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Sarulla 330 MW Geothermal Project Key Success Factors in Development

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ABSTRACT

Located in the Tapanuli Utara District, North Sumatra province in Indonesia, the 330 MW Sarulla power plant is set to be the world's largest geothermal power plant when its construction is completed in 2019. At this time construction has started but the story of the development of this power plant is a long and interesting one on many levels; it demonstrates the challenges and risks that geothermal developers will face on the road to success, from regulatory through economics, technical, legal and financing aspects. Many people and organizations have worked tirelessly for years to bring the plant to fruition and in this paper we shall outline the history and the various challenges the project has faced, highlighting the major criteria for overcoming such challenges, while ensuring successful development.

The project originally started development by Unocal in 1993, and in 2004 was retendered by PLN (the Indonesian national electricity company). PLN took over Unocal's interest in the JOC (Joint Operation Contract) and the PPA (Power Purchase Agreement). In 2006, the Medco-Ormat-Itochu Consortium won the tender to develop the project. Today the Consortium consists of Medco Energi Internasional Tbk, Ormat Technologies, Inc.; Itochu Corporation and Kyushu Electric Power Co. Inc.

Based on the above considerations, SOL (as contractor to PT Pertamina Geothermal Energy, "PGE") formally gave notice of its intention to develop a geothermal power plant of approximately 330 MW capacity in the Sarulla Contract Area. This will be comprised of the following units (or stages) as set out in Appendix IV of the JOC.

- First Unit and Second Unit - the SIL Plant: approximately 83-110 MW in 2016 (possibly in several increments)
- Third Unit and Fourth Unit - the NIL I Plant: approximately 76-110 MW in 2017 (possibly in several increments)
- Fifth Unit and Sixth Unit - the NIL II Plant: approximately 76-110 MW in 2018 (possibly in several increments)

1. INTRODUCTION - PROJECT STRUCTURE

1.1. Project Description and History

The 330 MW Sarulla geothermal power project is located in Tapanuli Utara, North Sumatra, Indonesia (Figure 1). The project will be constructed in three phases of 110 MW each, utilizing both steam and brine extracted from the geothermal field to increase the power plant's efficiency. The first phase is scheduled to commence operations in 2016, and the remaining two phases are scheduled to be completed in stages within 18 months thereafter.

The project is developed, and will later be owned and operated, by the SOL consortium of which Ormat has a 12.75% share. Other members of the consortium that owns SOL include Medco Energi Internasional Tbk (Medco); Itochu Corporation (Itochu); and Kyushu Electric Power Co. Inc. (Kyushu). Ormat also plays the role of designer and will supply the Ormat Energy Converters (OEC) to the power plant.

The concession holder for the project PT Pertamina Geothermal Energy (PGE) has provided the consortium the right to use the geothermal field under a JOC. PT PLN, the state electric utility, is the offtaker for 30 years under the ESC agreement. Amendments to both JOC and ESC were signed on April 4, 2013. The project will be developed and implemented under a 30-year energy sales contract with Perusahaan Listrik Negara, the national electricity utility company, a 30-year joint operating contract with Pertamina Geothermal Energy, and a 20-year guarantee from the Ministry of Finance.

Exploration of the project's geothermal resources started in 1993 but stopped in 1998 due to challenges presented by the Asian Financial Crisis which also led to the original developer to sell its development rights to PLN. When a law to promote private sector participation in the geothermal sector was signed in 2004 PLN opened an Independent Power Producers (IPP) bidding process for the Sarulla development rights, which the SOL consortium, in its original makeup of Medco, Ormat and Itochu as Kyushu only joined the consortium in 2008, won in 2005.

Figure 1: Sarulla location the North Sumatera area of Indonesia

1.2. The Sarulla Consortium

The SOL consortium includes Itochu Corporation, Kyushu Electric Power Company, Ormat International and Medco Power Indonesia. The sponsors own multiple special purpose vehicles that act together as borrowers and be jointly and severally liable to the lenders. The borrowers are Sarulla Operations Limited (S0L), Sarulla Power Asset Limited, Kyuden Sarulla Private Limited, OrSarulla Incorporated, and PT Medco Geopower Sarulla. SOL will be the operating company for steam resource development, and construction and operation of plant facilities.

