Geothermal Energy Developments of Sri Lanka

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Keywords: Energy consumption, Geothermal energy, Preliminary phase, Explorations, Challenges

ABSTRACT

Although Sri Lanka is not located in tectonically active margins and active fault zones with thermal signatures, there are many occurrences of hot springs in the country. There are two major hypotheses explaining the origin of geothermal fields in Sri Lanka, the Highland- Vijayan (H/V) boundary which is an inactive plate boundary passing through the country as a source of hot springs being the oldest. Although some of the hot springs are apparently arranged along the H/V boundary, it could be observed that most of them have been deviated from it. The dolerite dykes as a source of hot springs is the other hypothesis which has been substantiated by the surface evidence and geophysical exploration results. Among the eight recorded hot spring sites in the country, the highest temperature is observed at Kapurulla hot spring in Tampitiya area. The other sites of hot springs are Mahapelessa in Hambanthota, Kanniya in Trincomalee, Rangiriulpotha in Gomarankadawala, Nelumwewa in Polonnaruwa, Wahawa in Padiyatalawa, Maduruoya and Mahaoya. All these sites have acceptable surface temperatures for low enthalpy geothermal utilization. The scope of the paper to be presented is to provide an insight into the geothermal energy exploration in Sri Lanka, with a focus on the developments over the history. In the first phase, the surface studies of manifestations, geological and surface geochemical explorations have already been completed and found that the surface activities have a direct implication with the geological structures. The geophysical studies which are of paramount importance for the modelling of the geological structures are currently being conducted. We also wish to discuss the apparent barriers and the challenges expected in the process of geothermal energy exploration in the country.

1. SRI LANKA

Sri Lanka is an island in the Indian Ocean, near the equator, between 5^{o} 55´ N to 9^{o} 55´ Latitudes and 79^{o} 42´E to 81^{o} 52´ Longitudes. The geographical location of Sri Lanka is comparatively far from known active tectonic plate boundaries (Figure 1).

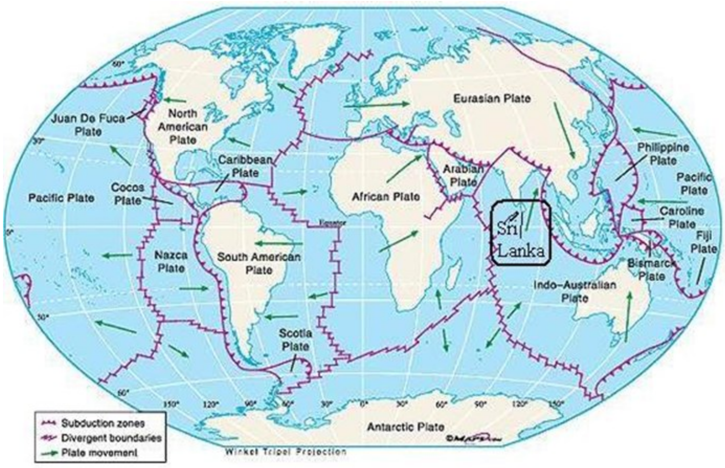

Figure 1: Plate boundaries and direction of movement (Samaranayake et al., 2015).

1.1 Energy consumption in sri lanka

Sri Lanka's economy has converted from an agrarian economy to an urbanized economy driven by services. In 2015, the Sri Lankan service sector accounted for 62.4 % of GDP, followed by the manufacturing sector (28.9 %) and agriculture sector (8.7 %). A result of economic growth has been the increasing demand for energy in the country.

Sri Lanka's energy demand is currently resolved by following energy sources. It consist of both indigenous non-fossil fuels and imported fossil fuels. It is very clear that in the country's energy needs are mostly filled with petroleum and coal. The remainder is made up of other indigenous sources which, include large hydro and renewables such as solar, small hydro and wind. The following Figure 2 explains Sri Lanka's primary energy consumption percentages in 2015 (Sing, et al. 2017).

