THE PROSPECTS FOR LARGE SCALE APPLICATIONS OF GEOTHERMAL COOLING IN INDONESIA

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ABSTRACT

Enhanced Geothermal Systems (EGS) and Ground Source Heat Pumps (GSHPs), whether providing electricity or heating or cooling of buildings, are arguably two of the most intriguing recently emerging worldwide geothermal utilization technologies. Despite the rapid growth of Enhanced Geothermal Systems (EGS) and Ground Source Heat Pumps (GSHPs) worldwide, commercial application of these technologies in Indonesia is largely expected to be some years off or is even considered to be irrelevant. However, the enormous potential cooling market in Indonesia demands investment for further research. This paper presents a study to identify hypothetical potential benefits and advantageous features that may be obtained from the application of geothermal cooling in Indonesia. This paper also discusses the potential challenges for the planning of geothermal cooling project in Indonesia.

1. INTRODUCTION

Situated on the ring of fire, Indonesia has been cited as having the largest high-enthalpy resources reserves in the world, of which still only a small fraction has been tapped for utilization up until the present time. The long encountered bottlenecks limiting the development of geothermal power in Indonesia in the past also remain largely unresolved. Meanwhile, the exclusive focus and pre-dominant campaign for geothermal power development has simply kept the direct-use of geothermal energy in a marginal state.

In the meantime, the growing national energy security issue and environmental concerns, has led to a great expectation for geothermal energy to meet a significant proportion of the national electricity demand. However, the government's projection of geothermal power generation is not being achieved and the installed capacity is some way below the targeted megawatts. Although we agree that milestone dates and numbers should be merely considered as indicative figures rather than absolutes, the under-achievement of targets should stimulate a change in the approach to geothermal development in Indonesia.

As Indonesia is located across the equator and is blessed by the scorching temperatures and a humid tropical climate, the increasing demand for electricity is highly associated with the rising demand for cooling, especially in the major cities such as Jakarta, Bandung, Medan, Surabaya and Bali. It is cited that up to 40-60% of the total power demand in those cities is contributed by the high cooling load. Therefore, Indonesia has become a massive potential cooling market, and yet, ironically this type of energy demand could lead to a major economic set-back if the energy security gap issue remains inadequately addressed.

The researches carried out and several demonstration projects successfully set up recently by tropical-neighbor countries of Indonesia (Thailand, Vietnam and Singapore), have shown the way to assess the possibility for geothermal energy to provide the required cooling energy in their countries. As a result, Indonesia is trailing behind those countries in finding such opportunities to use this worldwide growing geothermal technology. It is not that cooling and heating applications are inappropriate or unnecessary for Indonesia (due to the tropical climate) or that Indonesia does not have the required resources to be able to apply the technology. Rather the problem is that Indonesia has become complacent towards the abundant high-enthalpy energy source available in the country. Therefore, these facts should have had Indonesia to start to seriously consider geothermal cooling as one of the potential solutions of the national energy issues.

1.1 Common Perspectives on Geothermal Cooling in Indonesia

The biggest potential challenge towards the introduction of geothermal cooling in Indonesia is the common perspectives on the applicability of such geothermal cooling technologies in Indonesia i.e. the Enhanced Geothermal Systems (EGS) and Ground Source Heat Pumps (GSHPs). In general, the introduction of Enhanced Geothermal Systems (EGS) in Indonesia is largely believed to be years off in terms of commercial application. Meanwhile the application of Ground Source Heat Pumps (GSHPs) in Indonesia is also believed to be irrelevant because of the ambient air and ground temperatures. However, studies of the technical applicability of these technologies, on which these perceptions are based, are very limited in Indonesia.

Moreover, the large underachievement in meeting the national target for utilizing high enthalpy geothermal resources for power generation, has ironically led to a more aggressive supply-side management approach to try to meet the growth projections. Instead it might be better to consider an approach that is more likely to be successful, namely the demand-side management approach that the development of medium and low enthalpy geothermal resources potentially offers e.g. geothermal heating and cooling.