1.3. Business Model & Financing

On March 28, 2014, the Consortium signed the financing agreements with a syndicate comprised of Japanese Bank for International Cooperation (“JBIC”) and Asian Development Bank (“ADB”), acting as Lead Structuring Banks (ADB acting both at its own capacity, as well as an implementing agency for the Clean Technology Fund and for the Canadian Climate Fund), as well as six commercial lenders: Sumitomo Mitsui Banking Corporation (“SMBC”), Societe Generale (“SG”), National Australian Bank (“NAB”), Bank of Tokyo Mitsubishi UFJ (“BTMU”), Mizuho and ING. JBIC also provides political risk guaranty for the portion of the loan provided by commercial lenders, under an EPRG policy.

The financing package will provide up to approximately $1.2bn loans, to finance approximately $1.6bn of the project costs, provided along approximately 4 years of development phase, followed by a term repayment period of 16 years (20 years door to door). First drawdown under the loans occurred on May 23, 2014.

Upon financial closing, the consortium also engaged in an Interest Rate Swap (IRS) hedging transaction to hedge between 80%-90% of the interest payments payable under the LIBOR based tranches of the loan.

In order to achieve financial closing, both the financing syndicate and the project sponsors had to agree on numerous risk mitigation measures. These included allowing for sufficient contingencies, including contingent equity facility, robust Debt Service Coverage Ratios, and prudent term loan when compared to the project term of 30 years.

2. PROJECT DESIGN

2.1. General

The geothermal world utilizes several common technologies that can be classified as: a) back pressure steam turbine; b) condensing steam turbine; c) binary cycle. In addition there are several combinations of the above that may be utilized depending on the several parameters, chiefly amongst them are the characteristics of the geothermal fluid, (e.g. enthalpy, chemical composition), and other considerations are other aspects derived from the plant’s location such as availability of water, environmental consideration etc.

Considering the amount of brine in the Sarulla field as well as the high content of NCG the selected generating units are a combination consisting of back pressure steam turbines and ORC units.

The following sections describe the geothermal field as well as the power plant technology.

2.2. The Sarulla Geothermal Field

The Sarulla geothermal project located in the state of North Sumatra Indonesia, is currently under development by the Sarulla Operations Limited (SOL). The project consists of two field areas: Namora-I-Langit (NIL) and Silangkitang (SIL), slated for a total of about 330 MW net production. Exploration of the Sarulla field began in 1993 under the direction of Unocal North Sumatra Geothermal Ltd. (UNSG) under a Joint Operation Contract (JOC) with Pertamina, the Indonesian National Oil Company, identifying the area as a favorable high temperature geothermal concession. The fields are located immediately adjacent to the Great Sumatran Fault (GSF), a major right-lateral strike-slip fault system which transects the length of the Sumatra volcanic arc. No active volcanism is present at Sarulla with the youngest intrusive domes dated at 120ky. The Namora-I-Langit field hosts a prolific gas-rich fumarole area with boiling acid-sulfate springs atop a thick altered clay-cap exposed near surface, west of the Great Sumatran Fault. Drilling of four deep exploration wells to over 1500m at NIL demonstrated a 275°C liquid dominated system. Silangkitang, hosts a 4km span of fumaroles, sinter and boiling hotsprings along the main axis of the GSF. Equilibrated distal hotsprings indicate temperatures of about 270°C. A total of five deep exploration wells were drilled at SIL between 1994 and 1998 to a maximum depth of 2300m demonstrating upwards of 310°C. Both the NIL and SIL reservoirs are hosted within a tectonic half-graben forming to the west of the GSF with conjugate structures controlling the main permeability within a thick sequence of Quaternary age rhyolitic to dacitic volcanics underlain by a basement of Paleozoic meta-sediments.

