Geothermal Capacity Building Program Indonesia - Netherlands

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NEW GEOTHERMAL POWER PLANT TECHNOLOGIES
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Author: Tom Geurink

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1 INTRODUCTION

The geothermal sector is improving the efficiency of their assets by developing new technologies for electricity production. The can either be an improvement of existing Geothermal power plants (GPP's) or the development of a new plant with improved efficiency compared to existing plant. Section 2 will explain the possibilities of improving the efficiency of existing GPP's. Section 3 explains new technologies that are or can be used when developing new GPP's for electricity production. The division of geothermal power plants types over the world is shown in Figure 1-1, this figure does not include combined power plants. The technologies explained in this document are all applicable for Indonesia, but some are more appointed to get maximal efficiency from low temperature resources.

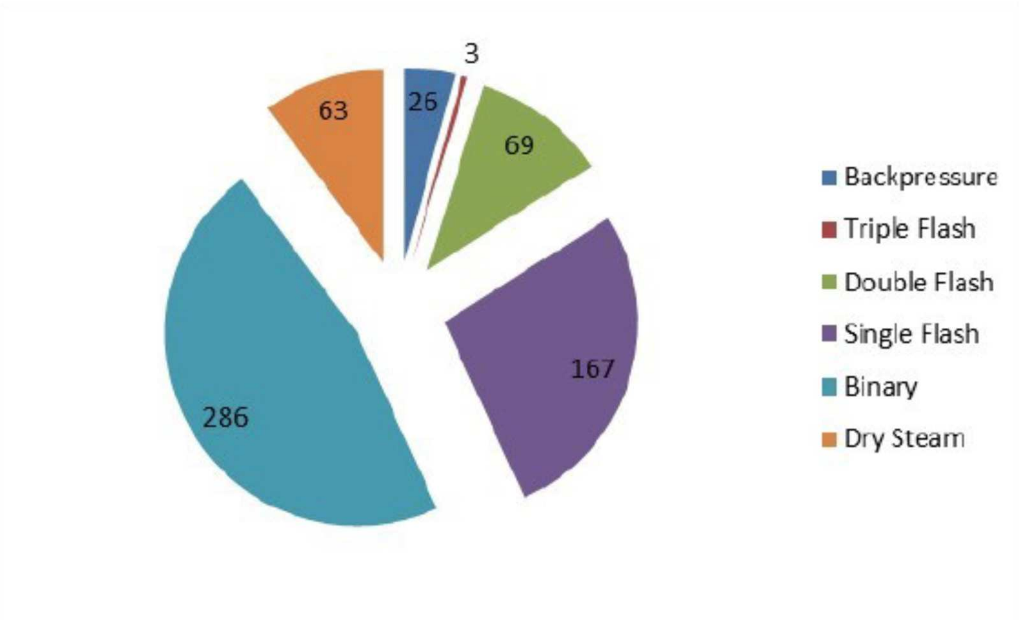

Figure 1-1 Number of geothermal power plants for each type in 2015[1]

2 IMPROVEMENT OF EXISTING PLANTS

This chapter explains possibilities to improve existing geothermal power plants.

2.1 ADDING SECOND OR THIRD FLASH

The majority of the realised GPP's use a single or double flash cycle for electricity production. These cycles can be optimized by adding an extra flash cycle. The switch from single to double flash is almost always profitable, adding a third flash cycle to a double flash can be profitable in some occasions dependent on geothermal fluid specifications. The additional investment must weigh up to the additional electricity production, this is often the largest hurdle for triple flash cycles.

2.2 ADDING ORC

To dry steam cycle

GPP's with high temperature reservoirs often use dry steam cycle to produce electricity. These are often the older power plants since this only works with the best reservoir locations. Adding an Organic Rankine Cycle (ORC) or in some cases a flash step to the dry steam process can improve efficiency.

To flash cycle

Many GPP's use the flash principle and a turbine to produce electricity. This often is a single or a double flash process. After flashing the geothermal fluid still has a high temperature but due to the one or two pressure decrease steps the pressure is too low to do another flash step. Also, the steam after the turbine has a high temperature and heat content but pressure is too low to use another turbine. These two steams can be used separately or combined to power an ORC. Figure 2-1 shows a single flash GPP combined with an ORC that works with the combined flow from turbine and separator. Figure 2-2 shows a GPP wit ORC that uses the liquid flow from the separator.

