

Geothermal Resources at Maluku Islands, Eastern Indonesia

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ABSTRACT

The mapping of distributed renewable energy such as geothermal resources and its thermal surface features could give a policy consideration for geothermal development in Indonesia. As an archipelago, the country has 349 geothermal locations (25 GWe) by December 2018; the 34 locations are at Maluku islands, Eastern Indonesia with total resources of 1,156 MWe and total reserves of 505 MWe. They consist speculative of 560 MWe, hypothetically 91 MWe, possibly 497 MWe, probably 6 MWe, and proven 2 MWe. Maluku consists of 2 provinces: North Maluku and Maluku. North Maluku has more volcanic areas rather than the Maluku. North Maluku with 15 geothermal areas has resources about 190 MWe speculative, 7 MWe hypothetical, and 379 MWe probable. Maluku with 19 geothermal areas has resources about 370 MWe speculative, 84 MWe hypothetical, 118 MWe possible, 6 MWe probable and 2 MWe proven. Natural resources of mining, plantation, and fishery industries are very prospective in Maluku islands and the geothermal development could be one of the answers to fulfill the required energy for these natural resources. This paper will explain about geothermal resources in Maluku and North Maluku because Indonesia government is focusing on the development of Eastern Indonesia. As Maluku is an archipelagic region, the Indonesian government has a strategic policy for increasing economic clusters based on local resources. Geothermal is a clean and an in situ energy, so the geothermal resources information of Maluku could be a consideration for everyone who will be developing renewable energy based on the industrial development in Indonesia.

1. INTRODUCTION

Maluku is an archipelago in eastern Indonesia and consists of two provinces namely the Maluku Province and the North Maluku Province (Figure 1). Tectonically, they are located on the Halmahera Plate within the Moluccas/Maluku Sea Collision Zone. Geographically they are located in the east of Sulawesi, west of New Guinea, and north and east of Timor and the deep sea separates it. This geographical character certainly becomes a challenge in order to encourage inter-island connectivity and encourage equitable development across the islands in the Maluku Islands. At least there are several major islands, i.e. from the North to the South: Halmahera, Bacan, Obi, Taliabu, Mangole, Ternate, Buru, Seram, Tidore, Ambon, Haruku, Saparua, Nusalaut, Banda Neira, and Wetar. In the framework of economic equality, the crucial key is to encourage the cluster model business (Darmin Nasution in ekon.go.id, 2017). This cluster system has the advantage of increasing economies of scale, increasing added value, and encouraging entrepreneurial innovation. So, mapping of the resources of new and renewable energy such as geothermal at the local region is compulsory for accelerating and supporting the cluster industrial development and of course increasing the energy accessibility. Study geothermal perspective for electricity on Maluku and North Maluku province already presented by Nazif, et al. (2015, focus on North Maluku Province) and Isnaniawardhani, et al. (2018, focused on Maluku Province). They mentioned that geothermal energy could be a solution for electrical energy and direct use for Maluku as it is many scattered islands. The Maluku islands have an area of 712,480 km², consisting of 658,295 km² or 92.4% of land area and total area reaching 54,185 km² or 7.6%. North Maluku Province is bordered by North Maluku Province, bordering the Province of West Irian Jaya, in the west with the Province of Southeast Sulawesi and Central Sulawesi in the south bordering the State of Timor Leste and the State of Australia.

In December 2018, the Geological Agency MEMR had inventoried 349 geothermal areas, with total resources about 25.3 GWe, consisted of 6,407 MWe, speculative resources, 3,852 hypothetical resources, 10,099 possible resources, 2,016 probable resources, and 3,012.5 proven resources. By the end of October 2019, the geothermal installed capacity in Indonesia reached about 2,003.3 MWe or about 8 % from total geothermal resources (Nuryatin in katadata.com, 2019). The total of the geothermal potential decreased from 29 GW to 25 GW, but the number of reserves (probable and proven) has significantly grown from 3.3 GW to 5.03 GW. They are also scattered in medium and small islands such as Maluku islands. Not only geothermal energy is available in these islands, but also resources of tourism, mining, plantation, and fishery industries are very prospective in Maluku islands. The geothermal and the other resources could be a harmony team for developing the Maluku islands.

2. METHOD

The geothermal resources simply describe geothermal resources at Maluku islands in each province: North Maluku and Maluku province, by showing the geological resources in these areas, by Indonesia energy policy for geothermal and also by showing the challenging of developing geothermal in eastern Indonesia. This paper also combines secondary data from several works of literature.