Another common perception found is that since plenty of geothermal power development issues have remained unresolved, it is rather unlikely that Indonesia will be able to develop such geothermal cooling technologies (EGS and GHSPs), which are uncommon and not yet proven in Indonesia. There is a belief that the general problems Indonesia has experienced in developing high enthalpy resources will occur again in the development of geothermal direct utilization.

2. TECHNICAL ASPECT OVERVIEW

2.1. Adjustments and System Arrangement Alternatives

It is rather unlikely that the technical design of a particular type geothermal cooling system will be identical from one location or countries to another, since each location is subject to different available resources, energy demand and other particular local issues. Lesson learnt from the applications of geothermal heat pump worldwide - from the very much distinctive climates of European countries to the much more similar circumstances of the tropical countries - is that particular drivers in each of the countries leads to adjustments, new design and modifications to the conventional geothermal heat pump systems. It is likely that geothermal cooling systems in Indonesia would have several types of designs since Indonesia has a wide range of technical characteristics (geological settings and physical environments) along with specific encountering issues.

There have been numerous studies worldwide on geothermal cooling and heating and some recent studies in tropical, humid nearby countries, however, studies that review geothermal cooling and heating applications in Indonesia in particular are extremely limited.Therefore, there are still plenty of aspects and considerations of geothermal cooling and heating to be evaluated further in the present study.

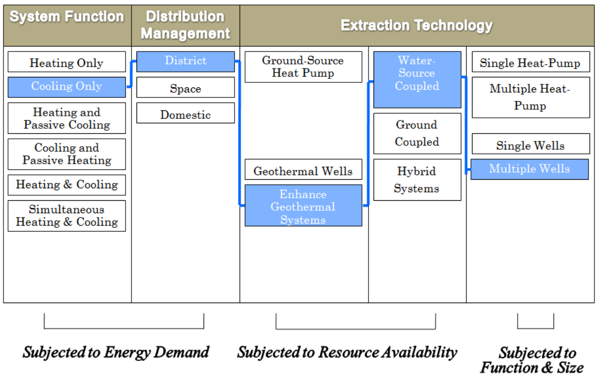

Figure 1: Permutations of geothermal cooling or heating system designs

The amount of benefit from a geothermal cooling and heating system strictly depends on the selection of the system design. An appropriate selection will result in effective performance of the system, which will further leads to, for instance, a large energy saving or perhaps a substantial emission reduction. Figure 1 provides an illustration of different designs of geothermal cooling systems.

Starting with the distributed management system, there are two general distribution modes to transport the geothermal cooling energy: a centralized distribution system or an individual distribution system. A centralized distribution system is usually associated with the requirement for a large amount of cooling energy to be transported from a central geothermal energy source, and then to be distributed to a large area (space) or multiple users (district). Whereas, an individual distribution system is associated with cooling for domestic use, with an individual user producing their geothermal energy required for a cooling application, either for commercial or non-commercial use.

The geothermal cooling systems may also be installed in a de-centralized manner, to fit individual needs, avoiding costly heat distribution systems. The application of such a de-centralized mode may offer the opportunity to get numerous intangible benefits, e.g. encouraging the local economy, by creating an intensive price competition and thus leading to a faster improvement in technology.

Despite the fact that new technology may take a long time to reach an established market state, once reached, the development of the market often experiences a substantial rate of growth, which explains why geothermal heat pump technology - largely associated with individual distributed systems - has become one of the fastest growing global markets. However, a centralized distribution system could be a safe option for early stage development for a future geothermal cooling and heating application campaign in Indonesia. Also, centralized systems would preferable nowadays, in terms of the impact control (safety, quality and environmental issues).

2.2. Energy Extraction Technologies

2.2.1. Enhanced Geothermal Systems

The largest demand for cooling in Indonesia is from major cities (Jakarta, Surabaya, Bandung, Medan, and Bali) that are located in non-hydrothermal areas, and in which only normal temperature gradients occurs.The technology that is best suited for geothermal energy extraction from this type of resources is the Enhance Geothermal System (EGS). The worldwide commercial application of Enhance Geothermal System (EGS) still faces large economic and technical challenges prior to its implementation, not only in Indonesia. However, the economic challenges related to these less desirable geothermal resources may be easily offset or compensated for by themassive potential marketfor cooling.