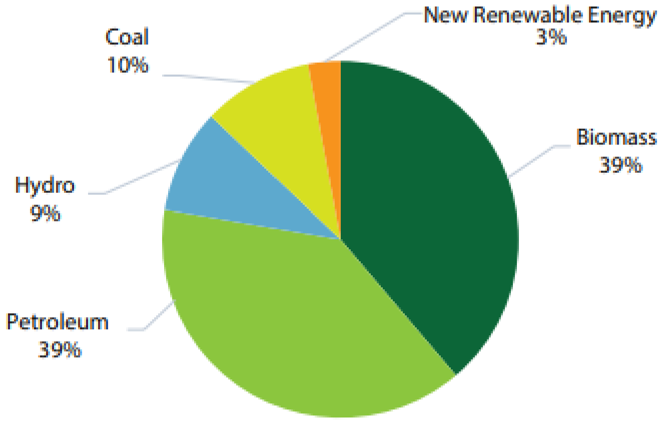

Figure 2: Sri Lanka Primary Energy Consumption (2015) (Sing., et al. 2017).

However, with increasing demand, Sri Lanka has had to increase its dependence on costly imported fossil fuels. This increased dependence on fossil fuels has also led to an increase in Sri Lanka's Green House Gases (GHG) emissions.

Since Sri Lanka wants large quantities of fossil fuel resources, it is essential to secure the country's energy demand by developing and adopting renewable sources of energy to meet its ever-growing demand. This will reduce Sri Lanka's expenditure on imported fossil fuels and also help to reduce GHG emission. It will also ensure that development and economic growth towards the low energy price (Sing, et al. 2017).

1.2 SRI LANKAN ENERGY GENERATION TRENDS

Normally renewable energies are known to be energy generated by wind, solar, biomass and geothermal sources. This means that all energy sources renew themselves within a short time or are permanently available. Hitherto, Sri Lanka mainly depends on the non renewable energy such as electricity generated by fossil fuels. Nevertheless Sri Lankan policy has changed by promoting renewable energy resources with adding up more percentage of renewable energy into its energy generation source mix as shown in the Figure 3.

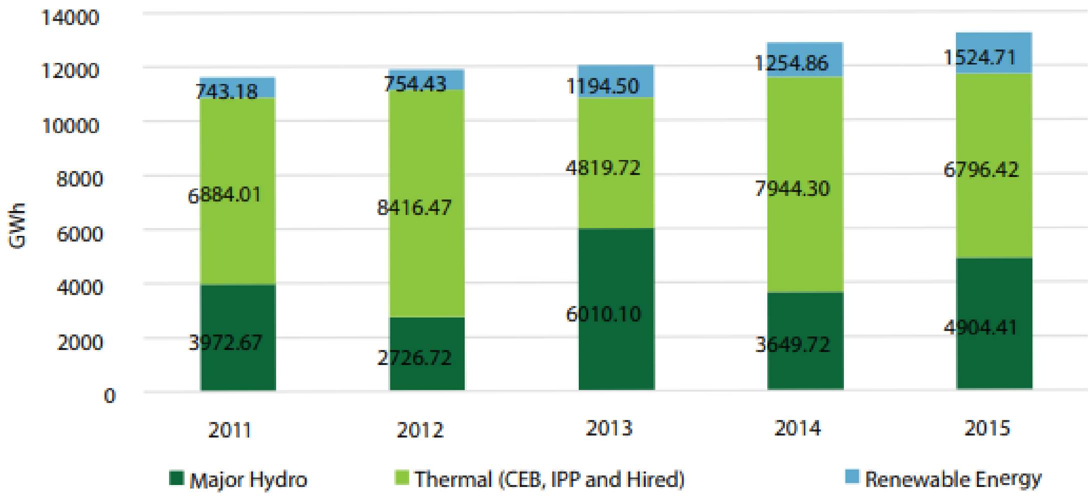

Figure 3: Sri Lanka electricity generation trends (2011 to 2015)(Sing, et al. 2017).

As seen in Figure 3, it is dominant that the alternative renewable energy usage increase with the time. In 2014, Sri Lanka met its target of generating at least 10 % of its electricity using renewable energy, as set by the National Energy Policy and Strategies of Sri Lanka (NEPS). However, Sri Lanka is still seeking opportunity to increase the production through renewable energy resources. The initial geothermal development studies come under this and extensive researches are annually conducting in this field to develop strategies to harness that energy resource (Sing, et al. 2017).