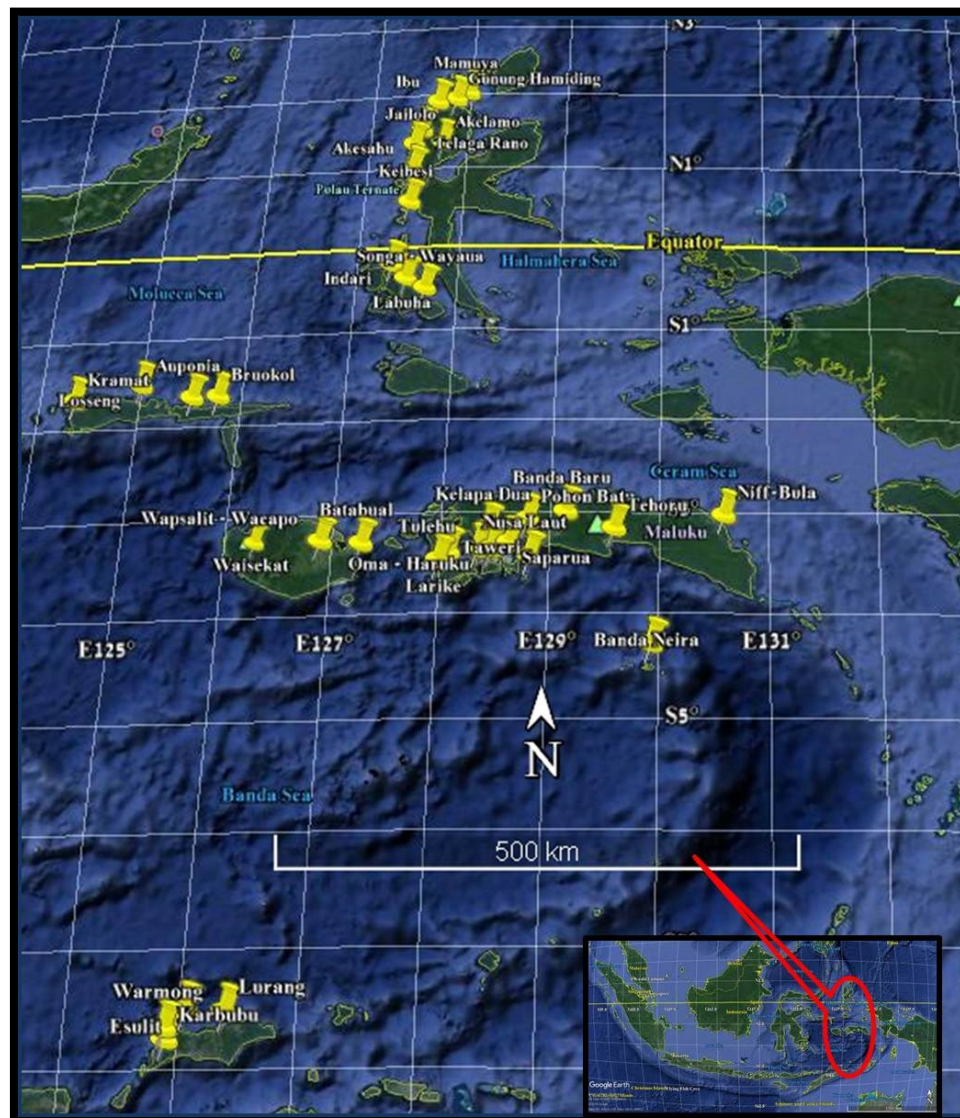


Figure 1: Map location of the Maluku Islands and Geothermal locations in Maluku, Indonesia (Google Earth)

3. A BRIEF OF GEOLOGY

The Indonesian archipelago is an extremely complex collection of continental blocks, active and extinct volcanic arcs and associated subduction complexes (commonly with ophiolites, marking sutures where former oceans consumed) and old and young ocean basins. It is now at the convergence of three major tectonic plates: Eurasia, Pacific and Australia. Eastern Indonesia contains a number of small continental microplates derived from the Australia- New Guinea Gondwanan margin, now separated by a young age oceanic marginal basins and volcanic arc systems. Based on heat flow database at SE Asia region, the geothermal areas in the Maluku Islands are several parts, having $>80 \text{ mWm}^2$ average and the others $< 80 \text{ mWm}^2$ (Figure 3, Hall and Morey (2004)). This increases the confidence of extracting the heat from depth manifested by hot springs at the surface.

The physiography of Maluku is divided into two parts, namely North Maluku and South Maluku. Several works of literature explained that North Maluku partly connects with a series of East Asian islands, and partly with the Melanesian system. South Maluku (Banda Bow) is a part of the Sunda Mountains System. North Maluku is an archipelago consisting of volcanic islands and non-volcanic islands. Volcanic islands occupy the western part including Ternate Island, Tidore Island, Moti Island, Mare Island, Makian Island, and Sangihe Island. Volcanics include Bacan Island, Kasiruta Island, Talaud Island, and Obi Island. South Maluku is geologically a Banda Bow, namely the system of islands forming arcs around the Banda Sea basin horseshoe that opens to the west. The South Maluku Islands system is divided into volcanic inner arcs and non-volcanic outer arcs. South Maluku Bow in volcanism consists of small islands (possibly underwater volcano peaks/seamount) such as Damar Island, Teun Island, Nila Island, Serua Island, Manuk Island and Banda Islands. Non-volcanic outside buses consist of several rather extensive islands and form islands complexes including Leti Islands, Babar Islands, Tanimbar Islands, Aru Islands, Kai Islands, Watu Bela Islands, Seram Island, and Buru Island.

The geological characteristics of the Maluku Province are composed of sedimentary rocks, metamorphic rocks, and igneous rocks with a spread that is almost evenly distributed on each island group. This is influenced by the age classification of islands formed in million years ago, in the Neogene to Paleocene periods. It is also influenced by the location of Maluku between the Indo-Australian Earth plate, the Pacific, the Philippine Sea and the Banda Sea, thus giving the distribution of several volcanoes both those that are still active and those that are no longer active.

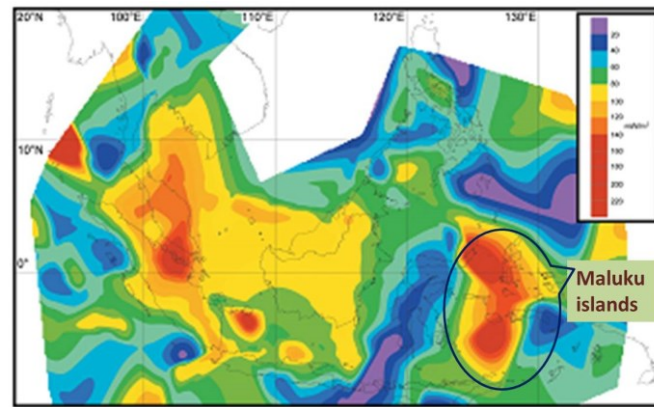


Figure 2: Contoured heat flow map for SE Asia (based on the database of Pollack *et al.* [1990; 1993] and oil company compilations Kenyon and Beddoes, 1977; Rutherford and Qureshi, 1981, in Hall and Morey, 2004)

