Contents list available at IJRED website

Int. Journal of Renewable Energy Development (IJRED)

Journal homepage: http://ejournal.undip.ac.id/index.php/ijred

Research Article

Investigating a Hampered NRE Utilization in Kaltim's Energy System: Is there an Energy Policy with a Syndrome of the Energy-abundant Area?

Novena Damar Asri[a*] and Purnomo Yusgiantoro[a,b]

[a] *Department of Energy Security, Faculty of Defense Management, Indonesia Defense University, Indonesia Peace and Security Center (IPSC), Sentul, 16819, Indonesia*

[b] *Department of Petroleum Engineering, Faculty of Mining and Petroleum Engineering, Institut Teknologi Bandung, Bandung, 40132, Indonesia*

ABSTRACT. Kaltim presumably experiences an energy paradox, where the energy system is unreliable and unsustainable, despite energy-rich. This study presumes that the paradox is caused by the 'ill-advised energy policy' shown by 'energy-area incompatibility' that is exacerbated by the 'energy-rich syndrome' (a mindset of feeling secure due to energy-abundance leading to a wasteful behavior). This study investigates the indication of the syndrome in Kaltim energy policy by first investigating 'the incompatibility' and its impacts by examining Kaltim's geographical characteristics, energy potential, population-distribution, electricity system, and infrastructure. Also, the impacts of retaining the syndrome through cost analyses. This study finds the incompatibility between energy-sources utilization and geographical characteristics, by conducting a descriptive method with data collection and analyses. Kaltim is forest-dominated with scattered-population, suitable with an off-grid system. However, the electricity development is mostly on-grid, fossil-based designed, explaining the difficulties of electrifying the entire Kaltim, although electricity is surplus. While off-grid should be applied to NRE, the massive use of diesel-gen-sets shows wasteful behavior. By conducting a linear-regression method, this study finds that Kaltim's electricity consumption (indicating the infrastructure sufficiency) is lower than it should be, given its incredible economic performance. The incompatibility causes infrastructure insufficiency. The cost analysis finds that the massively-used fuel oil is the most expensive. The subsidy would be around 0.003%-0.275% of Kaltim GDRP or 17 billion-1.55 trillion IDR. As the new Capital location, NRE is a must for Kaltim. To conclude, NRE utilization is very low, although its potential is huge, and Kaltim's forested characteristics suit it. NRE only covers 3% of Kaltim's electricity, while the potential (hydro alone) is more than 6,900MW. The incompatibility causes an unreliable electricity system, although electricity is surplus. Following Kaltim's geographical characteristics, NRE should be optimized. This study intends to aware the policy-makers of the syndrome, thereby develop a 'proper energy policy'.

Keywords: Electricity-cost analysis, Energy-area compatibility, Energy paradox, Energy-rich syndrome, Kalimantan electricity

Article History: Received: 5th March 2021; Revised: 7th April 2021; Accepted: 11th April 2021; Available online: 20th April 2021
How to Cite This Article: Asri, N.D., and Yusgiantoro, P. (2021) Investigating a Hampered NRE Utilization in Kaltim's Energy System: Is there an Energy Policy with a Syndrome of the Energy-abundant Area?. *International Journal of Renewable Energy Development*, 10(4), 653-666.
https://doi.org/10.14710/ijred.2021.37135

1. Introduction

Renowned as the national energy barn, Kaltim (Kalimantan Timur or East Kalimantan Province) has a somewhat problematic electricity situation. Previously, Kaltim electricity is deficient, where daily blackout and rotating electricity supply are what people must experience (Aditya, 2016; Aliev, 2017). The situation is exacerbated by the fact that oil is abundant and easy to get. People and institutions independently use generator sets (gen-sets) to overcome electricity shortage. They choose fuel oil as the first option to solve the electricity problem. Oil-fueled gen-sets (diesel-gen-sets) are massively used in Kaltim (Necolsen, 2018; Sarita, 2018). Gensets are suitable for rural electrification, especially the areas with challenging geographical landscapes or remote (McFarlan, 2018), as it is relatively cheap and easy to apply (Slough *et al.*, 2015; Suárez *et al.*, 2012). However, diesel-gen-sets are very vulnerable, expensive in operation and maintenance, and have short (under ten years) life-time (López-González *et al.*, 2018). Thus, gen-sets are not the long-term solution to establish a reliable electricity system. Today, the electricity supply is surplus, but there are still unelectrified areas because the electricity network cannot reach these areas (Lestari, 2020; Prokal, 2019a, 2019b, 2020). This situation is a paradox, in which abundant energy sources cannot guarantee the establishment of a reliable electricity system.