2. GEOTHERMAL ENERGY DEVELOPMENT IN SRI LANKA

Geothermal energy is a new topic for Sri Lankan energy budget. Currently, most of the energy requirement in the country is fulfilled by hydro power and coal power. However, Sri Lanka is seeking opportunities for developing alternative energy sources to satisfy the energy demand in Sri Lanka.

Geothermal energy comes under this category and Sri Lanka can be recognized as a newcomer for this field. Sri Lanka is still conducting capacity building and resource exploration for future geothermal energy harnessing. According to Parada, 2016, there are several phases for geothermal development classified as follows:

Preliminary survey,

Exploration,

Test drilling,

Project review and planning,

Field development and production drilling,

Construction,

Start-up and commissioning and

Operation and maintenance.

2.1 Preliminary survey

The preliminary survey is the commencement step of the geothermal project and in this step surface manifestations were located by using existing knowledge. Sri Lanka has strong data base regarding surface studies of the hotspring fields. Although Sri Lanka is not located in a tectonically active margin and active fault zones with thermal signatures, there are many occurrences of hotsprings in the country. Among the six recorded hot spring sites, the highest temperature is recorded at Kapurulla hotspring in Tampitiya area. Mahapelessa in Hambanthota and Kanniya in Trincomalee, Rangiriulpotha in Gomarankadawala, Nelumwewa in Polonnaruwa, Wahawa in Padiyatalawa, MaduruOya and Mahaoya (Figure 4) are the other sites for hotspring occurrences. When considering the lateral extent of the hotsprings, Mahapelessa and Rangiriulpotha appeared to consist with single wells, though similar marshy settings with unique vegetation are prominent observations of these sites that match with similar characters of other largely extending hotspring sites with wide-range of wells. The temperature of hotsprings varied from different localities and contrast of temperatures are observed within the same field. At a distance of few meters, the temperature change can be significant as observed in geothermal field such as Kapurulla. Table 1 summarizes the average temperatures of the different geothermal springs of Sri Lanka.

Table 1: Average temperature of thermal springs in Sri Lanka.

Hot spring	Average Temperature(°C)
Rangiriulpotha	39
Kanniya	42-44
Nelumwewa	55-62
Kapurella	73.5
Mahaoya	47-54
Wahawa	44-48
Mahapelessa	46

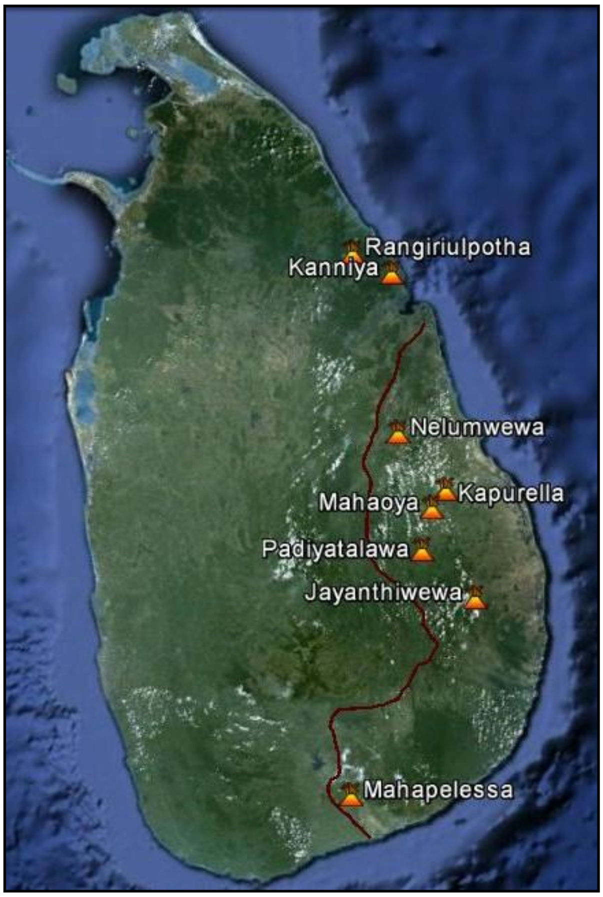

Figure 4: Occurrence of Hotsprings in Sri Lanka.