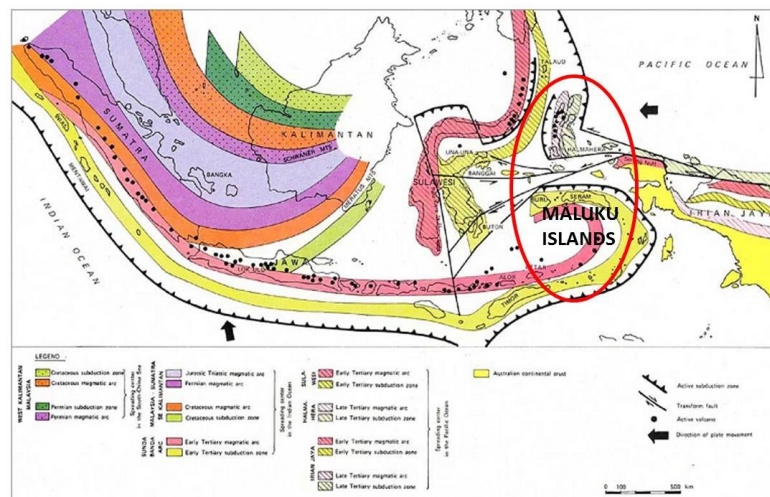


Figure 3: Perian-Recent magmatic arcs/subduction zones Indonesian Archipelago (Katili in Gorsel, 2012)

4. GEOTHERMAL RESOURCES OF THE MALUKU ISLANDS

The Maluku and North Maluku provinces are part of the Zone of Eastern Indonesia, these have at least 34 geothermal areas and total resources about 1,156 MWe, i.e., total resources of 651 MWe and total reserves of 505 MWe. They consist of speculative 560 MWe, hypothetically of 91 MWe, possibly of 497 MWe, probably of 6 MWe, and proven 2 MWe. North Maluku has more volcanic areas rather than Maluku. North Maluku with 15 geothermal areas has resources about 190 MWe speculative, 7 MWe hypothetic, and 379 MWe probable. Maluku, with 19 geothermal areas has resources about 370 MWe speculative, 84 MWe hypothetic, 118 MWe possible, 6 MWe probable and 2 MWe proven. The geothermal fields of Tulehu (2x10 MWe), Jailolo (4x10 MWe), and Songa Wayaua (5 MWe) are including to the list of development acceleration electricity projects stage 2 in Indonesia (MESDM No. 39 K/20/MEM/2019).

4.1 Geothermal Resources in North Maluku Province

North Maluku (Tabel 1) more has volcanic areas rather than the Maluku. North Maluku with 15 geothermal areas has resources about 190 MWe speculative, 7 MWe hypothetic, and 379 MWe probable. The distribution of geothermal areas in North Maluku Province is fifteen regions, namely:

- a) **Halmahera** Island: Mamuya, Gunung Hamiding, Ibu, Telaga Rano, Jailolo, Akelamo;
- b) **Makian** Island: Keibesi;
- c) **Tidore** Island: Akesahu;
- d) **Bacan** Island: Indari, Labuha, Songa-Wayaua;
- e) **Tali Abu-Mangole** Islands: Kramat, Losseng, Auponia, Bruokol.

The low-temperature systems are Ibu, Akelamo, Keibesi, Akesahu, Kramat, and Bruokol; The medium temperature systems are: Mamuya, Loseeng, and Auponia; and the high-temperature systems are Jailolo, Gunung Hamiding, Telaga Rano, and Songa Wayaua.

In general, the use of land status associated with the geothermal potential areas in North Maluku Province is protected forest. Some geothermal prospects in the province are included in the Geothermal Working Area (WK Geothermal), namely: Mount Hamiding in accordance with ESDM Ministerial Decree No.2779K / 30 / MEM / 2014, Telaga Ranu in accordance with Ministerial Decree ESDM No.2780K / 30 / MEM / 2014, Jailolo in accordance with ESDM Ministerial Decree No.1787K / 33 / MEM / 2007 with

geothermal business permit holders owned by Star Energy Geothermal Halmahera, and Songa Wayaua in accordance with ESDM Ministerial Decree No.2965K / 30 / MEM / 2008. The potential of geothermal supply from the Gunung Hamiding WKP managed by PT Star Energy Geothermal has an estimated 265 MW reserve and upside potential field development can reach 795 MW targeting the Commercial Operation Date (COD) in 2024. PT PLN (Persero) manages two WKPs namely Jailolo WKP with an unexpected reserve of 70 MWe and WKP Songa Wayaua with a potential of 10 MWe.

The Ministry of Energy and Mineral Resources (ESDM) is planning for Halmahera Island. The North Maluku Province became a pilot project of a geothermal energy-based cluster. There is potential for electricity from 800 MW of geothermal energy. With that much potential, the fishing industry and port will be built in the area, so it is potential for exploring Central and North Halmahera. Industrial development in Halmahera, he continued, will increase the need for electricity. The industry's need for electricity will be supplied from geothermal power plants (PLTP). Thus the construction of geothermal power plants will be utilized, on the other hand, the industry will also develop. Halmahera in North Maluku Province does have abundant natural resources. The island has a hypothetical potential for Nickel minerals of 238 million tons, then potential fisheries, and other industries, and geothermal potential. Those potentials behind the government make Halmahera a pilot of a geothermal energy based cluster. Halmahera Island is expected to be one of the centers of economic growth and a pilot for clean energy development. To fulfil this economic potential, electricity needs will increase, at least 700 MW in the next few years. Geothermal besides being environmentally friendly, it also provides energy security in the future, considering that geothermal energy does not depend on fluctuations in world energy prices. Currently, for geothermal on Halmahera Island, three regions have obtained WKP management permits, namely WKP Gunung Hamiding, Songa Wayaua and Jailolo (ebtke.esdm.go.id, 2019).

