A hard way towards sustainable management of Banda Sea ecosystems and their energy resources

S Susilohadi[1]

[1]Research and Development Centre of Marine Geology
Jalan Dr. Junjunan 236 Bandung-40174, Indonesia

s.susilohadi@mgi.esdm.go.id

Abstract. The Banda Sea region which includes the Moluccas and Nusa Tenggara consists of 3,478 small islands separated from each other by deep seas. This region can be regarded as the most complex energy supply chain in Indonesia due to geographic condition and lacking of energy infrastructure. The newly issued Indonesian general plan of energy aims to establish a strategy for planning the region's energy mix until 2050. By then, national primary energy should not be dominantly supported by oil and gas, and renewable energy should contribute 31%. In addition, government has committed to attain near 100% electricity ratio by 2020. Recent hydrocarbon discoveries and ocean energy mapping indicate that the Banda Sea region is an attractive area where the country's primary energy needs may partly be fulfilled. However, the region's sustainability in energy production still has to be established with greater efforts. Hydrocarbon search has been discouraged by the geologically risky nature of the region. The implementation of renewable energy, particularly ocean energy, is hampered by technology immaturity and constraining operational rules and policies.

Keywords: Banda Sea, energy consumption, hydrocarbon resources, ocean energy, energy policy

1. Introduction

The Banda Sea region which includes the Moluccas and Nusa Tenggara is unique, consisting of 3,478 small islands separated from each other by deep seas (Table 1). This region that has population of more than 11,755,632 people [1], may be regarded as having the most complex energy supply chains in Indonesia due to such a geographic condition, in addition to the lacking of energy infrastructure including network, storage facilities and tanker fleets to ensure their continued reliability and efficiency.

This year, Indonesian Government has issued the new general plan of national energy (RUEN) [2] which is intended as a guide for ministries, governmental institutions and local governments to plan and establish their strategy and planning on energy and to the community and private sectors on how they can participate in the energy developments. For the Banda Sea region where electrification ratio (population's access to electricity) is below 85%, this RUEN is a kind of government commitment since 100% ratio has to be reached within the next 3 years. In line with the national policy on energy [3], the uses of new and renewable energy sourced locally are made necessary by the archipelagic nature of Indonesia.

The Indonesian hydrocarbon production is currently in a declining state since 1995, as no new reserve has been found in at least last 10 years [4]. Meanwhile, eastern Indonesia is considered to be underexplored for hydrocarbons [5]. On the other mode of energy, the National Energy Council [6] indicates that Indonesian new and renewable ocean energy opportunities are abundant. Most of them are located in the Banda Sea region [7, 8]. These circumstances have led to an expectation that future energy reserves may rest in the eastern Indonesia.

This paper reviews the current state of energy resources in the Banda Sea region and discusses the energy related policies which could impact regional development. Ocean energy is highlighted since potentially would be part of the sustainable ecosystem of the region.

2. Statistics

Statistics provided by the upstream regulator agency of oil and gas [1] indicate that fuel consumption in the provinces around Banda Sea are very low, less than 1% of the national consumption (table 1) which reached more than 71.5 billion liters in 2015. Electrical consumption of the Banda Sea region also shows similar figures, with more than 90% used by residential consumers (table 2) [9]. Currently, electricity is generated by diesel or coal-fired steam power sourced outside the region.

This low consumption of energy may be due to the fact that the regional economic support to the national GDP is low, about 19%, which is mainly come from by mining industries [10]. Geographic condition and lack of infrastructure may have lead to the low non-mining industrial development in eastern Indonesia, as indicated by Competitiveness Industrial Performance (CIP) below 0.1% [1]. However, economic assessment by Bank Indonesia indicates that some provinces in eastern Indonesia are ready to develop such industries, such as cacao, palm oil and fishing industries, although slowing down of economic growth is also recorded [10].

Table 1. Demography and fuel consumption statistics in the Banda Sea region.