2.1.1 Provinance**of Hotsprings in Sri Lanka**

Conventionally geothermal fields of Sri Lanka, particularly occurrences of known hotsprings, are correlated to the H/V boundary (Chandrajith et al, 2013). A few coincidences of hotspring occurrences along and close to the H/V boundary justify this conclusion. Considering the age and possible thermal history of the H/V boundary, and the distance to some of the hotsprings from the mapped boundary; correlating and considering the H/V boundary as the source for geothermal activities is arguable (Figure 4). Many hotsprings appear as far as 40 km from the H/V tectonic boundary and not particularly associated with long-extending fractures and lineaments. As the H/V boundary is a continuous geological feature and many fracture zones and lineaments cut across the same in regular basis, confinement of hotsprings to selected locations is difficult to be explained in relation to the H/V boundary.

The work done by Dissanayake and Weerasooriya (1986) on fluorine as a mineralizer and granitic enrichment of uranium and its higher mobility along lineaments are used to justify the high concentrations of U and thereby proposing it as a probable heat source.

Samaranayake et al., 2015 revealed geological observations of dolerite dyke as a common geological feature in many locations where hotsprings occur. Except for the hotspring at Mahapalessa , where hotspring occur almost on the H/V boundary zone, all other known hotsprings are very close to dolerite dykes and crop-up along mega fracture zone where such fractures cut through the dolerite dykes.

2.2 Exploration

Depending on the surface observations and existing school of thoughts, geochemical and geophysical explorations were conducted in selected hotspring fields in Sri Lanka.

2.2.1 Geochemistry of Sri Lankan hotspring fields

Many have investigated the geochemical characterization of Sri Lankan hotsprings, Chandrajith (2013) can be identified as the leading research which discusses the characteristics of geothermal water in depth. In his study, seven hotsprings have been studied in detail with a comparison of associate non geothermal water.

In the study of Chandrajith (2013), the reservoir temperatures for the studied geothermal springs in Sri Lanka were evaluated by silica based and cation based geothermometers. Chandrajith (2013) suggested that Na-K-Mg geothermometers cannot be applied for the Sri Lankan hotsprings due to its mixing with the surrounding ground water. As the evident for this, Chandrajith (2013) gives the modified Na-K-Mg ternary diagram for above hotsprings in Sri Lanka. Most of the hot springs are plot away from the full equilibrium line and show immature or multiple mixing characters. These geothermometers indicate wide ranges of reservoir temperatures for the same hotspring, possibly due to errors in the coefficient of geothrmometric equations. For comparison, the silica- Quartz conductive cooling and steam loss temperature equation gave reservoir temperature ranges from 97°C (Kanniya) to 132°C

(Nelumwewa). Na-Li geothermoometric and silica base geothermometric calculations are comparable to each other and it gives 96°C (Mahapelessa) and 129°C (Nelumwewa). The average reservoir temperature calculated from all the methods varies from 88°C (Kanniya) to 120°C (Nelumwewa). These average temperatures calculated from the Chandrajith (2012) study tally with the surface discharge temperature variations recorded in the same study.

2.2.2 Geophysical studies relate to thermal springs in Sri Lanka

A few scientists have been engaged in studies on thermal springs and related aspects since 1968. Yet there is hardly a composite and reliable mechanism for the provenance of such springs, as each suggestions were having its own generic drawbacks. Therefore, geophysical studies were conducted from time to time for demarcating geothermal fields.

The regional gravity map indicates a gravity low in the region that is considered for this survey. However, the sampling interval of the Gravity map was not adequate to conclude details in the scale of this particular study. Further, the effect of the oceanic crust on the Bougure anomaly map towards the inland has not been compensated and a DC shift is visible masking finer details in the study area.

In general majority of authors agree that the provenance of hotsprings of Sri Lanka is due to the well-known boundary between Hghland and Vijayanlitho-tectonic complexes. A few suggest an occurrences of a heat body close to the hotsprings and others were in agreement that deep percolating water is heated-up by subsurface heat under standard geothermal gradient. Almost all the authors unanimously agree that there is a hydraulic connectivity between heat source and hotspring(s) via deep seated fracture zones though such zones are not mapped down to deep-seated environments (Dissanayake and Jayasena, 1988). Occurrence of a substantial pluton as a heat source for NelumWewa hotspring is suggested (kumara and Dharmagunawardhane, 2014) and the structural framework is linked to the Dibulagala rock. Further, a deep set of fractures connecting this proposed heat-source and hotspring has been identified. The existence of dolerite dykes in the vicinity has been identified as an integral part of the pluton; a sporadic occurrence, which contradicts that the source for hotsprings are either lateral to the hotspring locations and/or deeper origin as suggested by Hobbs et al, 2013 in their 2D Magneto Telluric (MT) studies . Further Samaranayake et al., 2015 suggested a probable physical relationship between hotsprings of Padiyathalawa and adjoining dolerite occurrences and a subsurface model for explaining the source of thermal springs.