Table 1: Geothermal Resources in North Maluku Province, Indonesia

| No | No. Indonesia Potency Map | Name | Region | Speculative | Hypothetic | Possible | Probable | Proven | Installed | Reservoir Temperature (°C) | Probably Geothermal System | Geothermal Manifestations | Characteristics islands |
|----|---------------------------|-----------------|---|-------------|------------|----------|----------|--------|-----------|----------------------------|---|--|--|
| 1 | 237 | Mamuya | Halmahera Utara/ Halmahera Island | 0 | 7 | 0 | 0 | 0 | 0 | 160 (SiO ₂) | volcanic area | Hot Springs, 49 °C | plan of industrial cluster development |
| 2 | 238 | Ibu | Halmahera Barat/ Halmahera Island | 25 | 0 | 0 | 0 | 0 | 0 | n/a | volcanic area | Hot Springs, 49 °C | plan of industrial cluster development |
| 3 | 239 | Akelamo | Halmahera Utara/ Halmahera Island | 25 | 0 | 0 | 0 | 0 | 0 | 180 (Na-K-Ca) | sandstone-conglomerate with andesitic and basaltic components of Quaternary age | Hot Springs, 81 °C | plan of industrial cluster development |
| 4 | 240 | Jailolo | Halmahera Barat/ Halmahera Island | 0 | 0 | 75 | 0 | 0 | 0 | 300 | quaternary volcanic | Hot Springs, 78.6 °C and Hot Ground 97 °C | plan of industrial cluster development |
| 5 | 323 | Gunung Hamiding | Halmahera Utara/ Halmahera Island | 0 | 0 | 175 | 0 | 0 | 0 | 250-300 (gas) | quaternary volcanic | Hot Ground 97.5-98.1 °C and Hot Springs, 47.5 °C | plan of industrial cluster development |
| 6 | 324 | Telaga Rano | Halmahera Barat/ Halmahera Island | 0 | 0 | 72 | 0 | 0 | 0 | 225-300 (gas) | quaternary volcanic | Hot Springs, 42-98 °C | Will be bidding in 2019 |
| 7 | 241 | Keibesi | Halmahera Barat/ Makian Island | 25 | 0 | 0 | 0 | 0 | 0 | 75 | quaternary volcanic | Hot Springs, 41 °C | small island |
| 8 | 242 | Akesahu | Tidore/ Tidore Island | 0 | 0 | 15 | 0 | 0 | 0 | 183 (SiO ₂) | quaternary volcanic | Hot Springs, 45 °C | small island, tourism |
| 9 | 243 | Indari | Halmahera Selatan/ Bacan Island | 25 | 0 | 0 | 0 | 0 | 0 | n/a | Tertiary volcanics and sediments | Hot Springs, 76 °C | n/a |
| 10 | 244 | Labuha | Halmahera Selatan/ Bacan Island/ Halmahera Island | 25 | 0 | 0 | 0 | 0 | 0 | n/a | metamorphic basement rocks and Tertiary volcano-sediments | Hot Springs, 67 °C | n/a |
| 11 | 245 | Songa - Wayaua | Halmahera Selatan/ Bacan Island | 0 | 0 | 42 | 0 | 0 | 0 | 260 | the reservoir of 400 m depth | Hot Springs, 99.8-100.2 °C, fumarole 100.4 – 103.50C | belongs to PLN |
| 12 | 273 | Kramat | Kepulauan Sula/ Tali Abu Island | 10 | 0 | 0 | 0 | 0 | 0 | 121 (SiO ₂) | sedimentary, volcanic rocks/not yet interpreted | Hot Springs, 39.2 °C | small island, limited access |
| 13 | 274 | Losseng | Kepulauan Sula/ Tali Abu Island | 30 | 0 | 0 | 0 | 0 | 0 | 127 (SiO ₂) | sedimentary, volcanic rocks/not yet interpreted | Hot Springs, 45.2-89.9 °C | small island, limited access |
| 14 | 275 | Auponia | Kepulauan Sula/ Mangole Island | 20 | 0 | 0 | 0 | 0 | 0 | 186 (Na-K) | sedimentary, volcanic rocks/not yet interpreted | Hot Springs, 42 – 56 °C | small island, limited access |
| 15 | 276 | Bruokol | Kepulauan Sula/ Mangole Island | 5 | 0 | 0 | 0 | 0 | 0 | 102 (SiO ₂) | sedimentary, volcanic rocks/not yet interpreted | Hot Springs, 49.4 °C | small island, limited access |

4.2 Geothermal Resources in Maluku Province

Maluku Province (Tabel 2) has eighteen geothermal prospect areas spread across six districts, namely South Buru, Buru, Ambon, Central Maluku, West Seram, and Southwest Maluku. The total potential of speculative geothermal resources in the province is 370 MWe, hypothetically at 84 MWe, possible reserves of 118 MWe, estimated reserves of around 6 MWe and proven reserves of 2 MWe.

They are:

- Buru Island** (115 MWe): Waisekat, Wapsalit-Waeapo, Batubual;
- Seram Island** (164 MWe): Kelapa Dua, Pohon batu, Banda Baru, Tehoru, and Niff (inventory hot springs);
- Ambon Island** (81 MWe): Larike, Taweri, Tulehu;
- Haruku Island** (55 MWe):: Oma-Haruku;
- Saparua Island** (50 MWe): Saparua, Nusa Laut;

- f) **Wetar Island (85MWe):** Warmong, Esulit, Lurang, Karbubu;
 g) **Banda-Neira Islands (30 MWe):** Banda Neira;
 h) **Aru Islands/ Wokam Island (inventory of the hot springs):**

The low-temperature systems are Larike, Taweri, and Saparua; The medium temperature systems are Waisekat, Batubual, Oma-Haruku, Nusa Laut, Kelapa Dua, Pohon Batu, Tehoru, Banda Baru, Niff, Warmong, Esulit, Lurang, Karbubu; and the high-temperature systems are Wapsalit, Tulehu, and Banda Neira (still correlated with volcanic active). The two geothermal prospects in the province, namely Wapsalit (Ministry of Energy and Mineral Resources No. 8084 K / 30 / MEM / 2016) and Tolehu are included in Geothermal Working Areas (WKP).