Moreover, the high ambient-temperatures and the slightly higher than normal temperature gradients below the major cities in Indonesia could provide favorable conditions for the economics of geothermal cooling projects. This slightly higher than normal gradient would help in finding the required rock temperature at a depth shallower than a normal temperature gradient area. Farizi (2011) provided the following aspects to be identified related to the implementation of such Enhance Geothermal System (EGS) for cooling in the densely populated major cities in Indonesia:

1. Temperature gradient and conductivity map. In a general EGS project, it is necessary to carry out extensive measurements and surveys concerning the geothermal gradient and permeability of the rock. The greater the gradient, the shallower can be the depth of the artificial reservoir. The permeability parameters are associated with fracture control and the required stimulation. These two parameters have a direct and substantial impact on the project economics.

2. Water adequacy. Major cities in Indonesia are mostly located near the sea-side, e.g. Jakarta, Bali, Medan and Surabaya. This means that these cities would be unlikely to have significant issues with regard to the required supply of water during the exploration and the production stages. Jakarta and Medan also have other abundant sources of water such as lakes and rivers.

3. Seismicity issue. The stimulation of a fractured hot rock body will create an energy release in the form of an earthquake. Often this earthquake is not large enough to be detected by humans, but in a seismically quiet area, even small earthquakes may be felt by humans. For EGS projects close to dense populations, the residents should be warned first about the possibility of induced seismicity (Tester et al., 2010).

Further, Farizi (2011) explained that the use of Enhanced Geothermal Systems (EGS) in big cities as cooling systems needs a considerable amount of research. At the present time when the technology is not yet available, the classic EGS concept of a doublet could be applied. However, from the application of combined power and heat application of Enhanced Geothermal Systems (EGS) in several countries, such as Singapore, the provision of cooling from the waste water of an Enhanced Geothermal System's (EGS) power generation activity significantly improved the overall project economics. Thus, the "passive" geothermal cooling application from the main Enhance Geothermal System (EGS) activity should be the implementation priority. Nevertheless, other emerging options such as cooling plants/stations, in which the cooling energy could be easily tapped and distributed to homes, buildings and offices, should be also considered as an alternative to electricity production.

2.2.2. Geothermal or Ground Source Heat Pumps

Geothermal heat pump systems (GHPs) are called by avariety of names worldwide - earth-source heat pumps, geoexchange systems, ground-coupled heat pumps, ground-source heat pumps, and water-source heat pumps. GHPs can make use of the stable ground temperatures near the surface of the Earth to provide both heating and cooling to buildings. The surrounding soil, groundwater, seawater or an available nearby water resource is used as a heat source in winter and a heat sink in summer (cold & mild climate).

Although a geothermal heat pump is most-effective in locations with large seasonal variations in temperature, a review of the present geothermal heat pump technology is still important even for application in tropical hot and humid countries. There are plenty features of these kinds of systems that could be taken into account for designing the best type of system to be adopted in Indonesia.

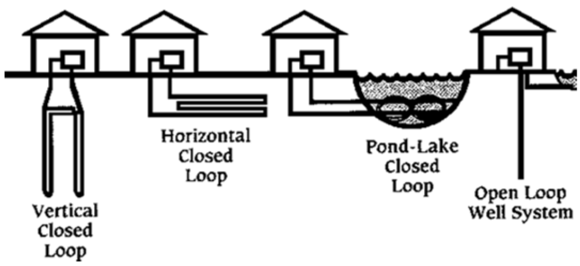

Figure 2: Common types of geothermal heat pump installations world-wide

There have been several studies on the applicability of heat pumps and the election of the most effective heat pump system to be used in tropical countries. Bi et al. (2009) investigated the application of Geothermal Heat Pump (GHP) systems in different temperature zones in China. They reported that in the tropical zone (Qionghai) and subtropical zone (Guangzhou), Geothermal Heat Pump (GHP) systems could possibly be applied for both cooling in summer and heating domestic water in these districts throughout the year.