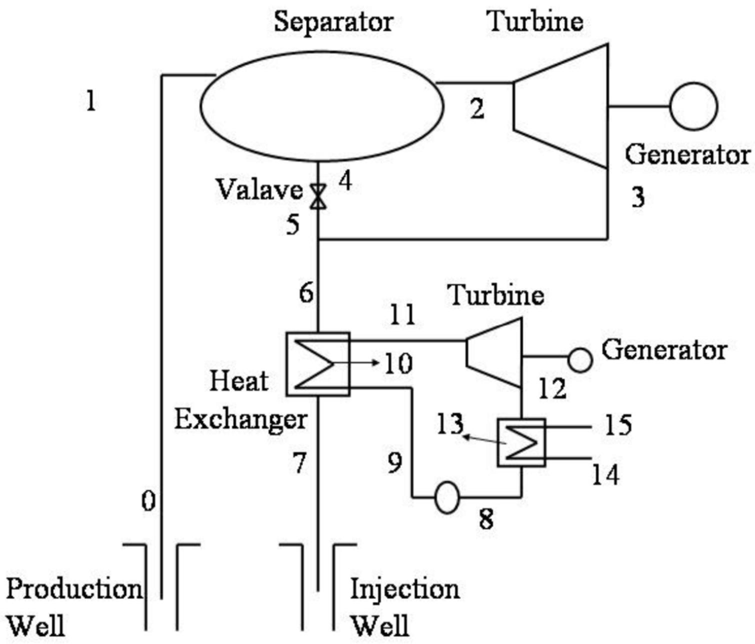

Figure 2-1 GPP with serial ORC[2]

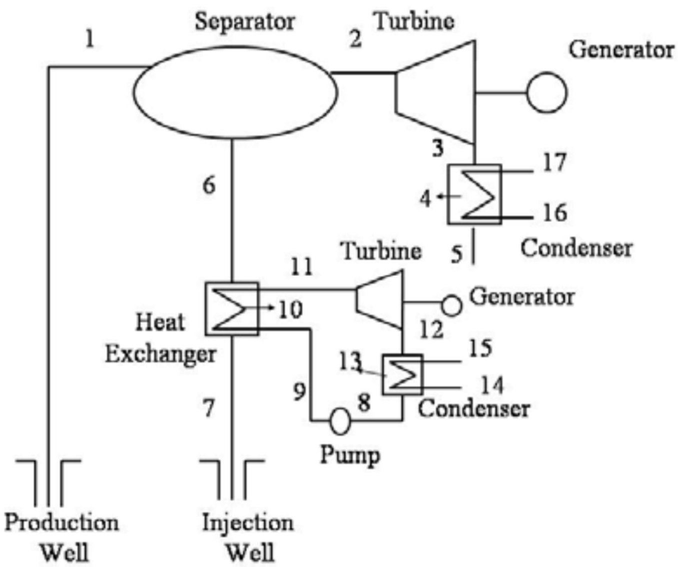

Figure 2-2 GPP with parallel ORC[2]

In existing power plants the parallel ORC can be implemented the easiest because is needs the least additions of the two in the existing power plant. The optimal chose for maximal production is dependent on the fluid conditions after separator and turbine. The business case is a combination of investment and the increase of production realised.

3 New GPP's

There are developments in new technologies to convert heat into electricity. Application of these new technologies in geothermal power plants is limited, often because of the new technologies not being competitive at large scales. Dry steam cycles are often not applied in new geothermal power plants anymore, mostly because of the CO_2 release with this technology, the same holds for backpressure geothermal electricity production. Most geothermal electricity production facilities relay on turbines to produce electricity. Some technologies that are investigated or under development are shown in the sections of this chapter.

3.1 Transcritical and zeotropic Rankine cycle

The heat transfer of the basic Rankine cycle can be optimized by using an transcritical or zeotropic fluid. Zeotropic means a mixture of two fluids with different boiling points and transcritical is heating under high pressure. Figure 3-1 shows the schematic which is the same for the ORC's with different fluids and the T-s diagrams of the different fluid, which show a difference between point 2-3 and 4-1. This line being more straight between the points will lead to a better heat transfer between geothermal fluid and secondary fluid and between cooling fluid and secondary fluid.