No.	Provinces	Islands	Population (2010)	Economic growth 2016	Fuel consumption 2015 (Liter)	% of national consumption
1.	North Moluccas	1,474	1,038,087	5.8%	270,819,144	0.38%
2.	Moluccas	1,422	1,533,506	5.8%	415,307,408	0.58%
3.	West Nusa Tenggara	864	4,500,212	5.8%	76,6201,764	1.07%
4.	East Nusa Tenggara	1,192	4,683,827	5.2%	485,87,0450	0.68%

Table 2. Electricity consumption statistics (as of 2015) in the Banda Sea region.

No.	Provinces	Electrification ratio	Installed Capacity (MW)	Diesel (MW)	Coal (MW)	Residential customer	Industrial & Commercial
1.	North Moluccas	94.46%	58.00	51.00	7.00	91.78	4.81%
2.	Moluccas	84.80%	159.01	158.12		91.39%	5.77%
3.	West Nusa Tenggara	72.77%	166.52	110.29	50.00	94.31%	3.23%
4.	East Nusa Tenggara	58.64%	216.79	153.82	47.00	92.29%	5.04%

3. Energy resources in the Banda Sea region

3.1. Hydrocarbons

The geology of eastern Indonesia results from a complex interaction between Indo-Australian, Western Pacific, Philippine Sea and Eurasian plates. The relative NNE movement of the Indo-Australian plate and westward movement of the Philippine Sea and Western Pacific plates since Late Oligocene have formed the horseshoe-shaped of Banda arc which extends from Flores to Buru, including Timor and Seram [11]. In contrast to western Indonesia, which is largely underlain by continental crust, eastern Indonesia is dominated by arc and ophiolitic crust, and several young ocean basins.

Petroleum systems are well developed in the Banda arc area. There are more than 25 sedimentary basins and 50 active petroleum company working areas in eastern Indonesia (figure 1). Seram, Bula and Salawati are well known oil producing areas that have been operating since the Dutch colonialization. The newer discoveries are in Bintuni basin (mid 1990s) and Masela Block (early 2000s), which reserve 14 and 18 TCF of gas, respectively [5]. Surprisingly, compared to the western Indonesian hydrocarbon basins which are mostly of Tertiary age, in both Bintuni and Masela gas was found within pre-Tertiary rocks and may be regarded as a new insight in hydrocarbon searching in eastern Indonesia [12]. Similarly, gas was also found along the margin of Sahul Shelf in the Australian territory (southeast off Timor Leste), such as in Bayu-Undan and Elang-Kakatua Fields.