Moreover, one of Indonesia's nearby countries, Singapore, has carried out their first study of the potential applicability of subsurface cooling in their country very recently. The implementation of geothermal heat pump technology in Singapore perhaps could be a good model for dense populated capital cities in tropical areas, such as Jakarta, especially to reduce the Urban Heat Island (UHI) Effects. Both Singapore and Jakarta face a similar issue, which is that the air conditioning activities, as the dominant energy consuming end-use appliance in buildings, are the biggest contributor to the peak loads. Liu, et.al (2013) reported that since the Geothermal Heat Pump (GHP) system has shown good performance in reducing energy costs, especially water usage in Singapore, it is a competitive alternative to the currently existing system. Elsewhere, tropical countries such as Vietnam and Thailand has started to look seriously at the possibility of the application of geothermal heat pumps. This has been shown by a number of studies conducted related to this topic and the latest breakthrough by Thailand, with an experimental installation of a GHP system in their country (Yasukawa, et al. 2009). Thus, in summary: Geothermal Heat Pump (GHP) use in tropical regions is still believed to be effective especially if 1) there are high heating activities concurrent with extensive cooling activities, which is usual in densely populated urban areas and 2) there is a nearby adequate water resource to be coupled with, and to act as a cold temperature heat source i.e. deep lake water, sea water, etc. Nevertheless, in these tropical areas, a Geothermal Heat Pump (GHP) always has a higher performance than an air-source heat pump such as conventional air-conditioner because of its high heat exchange rate. Other research conducted by IEA concluded that geothermal heat use may be most relevant in colder countries, but in warmer and hot climates, geothermal heat can be made useful in agricultural and industrial applications, and for space cooling using heat in excess as the driving energy for absorption chillers.

Particular studies related to geothermal heat pump application in Indonesia, has not been conducted thus far. However, many believe that with several modifications to the extension loop and adjustments to the earth connection aspects, the application of geothermal heat pumps in may perhaps be effective for several particular areas in Indonesia. For a start, geothermal heat pump systems could be applied in locations where abundant natural flowing brines occurs (.i.e. geothermal power plant vicinity, and downstream of hydrothermal areas) in which the the loops could be spread out simply in a channel of such flowing brines. Meanwhile, the abundant seawater, aquifers and deep lake water resources could also be an advantage for Indonesia when applying the Water Source-Coupled Heat Pumps. Moreover, modified heat pump systems of this type would not require expensive antifreezesolutions as is the case in some parts of the United States, for instance.

2.2.3. Geothermal Wells

The 'geothermal well' terminology in this paper may turn out to be rather puzzling since in a geothermal heat pump system, that term is often used to refer to the standing column of wells that serve as the groundwater-coupled heat pump system. Such ground-water coupled system consists of a vertical borehole that is filled with groundwater up to the level of the water table (i.e., asimilar construction to a domestic water well).

However, the term “geothermal well” used in this study refers to wells that corresponds to conventional hydrothermal wells. Moreover, the geothermal wells are also largely associated with centralized distribution systems (district and space energy provisions) or individual distributed system that requires a large amount of cooling (higher resource temperature and/or higher mass-rates). Therefore, the corresponding wells could be present as a single well, doublet system, multiple wells, depends on the energy needed.