A reservoir simulation study was carried out to verify the capacity of Silangkitang and Namora-I-Langit reservoirs to sustain a combined extraction of the mass to drive geothermal power units generating about 350 MW of gross capacity for 30 years. Both models were successfully calibrated to natural state conditions and to historical production and injection conditions by matching simulated underground pressure and temperatures to data from the NIL and SIL wells obtained during various production tests performed by Unocal.

To meet the design capacity of about 110 MW at 20bara separation pressure at SIL, three additional production wells and 5 injection wells shall be drilled. 20 new production wells are planned at NIL, and 6 injection wells, to supply the 230 MW expected units at 11bara separator pressure. Make-up wells are included in the ongoing drilling campaign which includes three drilling rigs operating in parallel. Several new drilling pads are planned for Sarullla to span the large extent of these fields and to combat the potential for break-through cooling from reinjection subject to these liquid-dominated systems. The first well at Sarulla will spud on September 15, 2014 and power plants are expected to be completed by 2017.

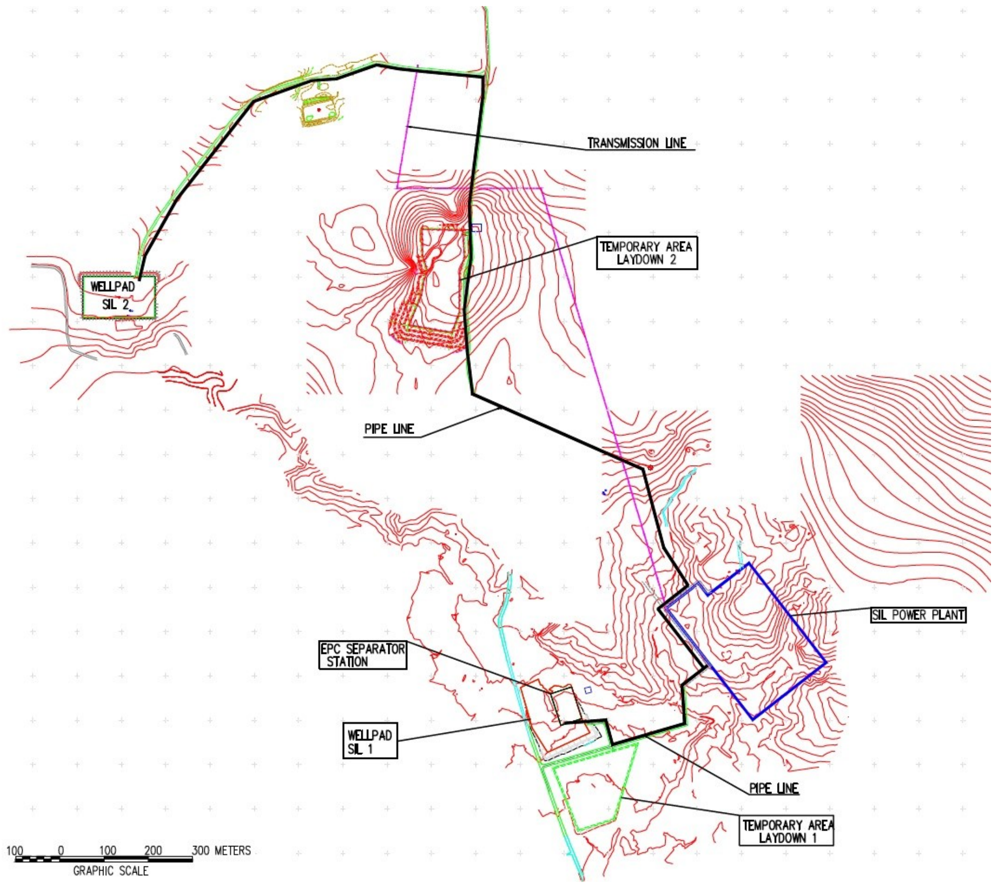

Fig 2: SIL site map

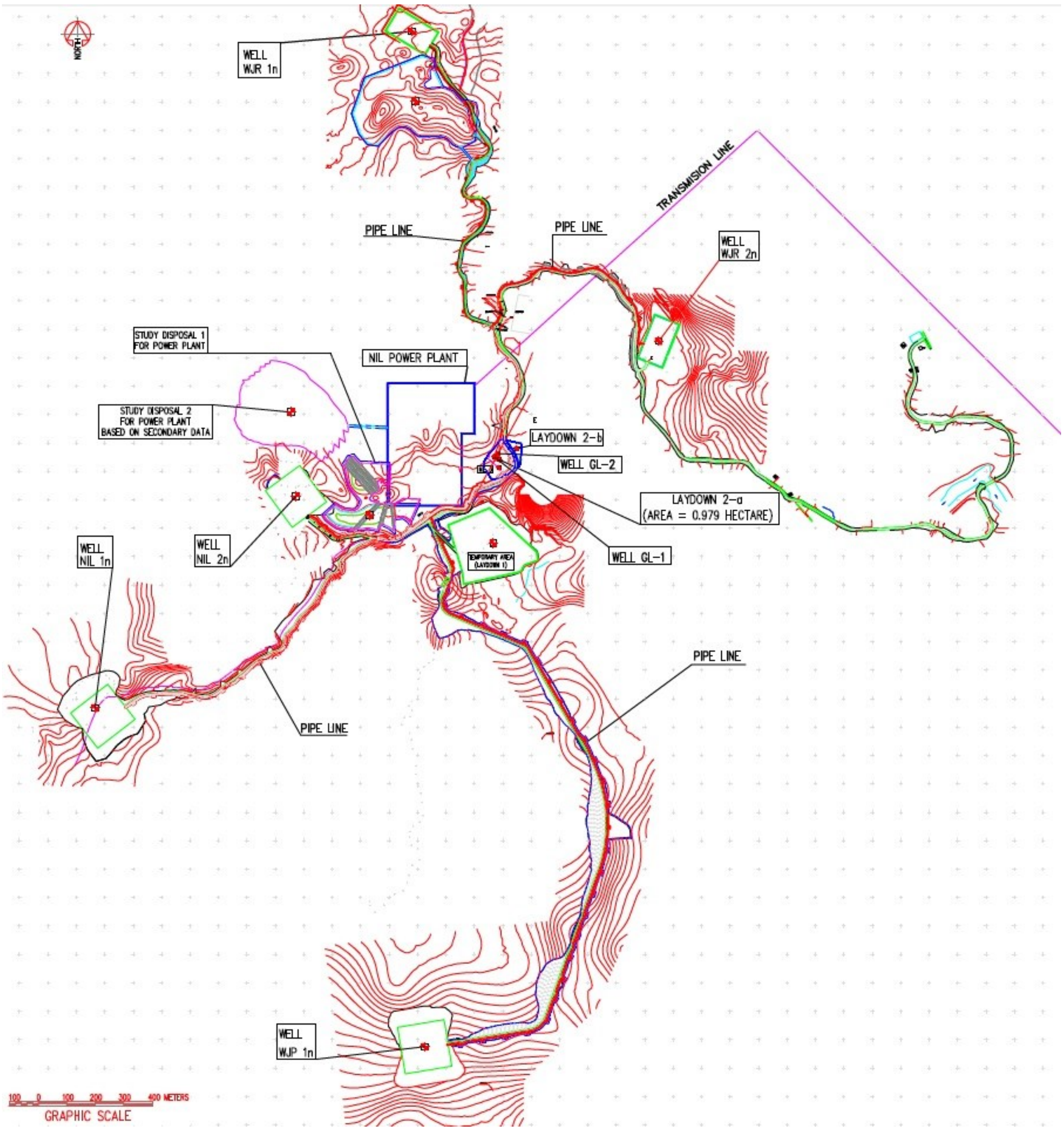

Fig 3: NIL site map

2.3 Power Plant design

Following a comprehensive study, taking into consideration the thermodynamic efficiency, the geothermal fluid characteristics and environmental aspects, a combination of technologies as developed by Ormat was selected as that best configuration for energy conversion in both Namora Langit and in Silangkitang. This configuration consist of a GCCU, IGCCU or an "Integrated Geothermal Combined Cycle Units". In more general terms the GCCU represents an excellent solution for medium to high pressure steam resources. The GCCU consists of a back pressure steam turbine and bottoming OECs (Ormat Energy Convertor) heated by the low pressure steam exiting the topping steam turbine. The steam exits the steam turbine and enters the OEC vaporizer at just above atmospheric pressure.

