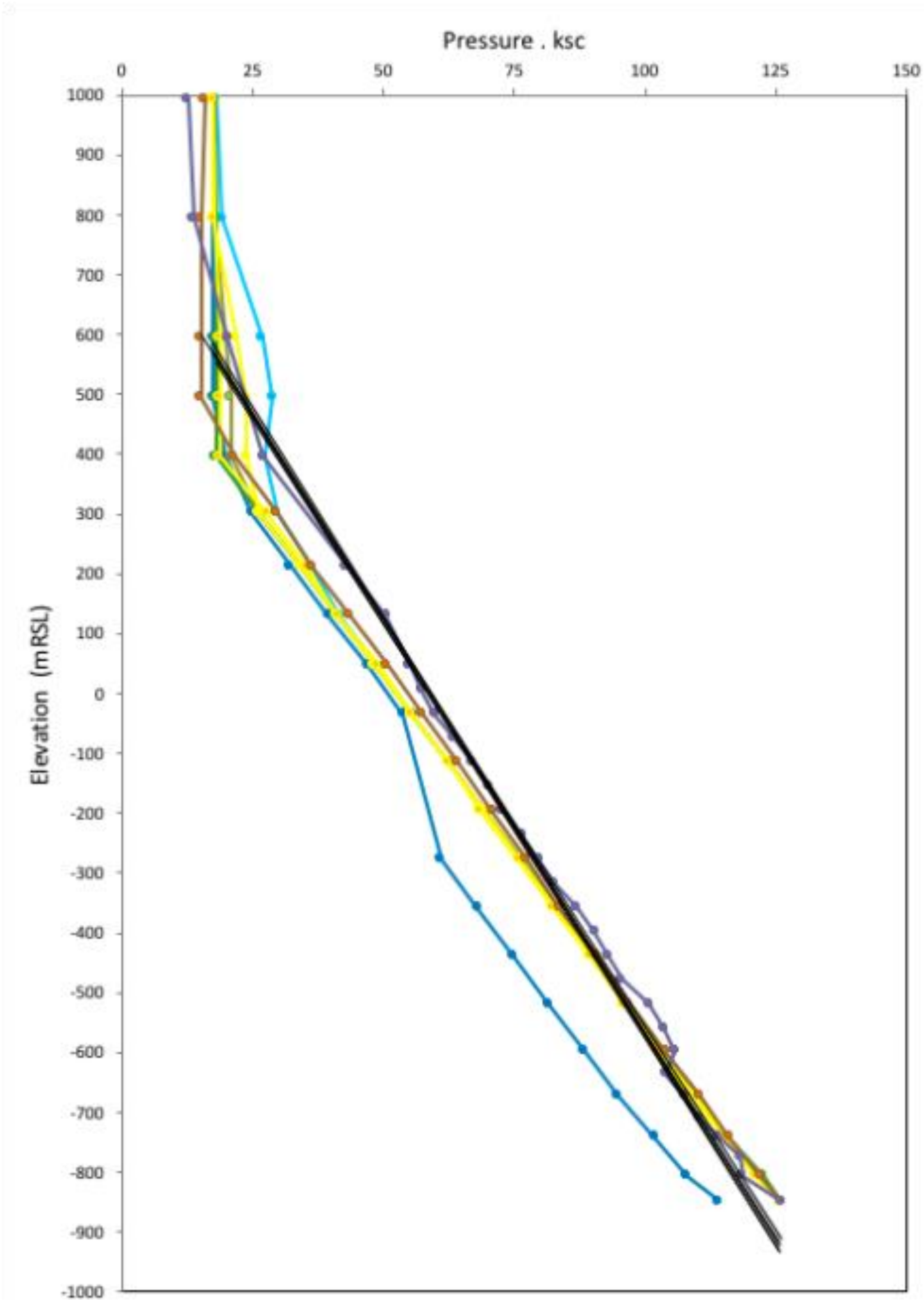

Figure 2. Pressures profile measured during heat up of well X C. The pressures form pivot at depth between (–) 350m.a.s.l and (–) 450m.a.s.l, represents the reservoir pressure of the X geothermal field is about 75 – 80 k.s.c.