Table 2: Geothermal Resources in Maluku Province, Indonesia

| No | No. Indonesia Potency Map | Name | Region/ Island | Speculative | Hypothetical | Possible | Probable | Plausible | Confirmed | Reservoir Temperature (°C) | the geothermal area | Geothermal Manifestation | Characteristic Islands |
|----|---------------------------|-------------------|------------------------------------|-------------|--------------|----------|----------|-----------|-----------|----------------------------|---|--|--|
| 1 | 246 | Waisekat | Buru Selatan/ Buru Island | 0 | 6 | 14 | 0 | 0 | 0 | 150 | metamorphic environment, plutonic is the heat source probably | Hot Springs 90.8 °C | several mining of gold |
| 2 | 247 | Wapsalit - Waeapo | Buru/ Buru Island | 45 | 0 | 25 | 0 | 0 | 0 | 247 | metamorphic environment, plutonic is the heat source probably | Hot Ground and Hot Springs 100 °C | several mining of gold |
| 3 | 248 | Batubual | Buru/ Buru Island | 25 | 0 | 0 | 0 | 0 | 0 | 165 | metamorphic environment, plutonic is the heat source probably | Hot Springs, 69.4 °C | several mining of gold |
| 4 | 249 | Larike | Ambon/ Ambon Island | 25 | 0 | 0 | 0 | 0 | 0 | 116 | n/a | Hot Springs, 49 °C | near to the Ambon, capital city |
| 5 | 250 | Taweri | Ambon/ Ambon Island | 25 | 0 | 0 | 0 | 0 | 0 | 116 | n/a | Hot Springs, 49 °C | near to the Ambon, capital city |
| 6 | 251 | Tulehu | Ambon/ Ambon Island | 0 | 0 | 23 | 6 | 2 | 0 | 230 | the reservoir of 600 m depth, high temperature reservoir | Hot Springs, 98 °C | Located at Ambon, the capital city of Maluku Province, belongs to the N |
| 7 | 252 | Oma - Haruku | Maluku Tengah/ Haruku Island | 25 | 30 | 0 | 0 | 0 | 0 | 225 (Na-K) | tertiary volcanic | Hot Springs, 100 °C | small island |
| 8 | 253 | Saparua | Maluku Tengah/ Saparua Island | 25 | 0 | 0 | 0 | 0 | 0 | 116 | n/a | Hot Springs, 49 °C | small island |
| 9 | 254 | Nusa Laut | Maluku Tengah/ Saparua Island | 25 | 0 | 0 | 0 | 0 | 0 | 218 | n/a | Hot Springs, 49 °C | small island |
| 10 | 261 | Tehoru | Middle Maluku/ Seram Island | 0 | 0 | 35 | 0 | 0 | 0 | 210 (Na-K) | heat sweep on the plate collision setting associated with the formation of young intrusive rocks. | Hot Springs, 68-99.6 °C | the biggest island in Maluku Province, Tourism Oma beach, etc; fishery, plantation |
| 11 | 262 | Banda Baru | Middle Maluku/ Seram Island | 0 | 33 | 21 | 0 | 0 | 0 | 190 (Na-K) | heat sweep on the plate collision setting associated with the formation of young intrusive rocks. | Hot Springs, 37.3-67.8 °C | |
| 12 | 263 | Pohon Batu | Middle Maluku/ Seram Island | 35 | 15 | 0 | 0 | 0 | 0 | 155 (Na-K) | heat sweep on the plate collision setting associated with the formation of young intrusive rocks. | Hot Springs, 40-60.9 °C | |
| 13 | 264 | Kelapa Dua | West Seram/ Seram Island | 25 | 0 | 0 | 0 | 0 | 0 | 139 (Na-K) | not yet being interpreted/ sea water mixing | Hot Springs, 58-60.4 °C | |
| 14 | n/a | Niff | East Seram/ Seram Island | n/a | n/a | n/a | n/a | n/a | n/a | 155 (Na-K) | not yet being interpreted/ hot springs inventory | Hot Springs, 44.9-49.1 °C | East part of Seram island, Bula basin, oil field company |
| 15 | 282 | Warmong | Maluku Barat Daya/ Wetar Island | 30 | 0 | 0 | 0 | 0 | 0 | 176 (Na-K) | tertiary volcanic/ not yet being interpreted | Hot Springs, 95.5 °C | wetar, small and isolated islands |
| 16 | 283 | Esulit | Maluku Barat Daya/ Wetar Island | 25 | 0 | 0 | 0 | 0 | 0 | 168 (Na-K) | tertiary volcanic/ probably sea water mixing/ not yet being interpreted | Hot Springs, 76.1 °C | wetar, small and isolated islands |
| 17 | 284 | Lurang | Maluku Barat Daya/ Wetar Island | 20 | 0 | 0 | 0 | 0 | 0 | 182 (Na-K) | tertiary volcanic/ not yet being interpreted | Hot Springs, 73.6 °C and travertine deposit | wetar, small and isolated islands |
| 18 | 285 | Karbubu | Maluku Barat Daya/ Wetar Island | 10 | 0 | 0 | 0 | 0 | 0 | 145 (Na-K) | tertiary volcanic/ not yet being interpreted | Hot Springs, 75.6 °C | wetar, small and isolated islands |
| 19 | 329 | Banda Neira | Maluku Tengah/ Banda Neira Islands | 30 | 0 | 0 | 0 | 0 | 0 | 260 (gas CO ₂) | still active volcano | Hot Springs, 47.4°C – 52.4 °C, at the center 93.4 °C | tourism, small islands |

5. GEOLOGICAL RESOURCES IN MALUKU ISLANDS

Halmahera in the North Maluku Province has abundant natural resources. The island has a hypothetical potential for Nickel minerals of 238 million tons, then potential fisheries, and other industries, and geothermal potential. The government of Indonesia will make Halmahera a pilot of a geothermal energy based cluster. The information of geological resources at Maluku islands are referring to the data from Center for Mineral, Coal, and geothermal Resources, Geological Agency, MEMR, which adapted from the web that contains map of the Indonesia geological resources, i.e. www.georima.esdm.go.id. The data shows that there are a lot of geological resources which have the potential for developing the local economy of Maluku islands and of course these cluster economy are urgently requiring the energy such as for the electricity and the others application. The geothermal energy in Maluku islands can be the answers for the energy necessity.