The brine OEC units utilize the brine as it leaves the separation station, thus, rather Bethan just being reinjected it is flows via the OEC brine units and provide additional power that otherwise, if only steam units were installed, would have be wasted. The GCCU advantage comprise of the advantages of the steam turbine, the ORC and the advantages in their combination, in the GCCU:

Advantages of the Steam Turbine:

- The exhaust pressure (back pressure) of the steam turbine is just above atmospheric pressure
- No need for large, complicated and high energy consuming vacuum systems
- No air ingress into the vacuum stages of a condensing steam turbine
- Less stages, especially eliminating the last stages of a condensing steam turbine which have very high blades (since the volume of exhaust steam at atmospheric pressure is ~10 times lower than at typical 0.1 bara exhaust pressure of a condensing steam turbine)
- Less moisture at the exhaust which reduces erosion and increases turbine efficiency

Advantages of the ORC (OEC):

- *High Turbine Efficiency at Low speed:* Due to the motive fluid's low acoustic velocity (compared to steam), favorable aerodynamic matching is achieved at low blade speed. This yields high turbine efficiency at 1800 rpm without a gearbox.

- *Less turbine stages:* The lower pressure ratio and enthalpy drop of the motive fluid during expansion require less stages. This significantly simplifies the turbine construction.
- *Moisture-free turbine expansion:* The OEC turbine remains dry under all expected working conditions (a thermodynamic consequence of the hydrocarbons' 'drying fluid' saturation curve). This eliminates the possibility of erosion damage to the turbine blades.
- *Condensing near atmospheric pressure:* The thermodynamic properties of the motive fluid provide much higher condensing pressures than comparable steam systems. By operating at condensing pressures near atmospheric, the turbine requires shorter blades and the ingress of air into the system is significantly minimized.

Advantages of the GCCU - Common Aspects

- *Better handling with NCG:* In binary cycle including GCCU, unlike condensing steam turbine, steam is condensed at a pressure slightly higher than atmospheric pressure. This allows for the NCG to be removed from the condenser (or heat exchanger) without an expensive, power consuming vacuum pumping system or steam consuming ejectors, giving advantage to the binary cycle over the condensing steam turbine cycles.
- *Use of air-cooling:* The ORC effectively uses air-cooled condensers due to the significantly higher specific density of the organic working fluid compared to steam/water. This eliminates water consumption and the use of cooling water chemical treatment. Further, air cooled system is eliminating water mist which is blown out and sprayed over the environment as well as the highly visible plume of vapour mist and steam discharging on top of a water cooling system. Furthermore, is also eliminated in the use of an air cooling system which would minimize impact to the surrounding environment
- *100% injection of all gases and fluids* - The use of air cooled condensers allows for the total re-injection of all produced gases and fluids and improves the sustainability of the geothermal reservoir.
- *Utilization of the brine:* Since Sarulla field produces large amount of brine and since its chemical characteristics are manageable, the utilization of this brine to produce additional power and eventually to reduce drilling cost is an important aspect in the resource exploitation. The mixture of 100% condensed steam and the used brine to the reinjection wells makes the use of brine in the binary system ideal as it reduces potentials for silica scaling.