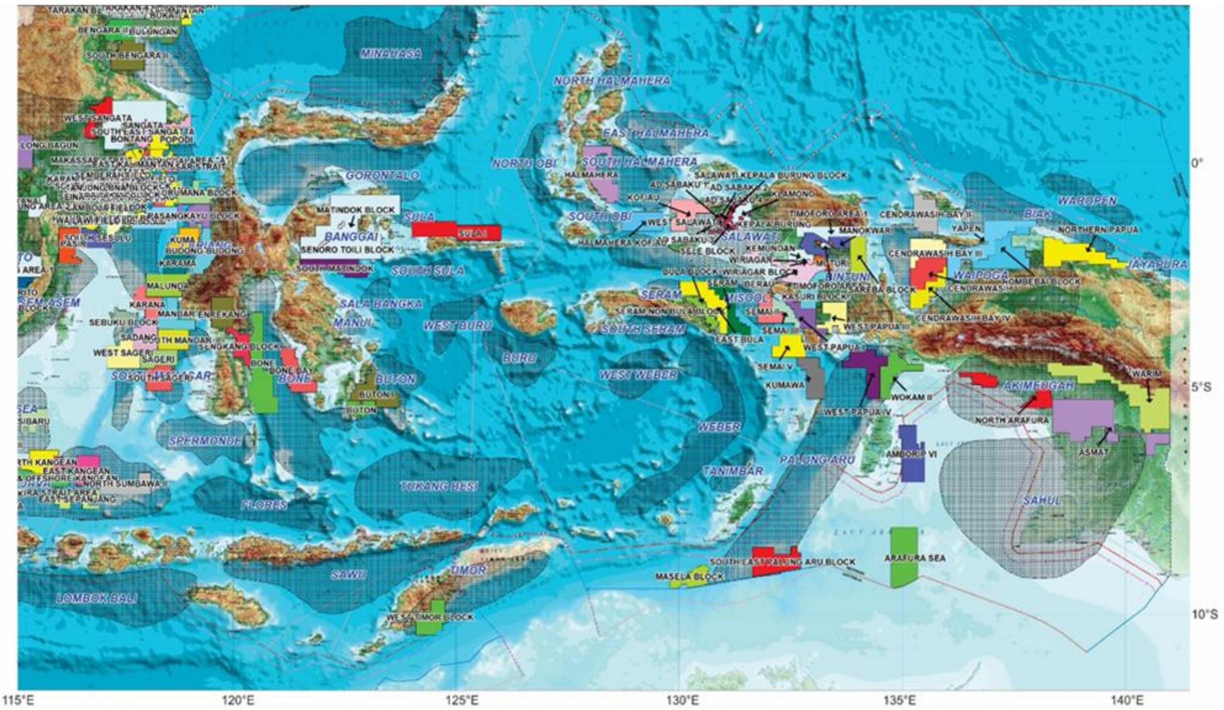

Figure 1. Sedimentary basins (shaded grey) and hydrocarbon working areas (colored boxes) in eastern Indonesia, drawn based on the data from the Data and Information Center, Indonesian Ministry of Energy and Mineral Resources (Pusdatin ESDM).

Despite the success, there are some unsuccessful exploration wells in the eastern Indonesia. Up to 2013, twelve contractors drilled 25 exploration well valued US$ 1.9 billion (table 3). All of them were dry, found uneconomic prospects or suffered technical problems [13]. These have indicated that eastern Indonesia is indeed geologically complex and cannot be studied partially based on limited data. High quality and denser spacing of seismic data are absolutely required in order to minimize risk and cost of the following exploration stages. Satyana *et al* [14] underlined that the earlier oil production successes in late 1970s and mid 1990s were due to massive exploration of almost ten years earlier.

3.2. Ocean energy

Ocean energy refers to renewable energy obtained from the sea, either as mechanical energy from the tide and waves or as thermal energy from the sun. Tidal energy arises from tidal movements, utilising the vertical changes in sea levels or the horizontal movement of the seas and currents to generate electricity. Wave energy uses the energy of ocean waves or swells to generate electricity. Ocean thermal energy conversion (OTEC) uses the difference in temperature between the warmer surface or shallow waters and the cooler deeper waters to generate electricity. Practical temperature difference is in the order of 20 °C [15], which is usually found on areas with water depth of more than 1000 m.

Table 3. Unsuccessful hydrocarbon exploration drilling in eastern Indonesia by various operators [13].