3.7. Reservoir type

The result of the temperature formation analysis, which mention the average temperature in the northern (cluster III) is 250°C, and can reach 275°C more which is represented by well XC) in the north part of the field. Based on that result, the reservoir can be classified as a high-temperature reservoir. Then, based on Boiling Pressure with Depth (BPD) curve analysis, which show the temperature curves of wells are below its saturation curve, so it can be concluded that the reservoir is a high temperature reservoir with liquid domination type. Furthermore, by combining analysis result of formation temperature and pivot point analysis, can be inferred that reservoir pressure is about 75 to 80 k.s.c. (kilogram-force per square centimetre). These thermodynamics properties have inferred a high enthalpy reservoir of 1210 – 1236 kJ/kg, by using pure substances characteristics approach [11].

4. Conversion technology selection

Selection of conversion is generally based on efficiency, so thermal energy can be converted efficiently. There are several approaches that can be applied to the selection of technologies that convert heat energy to electricity, namely simple approaches and thermodynamics. The thermodynamics approach is one of the most accurate and world widely accepted method to calculate potential electrical energy for every geothermal power cycle and size, almost every aspect which has an impact on conversion factor is considered. It gives more accurate estimation result compare to the simplistic approach [12,13]. Considering to data availability, the approach applied in this study is simplistic method that is appropriate to the situation. analysis has been conducted by referred to several factors that affect the efficiency of a type of power plant namely temperature, pressure and enthalpy of reservoir. Simplistic method has been introduced by Hyungsul Moon [14] and Zadiq J Zarrouk [15]. They have examined the world-wide data of geothermal power plant, and has produced a generic model for the conversion efficiency as a function of enthalpy as follow:

$$\eta\ actual = 7.879\ln(h) - 45.651$$

Where,

h is reservoir enthalpy, [kJ/kg].

Based on this relation they summarized the conversion efficiencies for stands alone type of several conversions of technology namely binary, single flash and double flash, is given in figure 3, which shows that double flash plant has a higher conversion efficiency than a single flash for the high enthalpy range. A double flash plant has a higher efficiency at reservoir enthalpy of 1210 -1236 kJ/kg. This may can be recommended that best utilization of the X field is using a double flash system.

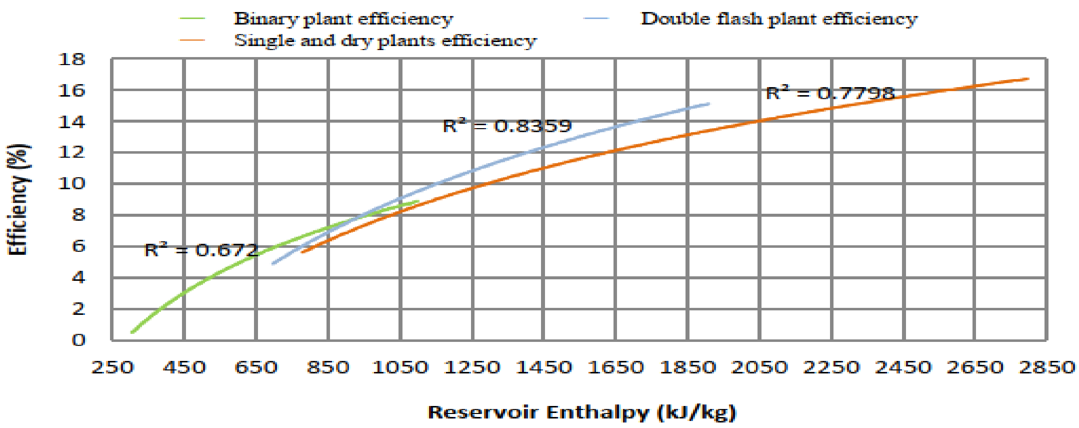

Figure 3. Simplistic approach for determining plant efficiency [14].