With regard to the potential application in Indonesia, the hydrothermal resources are usually located below high terrain areas, where the air is much cooler and dryer. However, several hydrothermal areas in Indonesia turn out to have a large cooling demand, especially in tourism centres, such as Ciater. Accordingly, the application of geothermal cooling in hydrothermal areas would require a lower investment cost compared with locations with no natural hot water or where no temperature anomaly occurs. The lower capital cost is largely associated with the lesser efforts required to tapa heat resource of the temperature required for a particular process or application. i.e. shallower well drilling depth, shorter length of extension loops, etc. Nevertheless, the application of GHPs in hydrothermal areas would have extra technical issues to address. These technical issues will comprise production problems related to the brine characteristics - scaling, corrossion, etc - and issues related to brine quality and supply, e.g. flow rate, temperature and pressure decline. The smaller market segment and application scale in hydrothermal areas is also an aspect to consider in terms of the investment returns and projected revenues. Meanwhile, in a non-thermal locationwhere normal temperature gradientsoccur, higher investmentcosts are believed to be easily offset (compensated for) by the significantly larger potential market, i.e. densely populated cities, capital cities, etc.

3. IDENTIFYING THE POTENTIAL BENEFITS FOR INDONESIA

3.1. Electricity Consumption Reduction

With regard to geothermal heating applications, the more common application worldwide, comparisons are mostly made with fossil fuel or gas energy heating rather than with the inefficient electric heaters. As a result, the energy savingsassociated with fossil fuel/gas replacement, is always the main talking point when it comes to geothermal heating. Whereas withgeothermal cooling, comparisons are mostly made with conventional air-conditioners,and the reduction in power consumption is the main advantageous feature.

From experiences with the implementation of geothermal coolings in Mumbai, India, it has been reported that they managed to obtain substantial reduction in electricity consumption with around 60-80% cut from the previous conventional use. The cooling application of GHPs elsewhere also shows a power use reduction, resulting in signifantly lower energy bills. Geothermal cooling and heating systems are most effective if applied in new buildings or if they are considered as a direct replacement for the conventional existing cooling or heating system. But if used only as an addition to the existing cooling system, then the expected electricity consumption reduction will be lower.

3.1.1. The Demand-Side Management

The adverse impacts of the current large gap between demand and production of electricity, such as the periodic and spontaneous black outs, have been noticeable lately. The growth of electricity demand has not been matched by the power generation development. Therefore we could face more major setbacks if we keep only focusing on the aggressive efforts to increase geothermal power generation, i.e. supply side managemen, instead it may be better to implement a more feasible demand-side management approach. The main focus of a demand-side management approachis energy efficiency and electricity use reduction. Geothermal cooling and heating provide an option for significantly reducing power consumption and thus are in line with the demand-side management campaign. Moreover, by implementation of geothermal cooling and heating, there will be an opportunity to shift the peak load periods, which is supposed to result in a lower electricity generation price. Also important to consider is the secondary benefits resulting from the power use reduction, such as the reduced urgency in power generation development, lesser investment required for transmission lines and lesser electricity subsidies required (e.g. for margins in the feed-in tariff)

3.2. Cost Savings

The upfront costs of geothermal will be more than conventional cooling and heating systems, but the savings are very substantial. There should be hardly any operating and maintenance costs throughout the lifetime of the geothermal system. As energy prices continue to rise, the investment return gets better and better. Assuming that the specific system is suited to the climate and usage patterns, and that the system is properly installed and maintained, the higher installation costs are quickly offset by the savings in energy costs.

According to the U.S. Environmental Protection Agency, such geothermal systems save homeowners 30–70 percent in heating costs, and 20 –50 percent in cooling costs, compared to conventional systems. The application of cooling by geothermal heat pumps in the harsh scorching climate of India has also introduced savings of around 40-70 percent. It is easy task to find similar experiences in savings resulting from the use of GHPs elsewhere around the world.

If heating is the dominant energy requirement in cold and mild climates then low electricity prices and high gas or oil prices will make the geothermal system more attractive than the corresponding combustion systems. If cooling is dominant, as in subtropical and tropical climates, then high electricity prices will favor such geothermal systems over conventional air conditioning, which is less efficient. Moreover, if both heating and cooling requirements are high, then geothermal systems are ideal where electricity prices are low year round, but high peak load charges are levied during summertime.

Particular to the potential applications in Indonesia, the specific electricity tariff for each different segments of users, has made the potential range of cost savings from GHPs in Indonesia very wide. At some point in the future, geothermal cooling and heating costs in Indonesia could actually be substantially lower since antifreeze solutions are unnecessary and the equipment used should not be as complicated as that required in locations where high seasonal temperature changes occur.