No	Operator (KKKS)	Working area	Well name	Spending (million US$)	Well status
1	Exxon Mobil	Surumana	Rangkong-1	123	Dry
			Kris-1	45	Biogenic Gas Uneconomic
2	Exxon Mobil	Mandar	Sultan-1	110	Dry
			Kriss Well-1 ST	24	Dry
			Gatotkaca-1 ST	98	Dry
3	Statoil	Karama	Anoman-1	43	Dry
			Antasena-1	33	Dry
		Kuma	Kaluku-1	150	Waxy Oil (MDT)
4	Conoco Phillips	Amborip VI	Aru-1	58	Dry
		Arafura Sea	Mutiara Putih-1	103	Dry
5	Talisman	Sageri	Lempuk-IX	84	Dry
			Bravo Well	103	Dry
6	Marathon	Pasang Kayu	Romeo Well	23	Dry
			Romeo B-1	25	Technical Problem
			Romeo C-1	58	Technical Problem
7	Tately	Budong-Budong	KD-1	34	Technical Problem
			LG-1	17	Uneconomic Well
8	Japex	Buton	Benteng-1	31	Dry
9	CNOOC	SE Palung Aru	Sindoro-1	50	Dry
10	Hess	Semai IV	Andalan-1	164	Dry
			Andalan-2	59	Dry
11	Niko Resources	Kofiau	Ajek-1	37	Sub Commercial Gas Discovery
		W. Papua IV	Cikar-1	87	Temporarily Suspended
		N. Makassar Strait	Pananda-1	90	Drilling
12	Murphy Oil	Semai II	Lengkuas-1	215	Dry
			Total	1900	

The Indonesian Ministry of Energy and Mineral Resources (ESDM) has mapped and carried out assessment of Indonesian marine energy potentials. The results are indicated in the general planning of national energy [2]. More than 17 GW of energy may potentially be harvested from Indonesian ocean. Mapping by the Research and Development Centre of Marine Geology since 2006 found even larger results [16]. Tidal current measured on narrow straits between islands in Nusa Tenggara and northern West Papua may reserve 17.9 GW of energy, while waves modelled along coastline southwest of Java and Sumatra, and south of Papua result in 1.9 GW of energy (figure 2) [17].

Ocean thermal means temperature different at about 20°C between surficial and lower ocean layers and usually occurs in an ocean which has the water depth of more than 1000 m. Many islands in Indonesia are directly adjacent to the water depth of 1000 m or more, particularly in eastern Indonesia. By taking into account the length of the coastline of such islands, the Agency estimates that more than 41 GW of energy can be harvested from this temperature different (figure 3) [18].