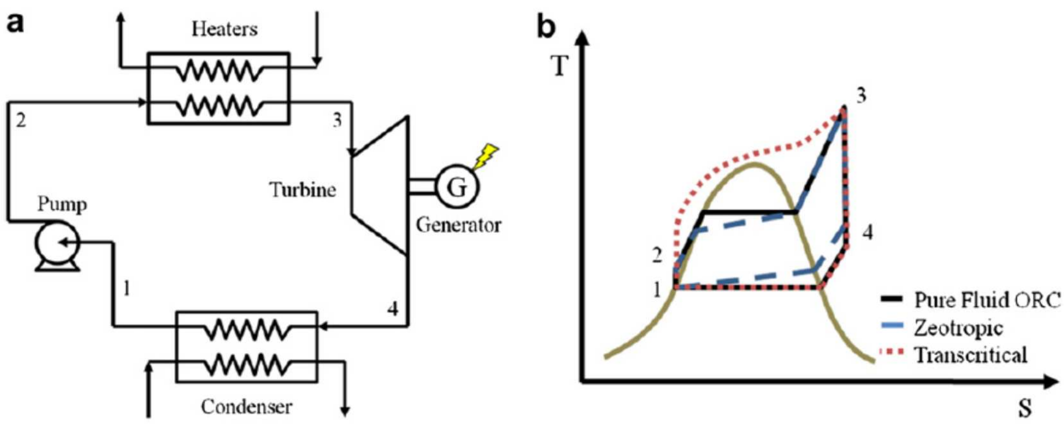

Figure 3-1 a) Plant schematic and b) T-S diagram for basic pure fluid ORC, zeotropic Rankine cycle, and transcritical Rankine cycle[7].

3.2 KALINA CYCLE

The kalina cycle works on a solution of two fluids with different boiling temperatures, this is called a zeotropic fluid (Section 3.1). Because the solution boils over a range of temperatures the heat exchangers will have a lot less problems with pinch point, so more heat can be transfer from primary to secondary fluid. Water and ammonia is the most used solution in kalina cycles. The T-s diagram in Figure 3-2 shows a comparison of the kalina cycle to an ORC. The process between line 2 and 3 is the heating of the secondary fluid, because the kalina cycle uses a mix this line is more constant. The more constant the line the better the heat transfer between the brine/geothermal fluid and the secondary fluid is.

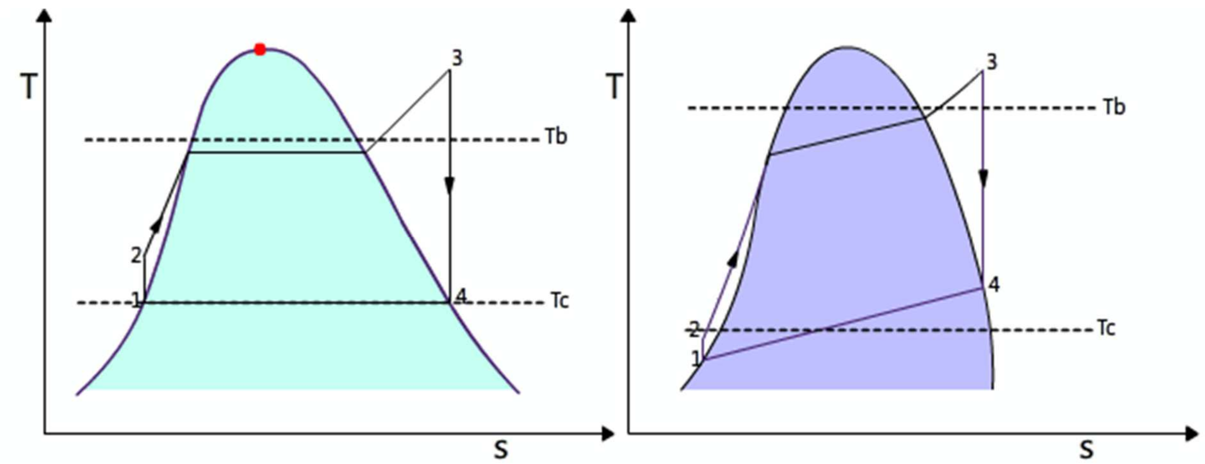

Figure 3-2 T-S diagram of Kalina cycles compared to ORC.

