



Potential of geothermal energy for electricity generation in Indonesia: A review



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ARTICLE INFO

Article history:

Received 8 October 2014

Received in revised form

26 May 2015

Accepted 17 September 2015

Keywords:

Renewable energy

Geothermal energy

Power plant

Indonesia

ABSTRACT

Geothermal energy is counted as a type of renewable energy, which means the availability is not affected by the lack of source and the increasing price of fossil oil. Environmental friendly is also one of the advantages of geothermal energy. In general, not all countries have the potential of geothermal energy, only countries traversed by the ring of fire have the geothermal energy resource. As one of the countries that traversed by the world's ring of fire, Indonesia hence holds the geothermal potential, which is indicated by the existing 117 active volcanoes spread across the country. Indonesia's geothermal energy potential is estimated about 40% of the world's geothermal energy potential or about 28,617 MW. However, only about 4.5% is being utilized as electrical energy in the country. The government of Indonesia is continuously putting the effort to increase the capacity of geothermal power plant. It is planned to install more geothermal power plant in Indonesia that amounted up to 9500 MW by 2025.

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1. Introduction

One of the most crucial factors in determining the quality of life that works as the booster to the economic and social growth in a country is the availability of electricity. The more availability and

accessibility of electricity can directly influence to a higher quality of life, economic and social growth in the country [1,2]. Therefore, the availability and accessibility of electricity in every county is being continuously improved. According to the International Energy Agency (IEA), it is estimated that electricity demand in the world is increasing at the rate of 1.6% per year in 2030 [3]. In addition, the increasing demand of energy in developing country is increased by 65% in 2020 [4]. Meanwhile in Indonesia, the

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average of electricity demand from 2011 to 2020 is increasing 8.5% per year [5–7].

1.1. The primary energy for power plant utilization in Indonesia

Indonesia is developing more power plants to meet the increasing electricity demand at the moment. However, the developed power plants are still dominated by fossil fuel driven power generation, such as coal, oil, and gas. Up to 2030, it is estimated that fossil fuel driven power plant will be as high as 78.32%, and the rest, which is about 21.68% will be utilizing renewable energy [8].

By continuously using fossil fuel, it will create a lot of problem to the world in general, including decreasing reserves of fossil fuel and greenhouse gas emissions [9–14]. Additionally, the price of fossil fuel will increase rapidly in the international market [15]. Furthermore, the rising usage of fossil fuel will increase the pollution in the atmosphere and exhaust the ozone layer [16]. It is possible since the CO₂ emission from the fossil fuel combustion accumulates in the air, which triggers the global warming and climate change [17–20]. It is estimated that more than 50% of CO₂ released to atmosphere is coming from the energy conversion sector [21]. At this rate, these environmental consequences will be worse, along with the increasing number of population in the world [22], which makes the energy demand drastically increasing. Therefore, this condition will force people to do more exploration and exploitation of fossil energy sources, which the condition that is unfavorable.

1.2. The potential of fossil energy in Indonesia

Fossil energy sources, namely of coal, oil and gas, are the primary energy resources for power generation in Indonesia. The mining area of fossil energy is spread across several regions in Indonesia. Coal mining areas are concentrated in Sumatra and Kalimantan, the biggest one is in South Sumatra and East Kalimantan to be exact.

Coal – From 2011 to 2012, declining resource was from 120 billion to 119 billion tons. While, the coal reserves and production has been increased from 28 billion to 29 billion tons, and 353 million to 386 million tons respectively. Therefore, the ratio of reserves to production (R/P) of coal is dropped from 79 years in 2011 to 75 years in 2012 [23].

Oil – Indonesia's oil reserves in 2011 amounted up to 7.73 billion barrels, consisting of approximately 4.04 billion barrels of proven reserves and 3.69 billion barrels of potential reserves. The total oil reserves in 2012 were declined to 7.41 billion barrels, consisting of 3.74 billion barrels of proven reserves and 3.67 billion barrels of potential reserves. Oil production level in 2011 and 2012 amounted 329 million barrels and 315 million barrels respectively. Reserve production ratio (R/P) of oil is around 12 years in 2011 or 2012. Sources of Indonesia's oil reserves are located mainly in Sumatra, which holds more than 60%, while oil reserves in Jawa is about 21% and the rest are in Kalimantan, Papua, Sulawesi, and Maluku.