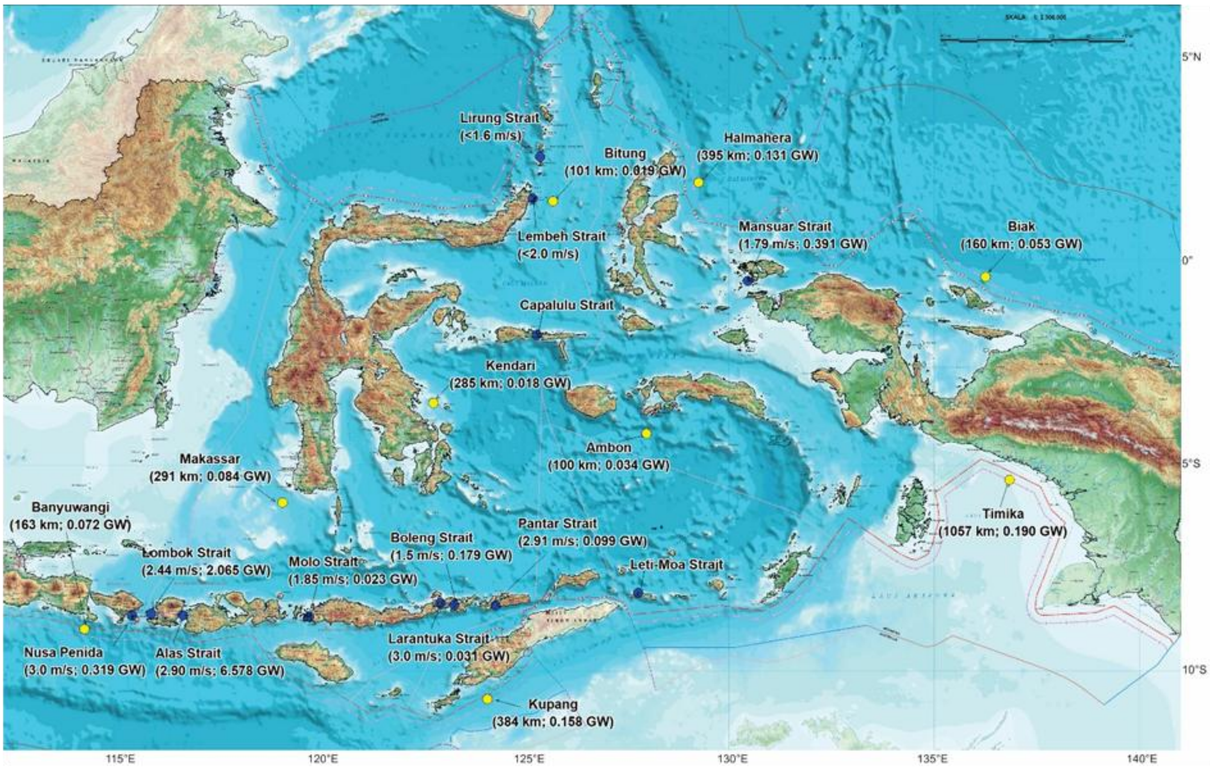

Figure 2. Map showing locations of field tidal current mapping (blue dots) and wave modelling (yellow dots) in Nusa Tenggara, Papua and Sulawesi, and their corresponding potential energy [16, 17].

4. Discussion

4.1. Hydrocarbon resources

Indonesian oil reserves are slowly declining by 1.2% and no longer sustainable as about 44% of national fuel demand is imported. Most of the known reserves are located in traditional places, such as in Sumatra, Kalimantan, and Java. Papua, Maluku, and Sulawesi may hold only 2.33% of national reserve, even though, gas is proven to be prolific. In line with economic and population growth, national energy demand is steadily growing, so the search for new hydrocarbon prospect is inevitable. Eastern Indonesia, despite being a geologically complex region, has been seen as a new frontier.

Most of eastern Indonesia has been considered to be underexplored due to lack of geological and geophysical data, its deep water nature and poor infrastructure. New hydrocarbon findings, such as in the Masela Block, suggest that the way they were generated and accumulated are different than in western Indonesia. Pre-Tertiary rocks should become exploration targets, although they have usually been involved in a complex geological history. Comprehensive geological studies are needed and to understand such a geologically complex region, good quality and denser geological and geophysical data are absolutely required. Multi-client seismic data acquired by private companies are already available; however, only few studies have been carried out based on these data as they can only be accessed commercially. Meanwhile, there is no government institution capable of providing such good quality data. It is suggested that the Indonesian government should provide stronger support to geological research institutes and universities to study eastern Indonesian geology comprehensively by providing better data acquisition facilities and access on any available data.