3.3 THERMO ELECTRIC GENERATOR (TEG)

Works with solar based materials to generate electricity. Electricity is generated through the Seebeck effect in which a voltage difference is generated in a conductor or semiconductor, due to a temperature difference in the material[3]. The TEG is a technology that is still in development and not used on large scale or large size, as is required for geothermal electricity production. The LCOE with this technology is still too high for commercial application.

3.4 CLIMEON

The Climeon[4] is an ORC with some innovative improvements to increase efficiency at lower geothermal temperatures, production is possible with temperatures between 70-120°C. The compact 150 kW module produces electricity at an estimated levelised cost of energy of €20–30/MWh[5].

3.5 TRILATERAL FLASH CYCLE (TFC)

Binary cycle where expansion starts from the saturated liquid line with an expander. Figure 3-3 Shows a T-s diagram for a ORC and a TFC, the major difference is that expansion takes place in the two-phase region instead of the vapor region. The expanders that can tolerate two-phase flow are scroll or rotary type expanders for small scale (1-50 kW) and variable phase turbines (VPT) for medium scale (50-250 kW) applications. Research show that the TFC has a lower efficiency/net power production then ORC cycles with the same working fluid. However, the TFC system is estimated to have a lower cost than the ORC due to the elimination of the evaporator, separator drum, gear box, lube oil system and the fact that simpler heat exchangers can be used[6].

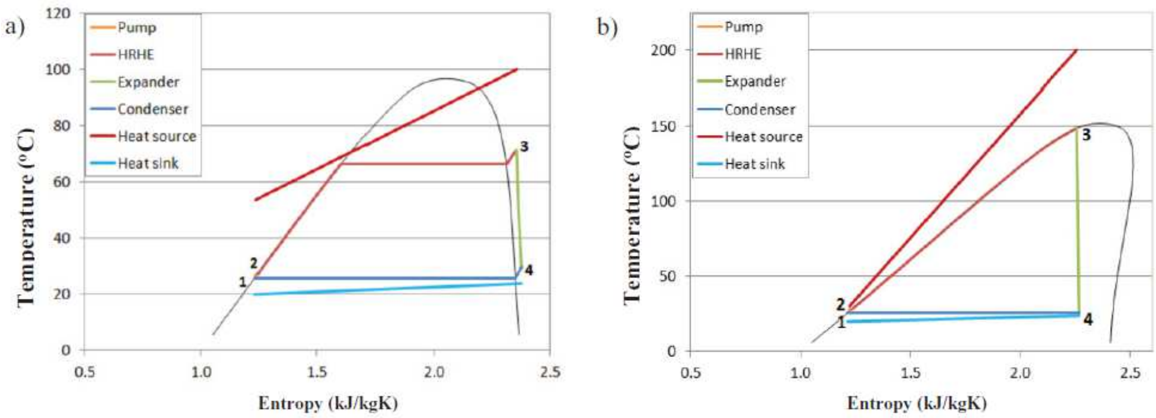

Figure 3-3 T-s diagram showing difference between a) ORC and b) TFC

3.6 ORGANIC FLASH CYCLE (OFC)[7]

Flash cycle with organic fluid as working fluid. Improves temperature matching and reduce exergy loss in heat exchanger. Figure 3-4 Shows the schematic and T-s diagram of a OFC, because the line between point 1 and 2 is straight this leads to an optimal heat transfer between geothermal fluid and secondary fluid. The OFC can also be executed as a double OFC when higher temperature geothermal fluid is available.