Recognized as the national energy barn, Kaltim has a huge NRE potential, both in type and quantity. Those are hydro, biomass, geothermal, solar, bioenergy, and wind. The three NREs with the largest potential are solar with the potential of 13,479 MW, followed by hydro (6,969.9 MW) and biomass (4,170 MW) (Bappenas, 2015; East Kalimantan Provincial Government, 2019b; MEMR, 2015;

* Corresponding author: novena.asri@idu.ac.id

PT PLN, 2016). However, NRE, in total, only supplies about 3% of Kaltim's electricity. The 3% total consists of solar with a total capacity of 2,403 kWp, hydro 1.6 GW, bioenergy 35.5 MW, and the rests are other the NREs (East Kalimantan Provincial Government, 2019b). Compared to fossils, the NRE proportion is very tiny. Oil, for example, with reserve 'only' 985 MMSTB, dominates the Kaltim energy mix by contributing 67.71% (East Kalimantan Provincial Government, 2019a).

There are patterns of inefficient energy consumption behavior in energy-rich countries, indicated by high carbon emissions (Friedrichs & Inderwildi, 2013) and high energy intensity (Nielsen *et al.*, 2018) or the ratio of energy consumption per unit of output. The wasteful behavior mainly due to habits and prevalent mindset that energy source is abundant. The initiatives, such as energy conservation, clean energy utilization, and the other wise-uses of energy leading to a more sustainable energy system would be abandoned. As energy sources are abundant and easy to get, they tend to opt for the more comfortable and avoid the excessive effort to conduct such initiatives. For energy-rich countries, achieving such initiatives are very challenging, although there is evidence that the rich-resource brings more curse rather than bless when it is used unwisely. Slow economic growth (Majumder *et al.*, 2020), environmental degradation (Friedrichs & Inderwildi, 2013; Salahuddin & Gow, 2014), and corruption (Dong *et al.,* 2019), are among the resource curse. Thus, to avoid more detrimental effects of energy-wasteful behavior, a robust energy policy is crucial to develop a more sustainable energy system. The policy includes demand-side management (Sahin *et al.*, 2019), electricity sector reforms (Poudineh *et al.*, 2020; Setyawan, 2014), and transition into NRE development (Oniemola, 2016). The heavy reliance only on the vast availability of energy reserve should be ended and switched into energy policy reformation.

Energy transition, which is the transformation in energy policy and the shifting from the non-renewable into the New and Renewable Energy (NRE) sources, is the key (Dutu, 2016). NRE offers a more sustainable system than fossil energy can offer. Not only its resource availability but also the impacts on the environment and the living system. However, its vast initial investment and advanced technology make it challenging to apply, especially in developing countries (Ghimire & Kim, 2018; Gómez-navarro & Ribó-pérez, 2018). In Indonesia, the issue becomes more complicated. It combines the political will, price gap between fossil and NRE, less attractive investment scheme, and weak coordination between the central and local governments. A radical reformation in the energy sector is required to optimally develop NRE (Kennedy, 2018; Marquardt, 2014; Martosaputro & Murti, 2014).