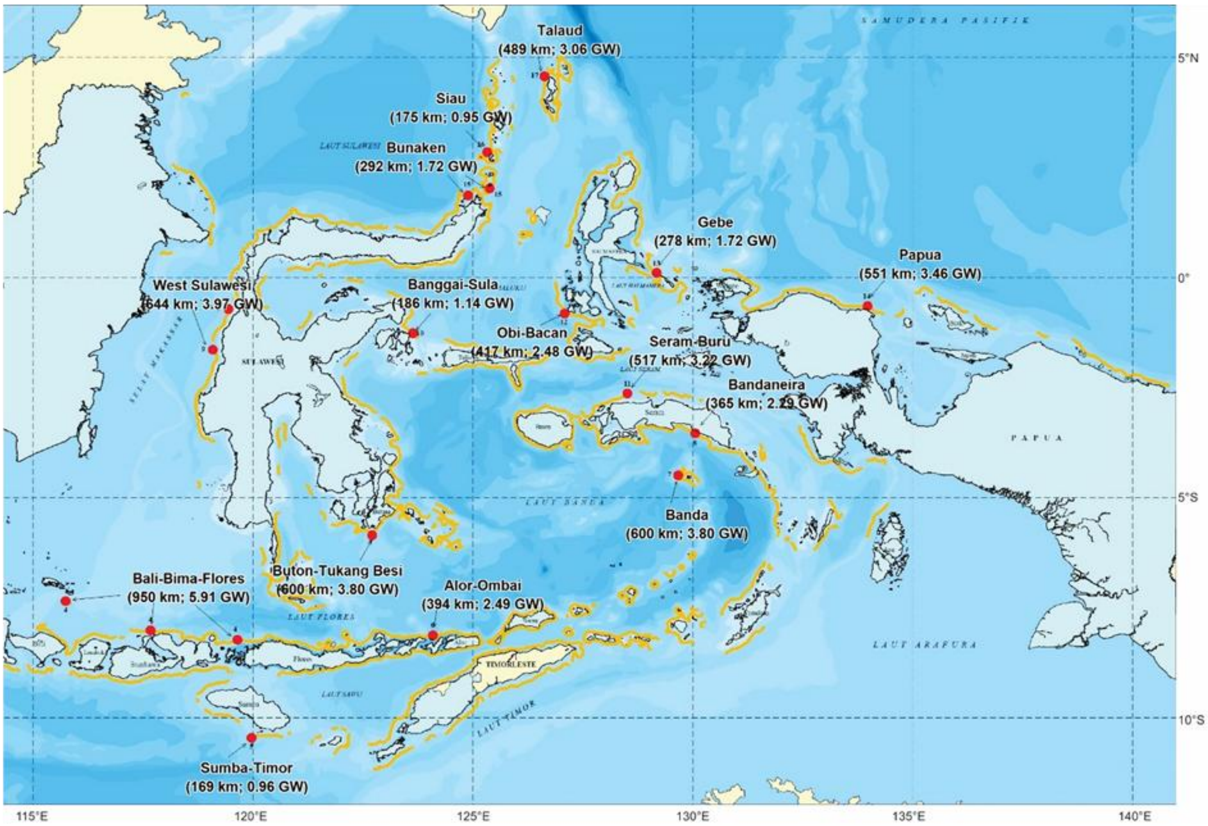

Figure 3. Map of ocean thermal energy potential in eastern Indonesia. Red dots represent location where measurement of coastline length adjacent to water depth >1000 m (yellow lines) was taken. Text accompanied dots indicates length of coastline and calculated practical energy potential [18].

4.2. *Marine energy resources*

In the new general plan of national energy [2] Indonesia has targeted that renewable energy has to share at least 23% (or 45.2 GW) of total primary energy supply by 2025, and at least 31% by 2050. Renewable energy such as ocean energy should contribute 3.1 GW along with bioenergy. Recently, the ESDM issued a decree [19] where operational steps of electricity procurement will be made as close as possible to those energy mix.

Official data has indicated that opportunities for ocean energy production are potentially high in the Banda Sea region. In 2015, the ESDM has indicated that Indonesia would encourage the use of energy potential from the sea as part of the government's marine development policy [20]. The ministry currently has two pilot projects underway - one in Nusa Penida and another in Nusa Tenggara. In line with that, the state oil company (Pertamina) has committed to develop 3 MW of ocean energy by 2019. Potential energy assessment of the Alas Strait, Lombok Strait and Badung Strait are currently on going, as the state electricity company (PLN) intends to develop ocean energy from a capacity of 12 to 140 MW [21].

Despite these strong intentions, the readiness of marine energy to support the national energy mix will unlikely to go as fast as expected. At least three major issues which may discourage the development are identified:

- Conversion technology may be site-specific due to hydro-oceanographic nature of eastern Indonesian waters and hence the technology that should be applied accordingly. Speed of tidal currents in straits of Indonesia is rarely reach 3.0 m s^{-1}, and strongly influenced by semi-diurnal nature of tides [16]. In addition, the nature of Indonesian narrow straits is very different to one another. Straits in Bali and Nusa Tenggara, for example, are characterized by steep slope and a rough sea floor, since their formations were influenced by volcanic deposits and geological structures. Most of the current technology to convert marine energy into electricity are developed and tested in western European and northern America where ocean current is much stronger influenced by diurnal tides. Such technology if to be applied in Indonesian water may need some technological adjustments.