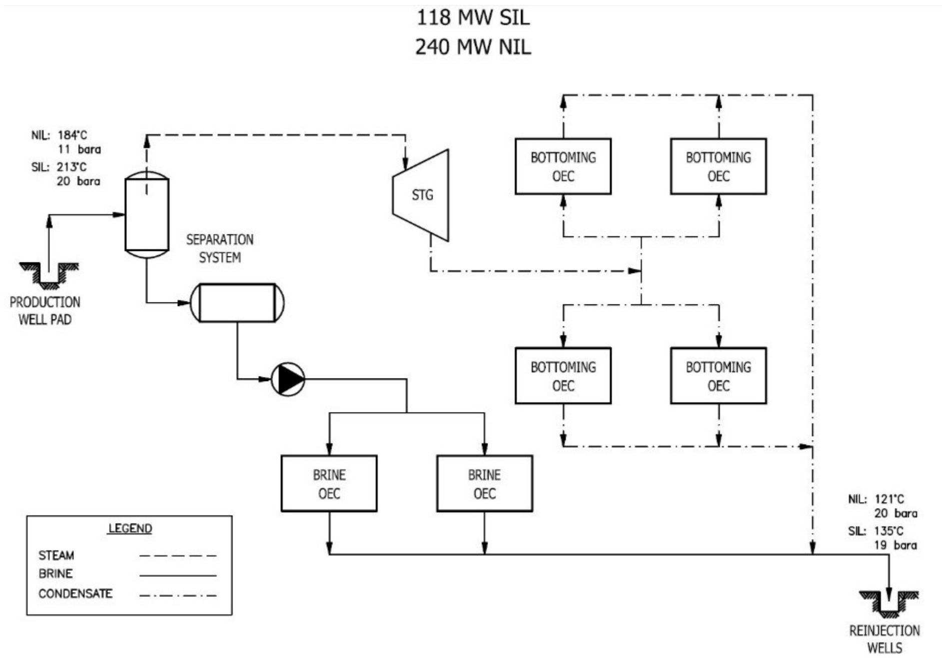

Fig 4: Nil & SIL process scheme

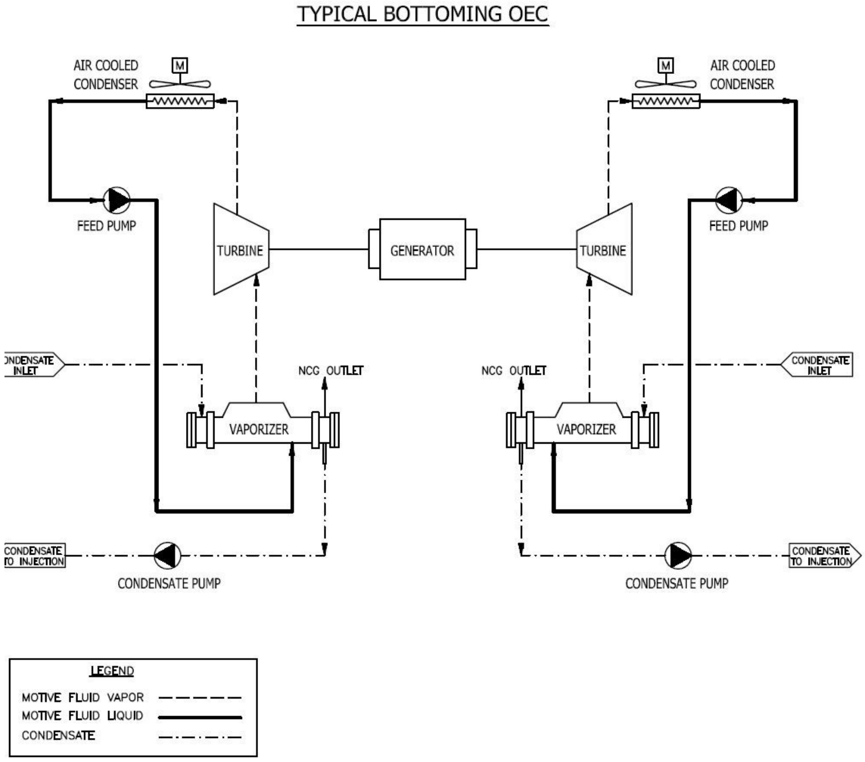

Fig 5: Typical Bottoming OEC Process scheme

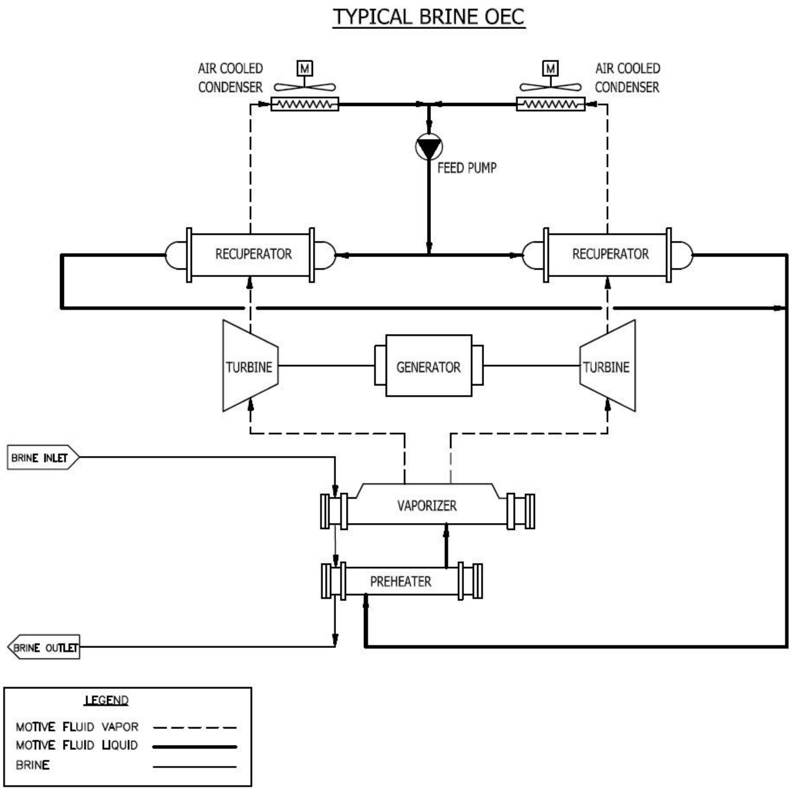

Fig 6: Typical Brine OEC Process scheme

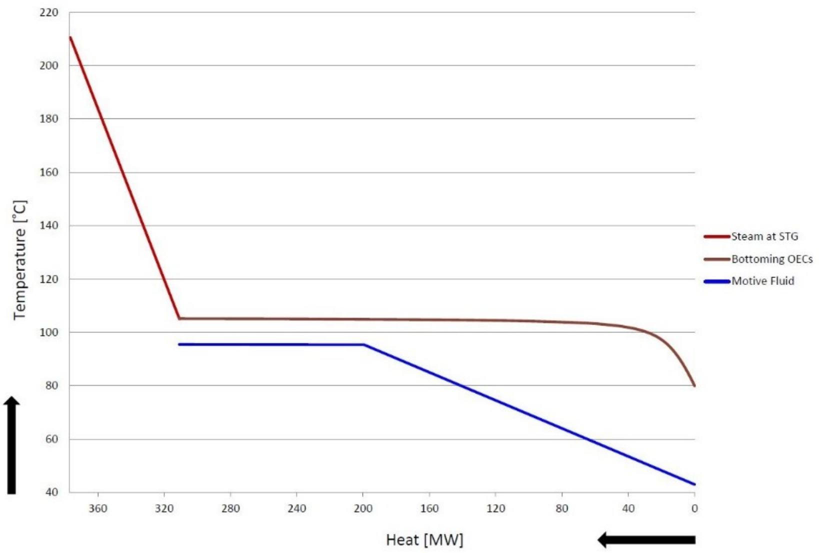

Fig 7: SIL GCCU T-Q diagram

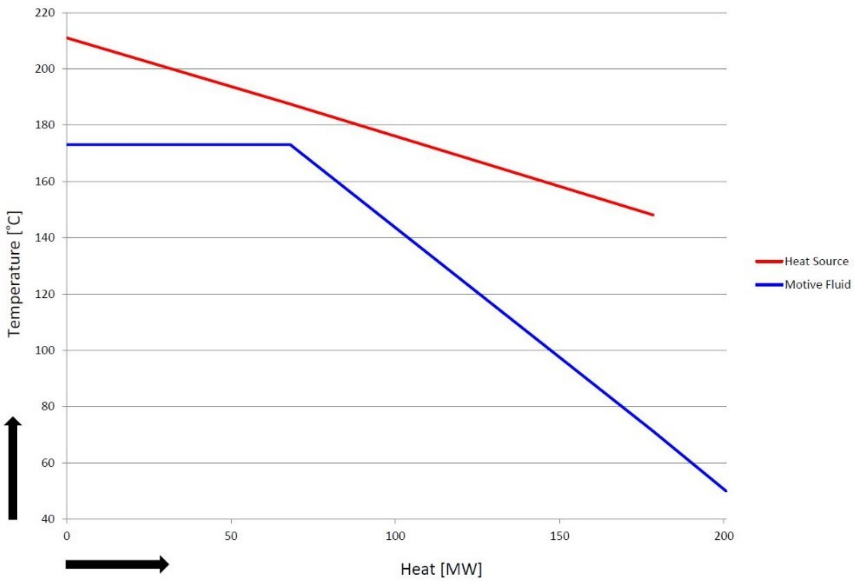

Fig 6: SIL Brine OEC T-Q diagram

3. ENVIRONMENTAL CONSIDERATIONS

In order to meet the Indonesian government environmental regulations, an Enviornmental Impact Assessment (EIS) was performed in accordance with those specific regulations that apply for power plant development which are larger than 55 MW and where the transmission line is larger than 150 KV. In Indonesia the EIS is called AMDAL, "Analysis Mengenai Dampak Lingkugan". The EIS has identified important impacts, both positive and negative, of the Sarulla geothermal power plant plan and in order to control and minimize the negative possible impacts the AMDAL include also environmental management and monitoring (RKL & RPL) instructions. As part of the AMDAL three items required special consideration and mitigation:

- Air pollution mainly from disgorge of Hydrogen sulfide