5. Discussion

This study has two finding. First, the formation temperature seems higher than the result from previously study that said 240 ^{o}C [4], which is determined by heat-up profile without calculation based on Horner method.

Second, up-flow zone is located at northern part, which was previously thought to be in the southern part of the field. The difference is due to the conclusions made in previous studies, based on the highest temperature disregard to convection heat transfer aspects that indicate hot water circulation. The highest temperature does not have to indicate the circulation of hot water (convection heat transfer mechanism). This is caused by the fact that reservoir having lower porosity has higher heat content than that of reservoir having higher porosity. As is known, most of the heat content in a reservoir (approximately 90% of heat content) is stored in rock, while much less amount of heat content is stored in water [16].

Less but not least, this study has confirmed the issue raised by Subir K Sanyal that said: Un-like in the petroleum industry, reservoir engineering and geoscience are intricately intertwined in geothermal [17].

6. Conclusion

The resource could be classified as a liquid dominated reservoir with temperature in range between 250 ^{o}C and 270 ^{o}C , the reservoir pressure in range between 75 and 80 k.s.c, the reservoir enthalpy, i.e. in range between 1210 and 1236 kJ/kg, the up-flow zone is located in the northern part of the field.

The possibility utilization of the reservoir, based on simple approach, is double flash type which has higher efficiency at reservoir enthalpy.

Acknowledgements

Authors may acknowledge to Universitas Trisakti – Faculty of Earth Technology and Energy Research, that supported to the study; as well as EBTKE and JACOBS, who supported in consulting the power plant selection approach.

References

[1] Alexander R 2018 *Think Geo Energy News*
[2] Anton S 2015 Wahjosoedibjo and Majedi Hasan 2015, Indonesia's Geothermal Energy Development: Past and Challenges *Proceedings of World Geothermal Congress, Melbourne Australia*
[3] Gudni A 2013 Conceptual model of geothermal system, Short Course V on Conceptual Modelling of Geothermal System *Santa Tecla, El Salvador*
[4] Jatmiko P A 2017 Thermodynamics of geothermal reservoir at Lumut Balai, Sumatera Barat *Proceedings of IEICES*
[5] Hanifah B S 2015 An update on the basic design of LumutBalai Geothermal Power Plant, Indonesia *Proceedings of World Geothermal Congress, Melbourne Australia*
[6] M Syarif F, Sugiatmo K and Kris P 2017 AnalisisSistem Geothermal Menggunakan Temperature Buildup, Dengan Data Lapangan X Di Sumatera *Internal Report*
[7] Malcolm A G and Paul F B 2011 *Geothermal Reservoir Engineering, second edition* 95-99
[8] Sebastien H, Yves G, Marc D, and Chrystel D 2013 *Geothermics* (Elsevier)
[9] Malcolm A Grant and Paul F Bixley 2011 *Geothermal Reservoir Engineering, second edition* 121-122
[10] Menzies T 2013 ITB *Geothermal Workshop, Bandung, Indonesia, Exploration drilling and early stage geothermal characterization*
[11] Saad M A 1997 *Thermodynamics Principles and Practice*
[12] Budi N A 2019 *JACOBS Input to SNI*
[13] EBTKE 2019 *RSNI Draft Report*

[14] Hyungsul M and Sadiq J Z 2012 Auckland New Zealand Efficiency of Geothermal Power Plant: A Worldwide Review *Proceedings of New Zealand Geothermal Workshop*

[15] Sadiq J Z and Hyungsul M 2014 Efficiency of geothermal power plant: A worldwide review *Geothermics* **51**14**B**53

[16] Yildiray P 2013 *Proceeding* Thirty-Eighty Workshop on Geothermal Reservoir Engineering, Stanford University, Stanford, California, A study on pressure and temperature behaviors of geothermal wells of single-phase liquid reservoir

[17] Subir K S 2003 One Dicipline, Two Arenas – Reservoir Engineering in Geothermal and Petroleum Industries, *Proceedings*, Twenty Eighth on Reservoir Geothermal Engineering, Stanford University, Stanford, California