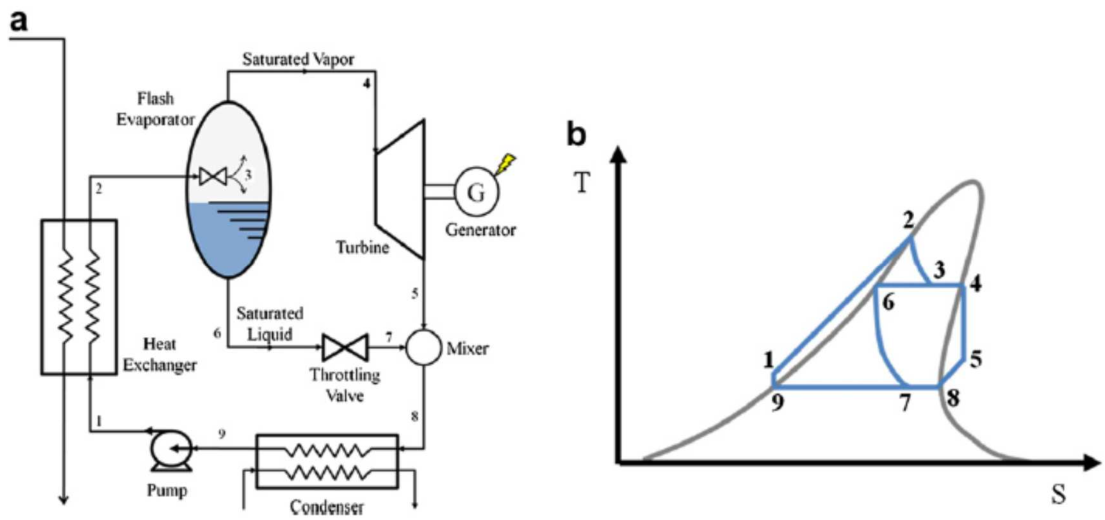

Figure 3-4 a) Plant schematic and b) T-S diagram for single flash OFC.

3.7 Series Double Cascade-evaporation Organic Rankine Cycle (SDCORC)

This technology is basically a normal ORC with an additional evaporator and pump. The Schematic overview and T-s diagram are shown in Figure 3-5. According research the SDCORC has a better performance as a basic ORC [8].

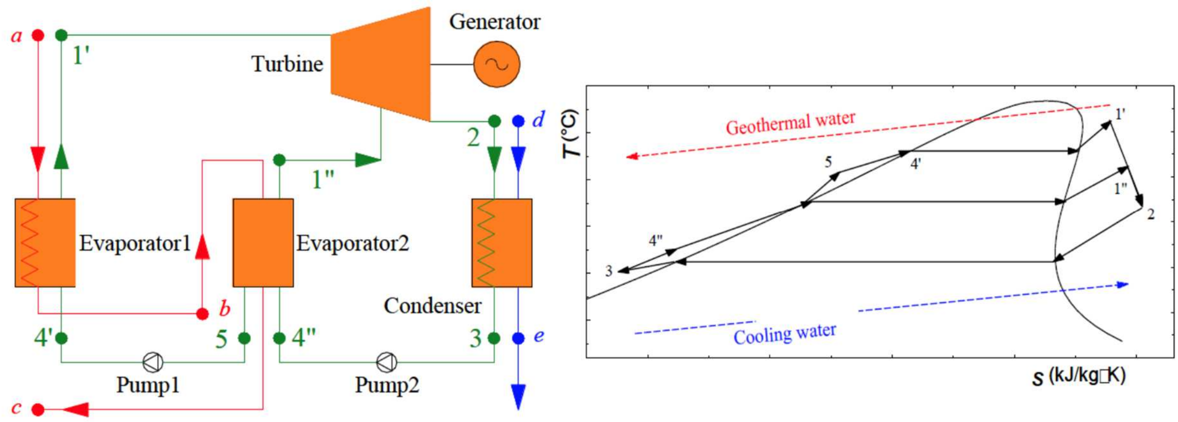

Figure 3-5 SDCORC schematic and T-s diagram

3.8 PCM engine[9]

Electricity production from the change of a material from solid to liquid state and back. By melting the material, it expands in volume, this expansion is used to generate electricity. The phase changing material (PCM) is mostly used for energy storage, not often for production of electricity.

3.9 OTHER TECHNOLOGIES

Some technologies are possible but the efficiency is still too low or prices too high to be applied are described in this section.

- Inverted Brayton cycle (IBC)

  The inverted Brayton cycle doesn't need a condenser but uses a turbine to transport the steam instead of a pump for the liquid.
- Organic Brayton cycle (OBC)

  Brayton cycle using an organic fluid.
- Goswami cycle

  A cycle that produces electricity and cold.
- Srinivas cycle[10]

  A combination of the kalian cycle and vapor absorption refrigerant cycle. Produces cold as well as electricity.
- TAG (Thermo acoustic generator)

  Generates electricity with acoustics, research is needed to understand the technology. Work with temperatures starting at 90°C.

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[4] https://www.climeon.com/how-it-works/

[5] http://www.energimyndigheten.se/en/innovations-r--d/business-development-and-commercialisation/the-agencys-portfolio/climeon/

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