- Water pollution resulting from arsenic in water
- Noise impact on residents living near by the site boundaries

Other environmental impacts such as waste water, socialization, etc. were also investigated. The consideration in those studies was also with regards to the activities which are within forestry areas mainly in Namura I langit field and as a result a Forestry Land Use License was required.

One should not forget however that all of those studies and environmental impact assessments are to support a large-scale base load geothermal power generation that will help displace fossil fuel-generated power, an lectricity source that is the dominant alternative for base-load generation in the Sumatra grid, thus supporting climate change mitigation through an estimated net reduction in carbon dioxide (CO_2) emissions equivalent to 1.3 million tons per year. In addition the construction and operation of the power plants will generate employment for the local community.

4. CONCLUSION

The Sarulla project is a large geothermal project and it creates many challenges in all aspects: environment, financing, field development, and selection of generating technology. Due to the large size of the project and concession area, the project shall be completed in three phases, each sized approximately 110 MW , dependent on steam and brine availability. The Date of First Operation of the SIL Unit is scheduled for approximately 30 months after full notice to proceed (End of 2016). NIL-1 Unit and NIL-2 Unit are scheduled to follow approximately 12 and 18 months following Unit 1, respectively, however these dates may vary.

The Ormat technology was selected for this project as it is able to maximize the efficient use of varied composition of geothermal fluid, which in this case includes steam, brine and gases. In addition Ormat's technology allows practically 100% reinjection of the geothermal fluid back into the reservoir, maintaining the sustainability of the geothermal resource thus increasing power and mitigates the negative effect of gases

The selected configuration provides the lowest project risks related to brine chemistry and maximizes the life of the reservoir. The proposed wells include a prudent margin of excess capacity. The anticipated well site locations are shown on the field layout in Figures 2 and Fig 3