3.3. Potential Wider Market

The direct use geothermal campaign in Indonesia has never experienced a great spell of development. Direct use development has remained limited to Corporate Social Responsibility Response (CSR) programs of the power generating developers and also limited to small enterprises or business entities. Most of the geothermal power developers, believe that the direct use activity often have a significant adverse impact on their production activities. Thus, the developers believe that programs not related to the use of geothermal resources for their CSR programs are much more likely to occur in the future..

Table 1: Geothermal cooling application offers potential wider market segment

	Target & Locations	Geothermal Areas				Non-geothermal Areas						
						Rural Areas				Remote Areas		
		C SR Programs	Small Scale Industries	Tourism & Resort Areas	Power Developers	Large Commercial Areas	Public & Residential Areas	Industrial Areas	Government Facilities	Small Scale Industries	Large Scale Industries	Tourism & Resort Areas
Direct Use Applications	Current	V	V	-	-	-	-	-	-	-	-	-
	Expected	V	V	V	V	V	V	V	V	V	V	V

The lessons learned from the worldwideexperience show that the benefits of direct use are wide spread:for instance, snow melting and building heating are enjoyed by every social segment of the community. Thus, awareness of the uses of geothermal energy in those countries is felt nationwide. This is contrary to the experience in Indonesia, where direct use developments have been fairly limited to Corporate Social Responsibility Response (CSR) of the power generating developers, and that have led to a marginal awareness of direct use in the population as a whole. Therefore, geothermal cooling in Indonesia, with a large market, has the potential to revitalize the development of the direct use development of geothermal energy in Indonesia.

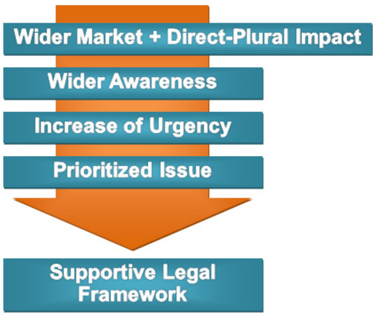

Figure 3: Steps for direct geothermal use to obtain a supportive legal framework.

3.4. Emission Reduction

Using geothermal energy for heating activities obviously replaces fossil fuel use and prevents the emission of greenhouse gases. Meanwhile using geothermal energy for cooling also significantly reduce freon (CFC) use in conventional air conditioning systems. However,geothermal heating and cooling technologies still rely on electricity to operate. For the area where our case study house is located, the majority of the electric power comes from coal burning plants that produce greenhouse gasses. Given the efficiency of the system however it still results in a significant reduction in the amount of CO_2 being released to the environment

3.5 Measures for Urban Heat Island Effect

Jakarta, along with a number of capital cities worldwide, are facing a large threat in terms of their environmental conditions, namely, the Urban Heat Island Effect. The freon produced from conventional cooling systems, along with the pollution from vehicles are the main contributors to the problem. Meanwhile, the air conditioning market is still growing in a significant manner, which could escalate the impact of the Urban Heat Island Efffect in Jakarta. Again, since air conditioning systems emit large amounts of chlorofluorocarbons, or greenhouse gases, geothermal cooling prevents their emission into the atmosphere.

4. INDONESIA GEOTHERMAL COOLING PROJECT PLANNING

The study concluded that the overall potential benefits and opportunities offered by geothermal cooling and Indonesia are substantial and a more detailed and comprehensive study should be carried out. Accordingly, a number of demonstration projects are going to be set up in the near future in order to enhance the design of the in-ground component of the geothermal cooling systems to maximize their economic and environmental benefits.

Table 2: Geothermal cooling application offers potential wider market segment

Specific Research Category	**Nominated Location for Demonstration Project**
Densely Populated Thermal Areas	Ciater
Less Populated Thermal Areas	Kamojang
Densely Populated Non-thermal Areas	Jakarta and Bandung
Less Populated Non-thermal Areas	Bali

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