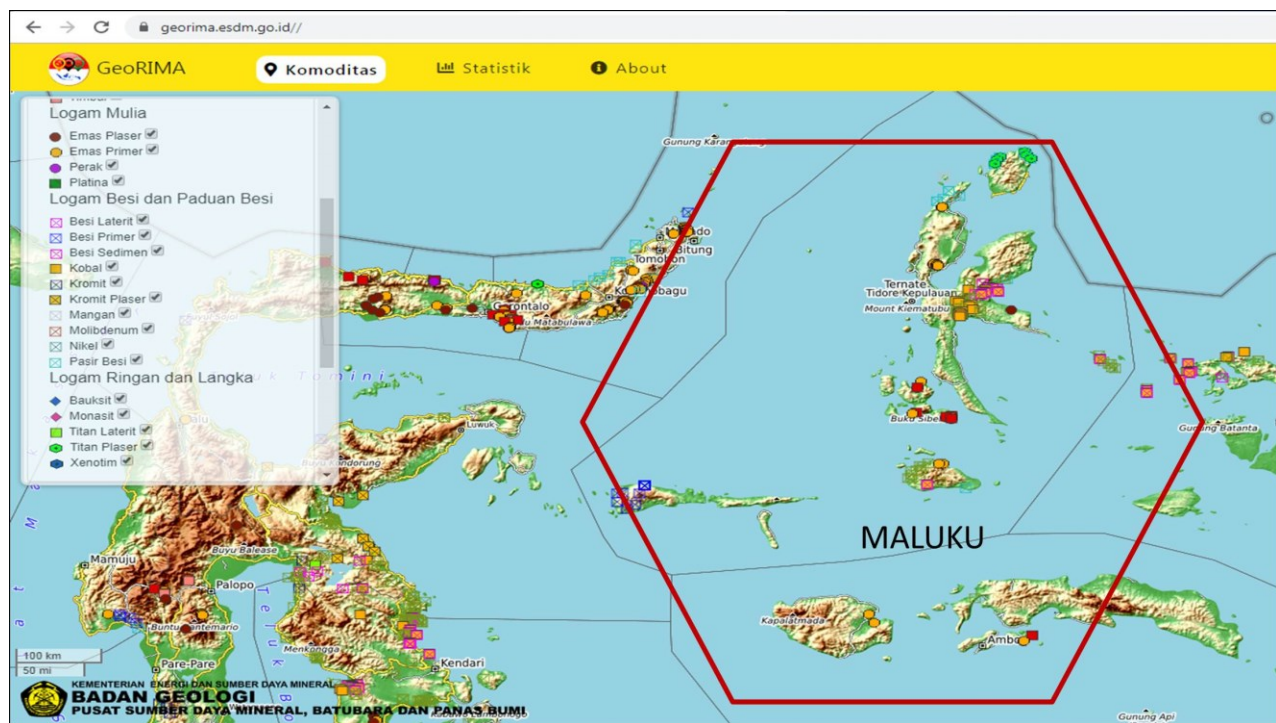


Figure 3: Map of Mineral Resources in the Maluku Islands at the hexagonal red box (www.georima.esdm.go.id)

6. INDONESIA ENERGY POLICY

The updating of Indonesia Geothermal Road Map Development (2019-2030) is still being arranged when this paper is being written, so the geothermal road map refers to geothermal road map development 2015-2025. The Ministry of Energy and Mineral Resources (KESDM) together with related stakeholders, is currently preparing a road map for Indonesia's geothermal development in 2019-2030 to achieve the target of developing EBT and national energy mix. In accordance with the National Energy General Plan (RUEN) and the energy mix target, the target of developing geothermal energy is 7,241.5 MW in 2025 (ebtke.esdm.go.id, 2019).

The geothermal energy is targeted to contribute about 7200 MWe or 7% from PLTP (geothermal power plant) for Indonesia energy mix 23% in 2025. However, 60% of the geothermal prospect area with medium-temperature geothermal resources is in the regions of Bali, Sulawesi, Maluku and Nusa Tenggara with basic costs of providing electricity generation (BPP) above the average National Generation BPP of 7.86 cents USD / kWh. It is hoped that this will become a special attraction and opportunity for the development of geothermal energy in the future considering that the economics expected by potential investors can be accommodated at the current attractive selling price of electricity. The PLTP's currently producing all come from high-temperature geothermal systems (reservoir $T > 225^{\circ}\text{C}$). Medium-temperature geothermal potential in Indonesia is spread over 167 locations out of a total of 349 identified geothermal locations or around 46% with a total resource of 8,677 MWe. At present, there are 65 WKPs that have been issued, of which 16 WKPs have medium temperatures or around 25% with a potential of around 1,370 MWe.

The concept for the development of a geothermal-based industrial cluster in the North Maluku Province is developed following the needs of mining industries for the construction of the smelters and other direct utilization around the location area. Nickel industries situated in North Maluku Province with the largest energy needs for power generation in the construction of smelters in 2014 are PT Aneka Tambang and the Eramet Group (PT Weda Bay Nickel) by 275 MW and PT Nusa Halmahera, which up to this present requires 20 MW. The total amount of electricity required only for the mining industries is 295 MW. (Nazif et al., 2015).