- Under ministerial decree [19], PLN will consider to buy electricity converted from ocean energy if the technology has been proven commercially reliable for 5 years. However, so far there is no single prototype has been running or even proved to be reliable in Indonesian water.
- The new ministerial regulation [22] sets the policy on tariff capping of renewable energy. It regulates the framework on how PLN procures electricity from renewable energy-based power plants. All renewable energy tariffs will be capped at 85% of the local generation cost, if this price is higher than the national average generation cost. If the local generation cost is the same or lower than the national average, then the limit will be 100% of the local generation cost. The regulation asks that proven conversion technology has to compete with other modes of conversion which may have already been mature technologically, such as hydro and hydrocarbon-burning electricity generators. Currently, ocean energy conversion technology is far from being mature and, Indonesian research institutes required to develop such technology have received severe research budget cuts.

5. Conclusion

The Indonesian energy demand steadily increas proportional to economic growth. The steady decline of hydrocarbon production has led the government to issue a new general plan of national energy which involves reducing the country’s dependence on hydrocarbons. New and renewable energy sources are now becoming the national target for exploration and exploitation. Nevertheless, Indonesian primary energy will still lean on oil and gas as much as 44% by 2050.

The Banda Sea region comprises provinces that are expected to be the next massive exploration target for hydrocarbons. The region is also rich in renewable energy, particularly ocean energy. Unfortunately, the region’s sustainability in energy may still have to be established with greater efforts. Hydrocarbon exploration has been discouraged by the geologically risky nature and lack of supporting infrastructures of the region. On the other hand, practical implementation of renewable energy, such as ocean energy, is hampered by technology immaturity and constraining operational rules and policies.

Acknowledgements

The author wish to thank Dr. Augy Sahilatua and Dr. Yosmina Tapilatu for the invitation and support to be involved in the International Symposium on Banda Sea Ecosystem 2017 on which this manuscript has been intended to. The author also would like to appreciate the reviewers for the corrections, comments and suggestions on the manuscript.

References

[1] Badan Pusat Statistik 2015 *Statistik Indonesia: Statistical yearbook of Indonesia 2015* (Jakarta: Badan Pusat Statistik) pp 710
[2] Kementerian Hukum dan Hak Asasi Manusia 2017 *Peraturan Presiden Republik Indonesia nomor 22 tahun 2017 tentang Rencana Umum Energi Nasional* (Jakarta: Sekretariat Kabinet RI)
[3] Kementerian Hukum dan Hak Asasi Manusia 2014 *Peraturan Pemerintah Republik Indonesia nomor 79 tahun 2014 tentang Kebijakan Energi Nasional* (Jakarta: Kementerian Sekretariat Negara RI)
[4] Direktorat Jenderal Minyak dan Gas Bumi 2015 *Rencana strategis 2015-2019* (Jakarta: Kementerian Energi dan Sumber Daya Mineral, Direktorat Jenderal Minyak dan Gas Bumi)