3. DIRECT UTILIZATION OF GEOTHERMAL FIELDS

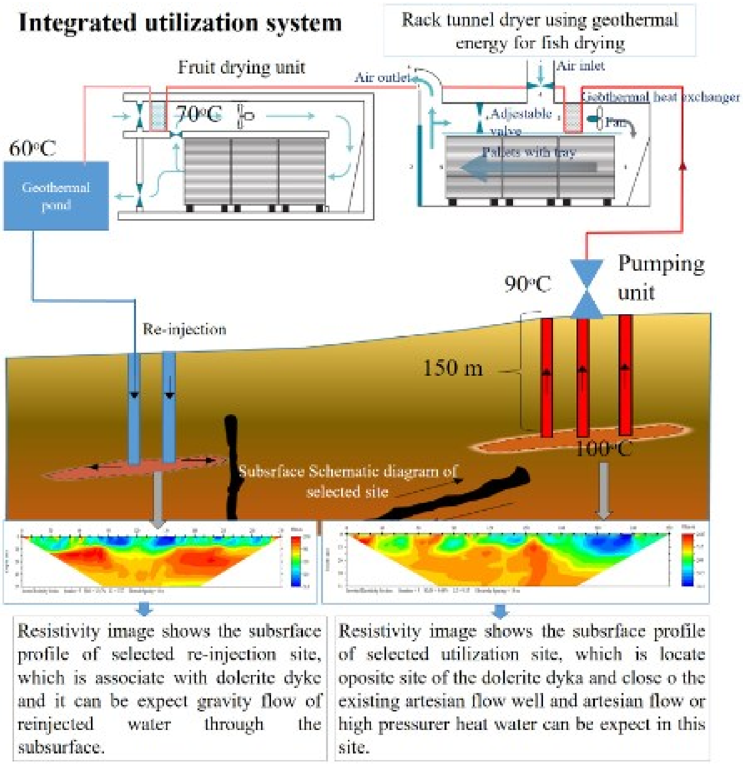

Figure 5: Iinitiative model for tapping Wahawa geothermal field.

Sri Lanka is still using hotsprings only for the recreational activities. There are 4 major hot spring fields utilized for recreational activities and those are recorded as one of the high tourist attract locations in Sri Lanka. However, other direct utilization methods are being studied in some geothermal fields. Figure 5 shows one of the initiative models for tapping Wahawa geothermal field.

4. CHALLENGES OF GEOTHERMAL ENERGY DEVELOPMENT IN SRI LANKA

Customary, the geothermal prospects are commonplace in magmatic geological settings; hence there is a substantial knowledge base for geothermal energy development in global scale. However, geothermal prospects in metamorphic terrains are a growing science, which is largely in the experimental level. Sri Lankan geology is composed of old/cold Proterozoic metamorphic rocks with hardly any thermal signatures, other than sporadic occurrence of a set of hotsprings. It is a geological wonder to occur hotsprings in such geological settings, which make it very complex to identify source characters for the hotsprings. The first and foremost step towards assessing the geothermal prospects would be the source characterization; geothermal gradient, depth to the heat source and temperatures levels. Considering the local expertise and available equipment, Sri Lanka is not in a position to conduct detailed and integrated surveys in this caliper. External expertise and equipment are required to address this prevailing issue of primary investigation to establish the potential of geothermal reserves for energy development.

Though Sri Lanka advances in assessing alternative power options such as solar power and wind power, the geothermal prospects hardly considered in the same echelon, mainly due to lack of initiatives both in government and private sector. If the studies enables to reveal the potential of geothermal clean energy option for Sri Lanka, investments could be drawn breaking the deadlock that prevent the development of the sector.

Despite all technical, financial and bureaucratic hindrances that accompany, the main challenge to develop geothermal energy prospects in Sri Lanka will remain as "identification the source with its potential".

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