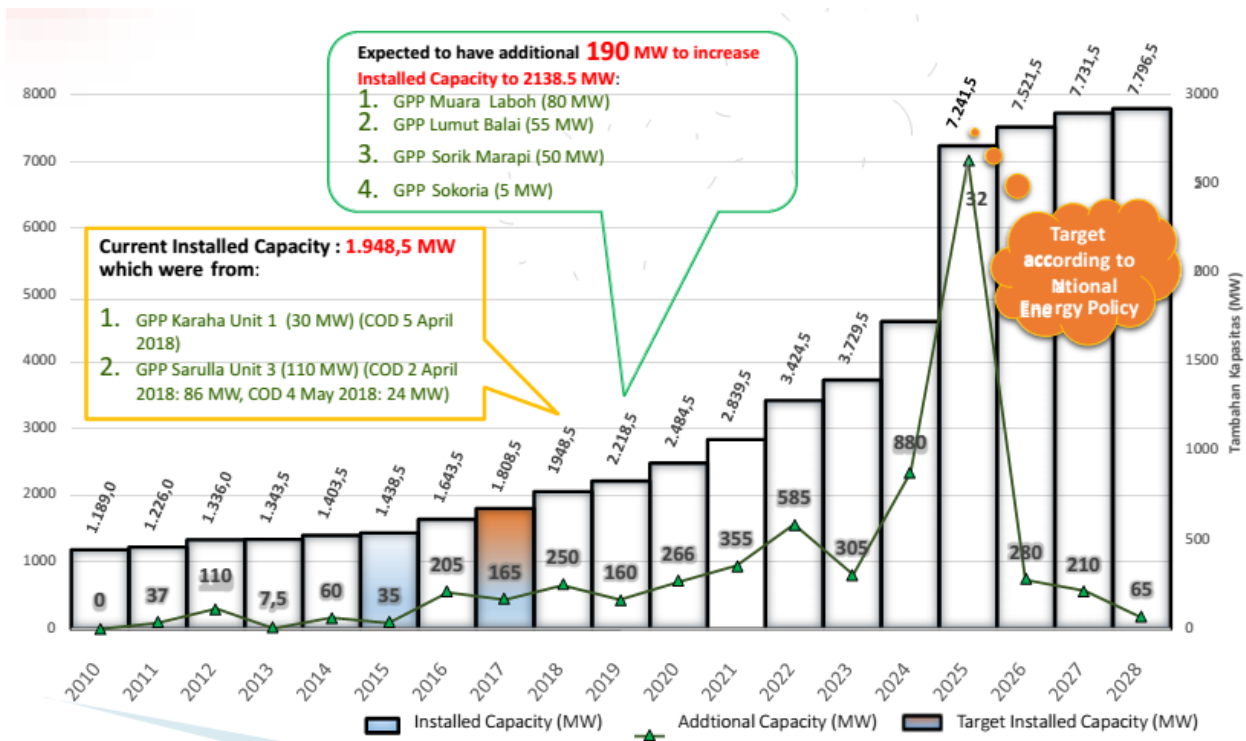


Figure 3: Geothermal Development Road Map in Indonesia (Effendi, 2019)

7. ECONOMIC POTENTIALS OF MALUKU ISLANDS

The Maluku Province has an electrical system with installed capacity reaching 134.65 MW, with a capable power of 60.87 MW and peak load reaching 56.90 MW. The Maluku power plant is dominated by PLTD and is supported by a number of small power plants such as PLTU and Marine Fuel Oil (MFO). The electrification ratio of the Maluku Province reached 72.07% and the ratio of the village electricity was 95.42%. Electricity in the North Maluku Province has an installed capacity of 82.54 MW, capable power of 45.37 MW with a peak load of 35.094 MW. The sold energy was 154,449 MWh. The largest system of electricity generation in North Maluku is the Ternate system where the system has a supply of around 35 MW of power consisting of 625 units of self-generating power capable of 14.8 MW and 20.3 MW rental machines. At present, the electrification ratio of North Maluku Province reaches 74.12% and the ratio of electrified villages is 100%.

As published on the page setkab.go.id in 2018, related to the plan, the government will divide Halmahera into two clusters based on the location, namely, North Halmahera (Economic Cluster 1), and South Halmahera (Economic Cluster 2). The metal mining industry dominates economic Cluster 1 while economic Cluster 2 has more diverse potential. Halmahera in North Maluku Province has abundant natural resources. The island has a hypothetical potential for Nickel minerals of 238 million tons, then potential fisheries, and other industries, and geothermal potential. Those potentials behind the government make Halmahera a pilot of a geothermal energy based cluster.

7.1 North Maluku province in Figures

This part contains an overview of the geography, governance, socio-demographic and economic developments in North Maluku Province Maluku Utara based on Badan Pusat Statistik Provinsi Maluku Utara (2018). The province is located between 3° North Latitude and 3° South Latitude, and from 124° until 129° East Longitude. The capital province is Sofifi, the Maluku Utara Province is bounded by - the Pacific Ocean on the North Side - Halmahera Sea on the East Side - Maluku Sea on the West Side - Seram Sea on the South Side. It is shaped inland by 31,982.50 km². The administration of Maluku Utara province consists of 8 districts and 2 municipalities, based on home affairs regulation No.56/2015 the land area of each regency/municipality is Halmahera Barat (1,704.20 km²), Halmahera Tengah (2,653.76 km²), Sula Islands (3,304.32 km²), Halmahera Selatan (8,148.90 km²), Halmahera Utara (3,896.90 km²), Halmahera Timur (6,571.37 km²), Morotai Island (2,476 km²), Taliabu Island (1,496.93 km²), Ternate (111,39 km²), and Tidore Islands (1,645.73 km²). In 2017, the population of Maluku Utara counted 1,209,342 people distributed into 10 regencies. The Halmahera Selatan Regency has most of the population with 227,280 people. In 2015, the production of rice plants in Maluku Utara province in 2014 increased compared to that of the previous 72,074 be 75,265 tonnes in 2015. Meanwhile, the production of crops in 2015, respectively amounted to 11,728 tonnes of maize, soybeans by 475 tons, cassava amounted to 120,283 tonnes, 30,674 tonnes of sweet potatoes, groundnuts amounted to 2,267 tons and 739 tons of green beans. Tomato and Eggplant are 2 vegetable commodities with the largest production during 2017, namely 1,834 and 1,971 tons. While commodity banana and orange, the production of fruits with 8,268 and 6,882 tons. The results were quite dominant plantation crops in the Maluku Utara, which is a plant of coconut and cocoa, each with a production amounted to 232,277 tonnes and 11,847 tonnes. In 2016, forests and waters in the Maluku Utara recorded an area of 3,373,364.82 ha, which consists of 578,998.20 ha of protected forest, limited production forest 675,731.94 ha, ha 485,322.62 permanent production forest 552,715.52 ha of production forests conversion, 219,012.44 ha of national parks, nature reserves and conversion of nature. Farm animals found in Maluku Utara in

2017 are beef cattle, buffalo, horses, goats and pigs. The livestock population is the largest beef cattle and goats, each of which numbers 89,636 and 128,107. The total production of fisheries for the Maluku Utara region in 2017 amounted to 254,876.7 tons, with value production reaching Rp3,868,342,583.8. Ternate is the largest city in North Maluku province and has the largest population. The province's natural wealth is also abundant from nickel and gold mines on the island of Halmahera. The provincial economic average in the last five years from 2013 to 2017 has averaged 5.74% per year.