pp 74
[5] Satyana A H 2013 Oil and gas in eastern Indonesia: production, proven plays, prospectivity, and risks *AAPG-UGM Student Chapter, Guest Lecture, Yogyakarta, 10 March 2013*
[6] Dewan Energi Nasional 2016 *Indonesia energy outlook 2016* (Jakarta: Sekretariat Jenderal Dewan Energi Nasional) pp 83
[7] Badan Pengkajian Dan Penerapan Teknologi 2014 *Outlook energi Indonesia 2014 pengembangan energi untuk mendukung program substitusi BBM* ed A Sugiyono et al (Jakarta: Pusat Teknologi Pengembangan Sumberdaya Energi Center For Energy Resources Development Technology, Agency For The Assessment And Application Of Technology) pp 129
[8] Badan Pengkajian Dan Penerapan Teknologi 2016 *Outlook energi Indonesia 2014 pengembangan energi untuk mendukung industri hijau* ed A Sugiyono et al (Jakarta: Pusat Teknologi Sumber Daya Energi Dan Industri Kimia, Badan Pengkajian Dan Penerapan Teknologi) pp 119
[9] Direktorat Jenderal Ketenagalistrikan 2015 *Statistik ketenagalistrikan 2015* (Jakarta: Direktorat Jenderal Ketenagalistrikan, Kementarian Energi dan Sumber Daya Mineral) pp. 41
[10] Bank Indonesia 2016 Kajian ekonomi dan keuangan regional *Laporan Nusantara* 11 4 pp 91
[11] Hall R 2009 *Encyclopedia of islands: Indonesia, geology* ed Gillespie R. and Clague D (Berkeley: University of California Press) p. 454-460
[12] Robertson J D 2002 Tangguh-the first major pre-Tertiary discovery in Indonesia *AAPG Annual Meeting, Houston, March 10-13, 2002*
[13] Sunardi L 2013 Pemerintah putus kontrak Marathon Oil di Blok Pasang Kayu *Bisnis Indonesia, 30 Juni 2013*
[14] Satyana A H, Armandita C and Paju J A 2012 Acceleration in regional exploration of Indonesia: Requirement for survival *Proceedings, Indonesian Petroleum Association, Thirty-Sixth Annual Convention and Exhibition, May 2012*
[15] Nihous G C 2005 An order-of-magnitude estimate of ocean thermal energy conversion resources *Transactions of the ASME, vol. 127, December 2005* p. 328-333
[16] Pusat Penelitian dan Pengembangan Geologi Kelautan 2014 *Peta potensi energi arus laut Indonesia* (Bandung: Pusat Penelitian dan Pengembangan Geologi Kelautan, Badan Penelitian dan Pengembangan Energi dan Sumber Daya Mineral)
[17] Pusat Penelitian dan Pengembangan Geologi Kelautan 2014 *Peta potensi energi gelombang laut Indonesia* (Bandung: Pusat Penelitian dan Pengembangan Geologi Kelautan, Badan Penelitian dan Pengembangan Energi dan Sumber Daya Mineral)
[18] Pusat Penelitian dan Pengembangan Geologi Kelautan 2014 *Peta potensi energi panas laut Indonesia* (Bandung: Pusat Penelitian dan Pengembangan Geologi Kelautan, Badan Penelitian dan Pengembangan Energi dan Sumber Daya Mineral)
[19] Kementerian Energi dan Sumber Daya Mineral 2017 *Keputusan Menteri Energi dan Sumber Daya Mineral Republik Indonesia no. 1415 K/20/MEM/2017 tentang Pengesahan rencana usaha penyediaan tenaga listrik PT Perusahaan Listrik Negara (persero) tahun 2017 s.d. 2026* (Jakarta: Kementerian Energi dan Sumber Daya Mineral)
[20] Kementerian Energi dan Sumber Daya Mineral 2015 *Renstra KESDM 2015-2019* (Jakarta: Kementerian Energi dan Sumber Daya Mineral) pp. 275
[21] PwC 2016 Power in Indonesia, investment and taxation guide: November 2016 - 4th edition (Jakarta: PwC Indonesia) pp. 180
[22] Kementerian Energi dan Sumber Daya Mineral 2017 *Peraturan Menteri Energi dan Sumber Daya Mineral Republik Indonesia no. 12/2017 tentang pemanfaatan sumber energi terbarukan untuk penyediaan tenaga listrik* (Jakarta: Kementerian Energi dan Sumber Daya Mineral)