Gas – In 2011, Indonesia has natural gas reserves of approximately 153 TSCF, consisting of proven reserves of 105 TSCF and potential reserves for more than 48 TSCF. The gas reserves in 2012 was decreased to 151 TSCF, which consisted of 103 TSCF and 47 TSCF proven reserves and potential reserves respectively. The rate of gas production is either follow-up (associated) gas or not follow-up (non-associated) gas, which reached 3.26 TSCF in 2011 and 3.17 TSCF in 2012. The reserve ratio of gas production was sequentially increased in 2011 and 2012 from 32 years to 33 years. The largest reserves of gas in Indonesia is located in Sumatra, including Natuna, which holds almost 56%, while Jawa holds about

Table 1
Fossil energy potential (oil and gas) [24,25].

Energy type	Year	Potential reserve	Proven reserve	Total
Oil (billion barrel)	2011	3.69	4.04	7.73
	2012	3.67	3.74	7.41
Gas (TSCF) ^a	2011	48.18	104.71	152.89
	2012	47.35	103.35	150.70

^a TSCF: Trillion square cubic feet.

Table 2
Fossil energy potential (coal) [24,25].

Energy type	Year	Resource	Reserve	Total
Coal (billion ton)	2011	120.33	28.01	148.34
	2012	119.42	28.97	148.39

8%. Gas reserves outside Jawa and Sumatra spread in Papua, Kalimantan, Maluku and Sulawesi, which hold 16%, 11%, 10%, and 2% respectively.

Based on the production reserve ratio, the potential utilization of coal is about 75 years, while the gas potential is up to nearly 33 years. Although both potentials are quite high, the reserves are depleting yearly with the drastic rise of the energy demand. Oil is the lowest potential of fossil energy resource, which only 12 years remaining for utilization, if there is no new oil reserves are found.

Potential fossil energy resources in Indonesia from 2011 to 2012 are shown in Tables 1 and 2 [24,25].

Indonesia's fossil energy sources are going to run out at this rate, therefore new solution is essential to encounter this problem. One of the best solution is to use geothermal energy [26] because geothermal energy is a form of renewable energy [27], which is environmentally friendly [28], can reduce greenhouse gas emissions [28] and potentially to be future energy of the world [29]. Geothermal energy is derived from a geological activity that is widely available at local fire ring or a ring of fire where Indonesia is included in this area [20].

1.3. The potential of renewable energy in Indonesia

Indonesia has several types of renewable energy potential such as hydro energy, geothermal energy, wind energy, solar energy, wave energy and biomass potential. Besides, as a tropical country Indonesia has a big potential of renewable energy such as biofuel, biomass and bioenergy from tropical biodiversity that is spread throughout the country [30–36]. Biomass has a potential up to 49,800 MW while geothermal energy has a potential about 28,617 MW. Solar energy has intensity about 4.8 kW h/m²/day, while wind energy has a potential energy about 9290 MW.

Based on the study by Hydro Power Potential Study (HPPS) and Hydro Power Inventory Study, big scale hydro energy potential in Indonesia is about 75,000 MW. Meanwhile, Nippon Koei estimated the Indonesia's hydro energy potential in 2011, which was about 26,000 MW, consisting the existing project (4000 MW), the planned and on-going construction project (6000 MW) and the new potential (16,000 MW). Also, the mini/micro hydro potential was estimated about 500 MW. The renewable energy potential in Indonesia are presented in Table 3 [23].

Indonesia has also another potential of renewable energy from the sea and ocean. The sea energy for power generation can be captured through, such as, tidal energy, Ocean Thermal Energy Conversion (OTEC), and also utilization of the difference in salt concentration or namely osmosis. Sea wave energy forms kinetic energy that is produced by the movement of the sea wave towards the land and vice versa. Besides, it also forms potential energy

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