By 2017, the number of electricity customers in Maluku Utara was PLN 231,589,694 customers (not include Sofifi Rayon), the amount of electricity production is 265,237,379 Kwh and sold (<https://malut.bps.go.id>) 231,589,694 kWh of energy. Maluku Utara export value in 2017 amounted to US \$ 272,089,765 or increased significantly compared to 2016 were recorded at US \$ 34,864,695. According to the country of destination, in 2017 most exports of Maluku Utara intended to two countries, State of China and Ukraine. As a means of supporting tourism accommodation in the Maluku Utara province, the classy hotel lodging accommodations are needed. In 2017, there were 202 hotels and 107 homestays. Number of Domestic and International Visitors to Maluku Utara during 2017 is 193,829 and 734.

As planned, Halmahera will become one of the centers of economic growth in eastern Indonesia with the main program being the development of the ferronickel processing industry and its downstream industry to obtain a higher value for rice. In addition, Morotai will also be developed in the processing and tourism industrial areas. This condition will be able to encourage the economy in this province to grow faster and electricity needs to rise.

7.2 Maluku Province in Figures

This part contains an overview of the geography, governance, socio-demographic, and economic developments in the North Maluku Province and Maluku Utara based on the Badan Pusat Statistik Maluku Province (2018). The astronomical location of the Maluku Province lies between 2° 30' - 9° south latitude and 124° - 136° east longitude. The boundary of the Maluku Province consists of four borders, which are the Northern of Maluku Province, bordered to Seram sea, the Southern in the Indonesia ocean and Arafura sea, the eastern in Irian Island/ Papua Province and western in Sulawesi Island. Eleven Regencies in the Maluku Province with land area ranging from the largest to the smallest is Maluku South West Regency with an area of 72,426.91 km², Maluku South East Regency 52,99.19 km², Ambon Municipality 35,944.62 km², Maluku Tengah Regency 11,595.57 km², Buru Regency 7,595.58 km², Seram Barat Regency 6,948.40 km², Kepulauan Aru Regency 6,426.77 km², Seram Bagian Timur Regency 5,779.12 km², Buru Selatan Regency 5,060.00 km², Maluku Tenggara Regency 4,178.66 km², and Tual Municipality 254.39 km². The population of Maluku in 2017 amounted to 1,744.654 people. The Municipality of Ambon is the region with the largest population of 444,797 people or 25.49 % of the total population of Maluku in 2017, the second largest population in Central Maluku Regency amounted to 371,479 people or 21.29 %, then Seram Bagian Barat Regency 170,494 people or 9.77 % and the regency with the smallest population of Buru Selatan Regency is 61,330 people or only 3.52 % of the total Maluku population. The land area of 54.185 km² and the population of Maluku reaching 1.74 million, in 2017, the population density per square kilometer were as many as 32 people. The three densely populated areas of Ambon Municipality are the density of 1,180 people per square kilometer, followed by Tual Municipality of 282 people per square kilometer and West Seram District of 42 people per square kilometer while the lowest density area is the Southeast Maluku Regency which is 11 people every square kilometer. The manufacturing data sourced from the Maluku Province Industry and Trade Office shows that the food industry in Maluku Province in 2017 which includes 653 formal companies increased from 2016 which amounted to 643 companies with a total workforce of 3,277 people increasing from 2016 totalling 3,257 people and the amount of investment reached 52,242,354,000 rupiahs up compared to 2016 which amounted to 51,467,336,000 rupiahs. In 2017, based on data sourced from PT. PLN (Persero), in the region of Maluku and North Maluku, the number of kWh of production produced was 427,577,909 with the number of kWh sold was 356,522,978 with a value of kWh sold is 399,936,365,362 rupiah (Ambon area). Whereas the Masohi area the amount of kWh produced is 110,407,260 with the number of kWh sold is 91.269.275 with a kWh value sold of 79,425,651,111 rupiahs. For Tual area, the amount of kWh produced is 121,087,608 with the number of kWh sold was 106,528,789 with the kWh value sold was 121,863,067,951 rupiah. The number of machines in each branch, namely 194 units in the Ambon branch, Masohi Branch has 138 units, and Tual has 134 units, bringing the total number of machines in the Maluku region to 466 units. The largest installed capacity is the Ambon Branch which reached 173,218 kW. Then the Tual Branch reached 66,344. Kw and the Masohi Branch reached 51,403 kW, the total installed capacity for the Maluku region was 290,965 kW.

8. CONCLUSION

Geothermal resources and thermal surface features could give a policy consideration for geothermal development in a country. The Indonesian government will divide Halmahera into two clusters based on the location, namely, North Halmahera (Economic Cluster 1) and South Halmahera (Economic Cluster 2). The metal mining industry dominates economic Cluster 1 while Economic Cluster 2 has more diverse potential. Halmahera in North Maluku Province has abundant natural resources. The Maluku islands, Eastern Indonesia, have geothermal with total resources of 1,156 MWe and total reserves of 505 MWe. Resources of mining, plantation, and fishery industries are very prospective in the Maluku islands. As Maluku is an archipelagic region, the Indonesian government has a strategic policy for increasing economic clusters based on local resources. Geothermal is clean and in situ energy, so the geothermal resources information of Maluku could be an answer for energy solution.

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