As Kaltim is energy-rich with a relatively small population, the reformation should not focus on the availability or demand management aspects but the compatibility between geographical characteristics and the type of energy source to be utilized (energy-area compatibility). The reformation should be on the policy-maker level, i.e., the mindset to arrange energy policy that suits the region's characteristics. They must realize that fossil-based systems can no longer be enforced for the entire area and utilizing NRE optimally. An extensive, centralized fossil-based electricity system (Handayani *et al.,* 2017) is incompatible with the entire Kaltim. A decentralized system (Carley, 2009) seems to be more suitable in some areas as Kaltim is forest-dominated with a scattered population. In challenging geographical areas, the grid extension will cost more (Bhandari & Stadler, 2011; Nouni *et al.*, 2008). Area's characteristics are essential in electricity provision, especially for an archipelagic country like Indonesia (Martosaputro & Murti, 2014; Veldhuis & Reinders, 2015). Energy policy ideally follows each region's characteristics, but energy development has been homogeneously conducted and neglected the region's characteristics. The incompatibility causes the paradox, the low electricity performance while energy is abundant. Although Indonesia has launched RUED (the general plan of regional energy), which delegates the provincial (regional) government to arrange the regional energy planning tailored to the region's potential energy sources and characteristics with sustainability principles, still, switching fossil with NRE is challenging. It can be seen from the current and targeted Kaltim energy mix. The Current (2015) energy mix is dominated by oil (67.71%) followed by gas (24%) and coal (5.16%), while NRE only 3.13%. In 2050, oil, gas, and NRE would be targeted around a third each, which are 29.52%, 29.45%, and 28.72%, while coal only 12.31% (East Kalimantan Provincial Government, 2019b).

The hypothesis of this study is constructed as follows. Developing countries are believed to face the dilemma of providing a sustainable energy system due to financial constraints (Asri & Yusgiantoro, 2020). While electricity is crucial for the economy, the dilemma heads to the tendency of choosing energy sources offering as immediate electricity provision as possible (Afful-Dadzie *et al.*, 2017), which potentially leads to the ill-advised policy. As Kaltim is rich in energy, there is an indication of an energy-abundant syndrome where the energy development is merely based on the easiest energy source to obtain, without regarding the sustainability principles (its life-time and long-term cost). In Kaltim, fossil (especially oil) is regarded as the easiest energy source to obtain, as it is everywhere and it (diesel-gen-sets) is suitable to electrify the remote areas (Slough *et al.*, 2015; Suárez *et al.*, 2012). However, its life-time is short (as it is non-renewable) and costly (López-González *et al.,* 2018) in the long-term (due to high generating cost and the potency of subsidy). Thus, there is an indication that the syndrome leads to the fossil-based energy policy. Here, a syndrome refers to a mindset of feeling secure due to the abundance of energy that leads to the wasteful behavior in energy consumption (Friedrichs & Inderwildi, 2013; Nielsen *et al.*, 2018) or the unwillingness to transform or to do the transition, to switch the non-renewable fossil with the renewable NRE (Oniemola, 2016; Sahin *et al.*, 2019). The mindset is believed to influence policy-makers to make which type of energy policy, i.e., NRE-based energy policy or fossil-based energy policy.

Thus, this study hypothesizes that the energy paradox Kaltim has been experiencing for years is caused by the 'ill-advised energy policy'. It is shown by the incompatibility of the utilization of energy type and area characteristics (energy-area incompatibility), which is exacerbated by the energy-rich syndrome. While proving the existence of mindset is very difficult, the study will reveal the characteristics leading to the indication of the paradox and the energy-area incompatibility, which indicates the syndrome's existence. Thus, this study investigates the indication of the syndrome in Kaltim energy policy by first identifying the existence of the energy-area incompatibility (causing the paradox) and its impacts. Last, the study tries to show the impacts of retaining the syndrome/mindset (fossil-based energy policy) through electricity cost and subsidy analyses.

This study attempts to fill the gaps from previous studies that have discussed energy-rich syndrome in a country scope but rarely discussed in a local scope. This study is crucial because the syndrome can also occur at the regional (province) level. In Indonesia, there are indications of the policy-makers' failure in paying attention to regional characteristics before formulating regional energy policies. They seem to be trapped and complacent with the 'abundance' of resources alone and neglect the other factors that should also be considered, such as regional characteristics. It can be seen from the energy paradox phenomenon Kaltim has experienced for years but missed from the government's attention. This study tries to reveal this phenomenon and the existence of a 'secure-feeling mindset' that can lull but dangerous. The regional energy planning policy (RUED) has indeed stipulated that energy policies must pay attention to regional's characteristics and energy potential. However, the implementation is not optimal. It is partly believed due to the syndrome that lulls the policy-makers, and they find it difficult to get out of the mindset they have trusted. This study is expected to raise awareness of the syndrome (mindset), thereby leading to the formulation of energy policies based on NRE (NRE-based energy policy), especially for the new, subsequent energy development projects.

Kaltim becomes the study object for at least two reasons. First, Kaltim is one of the largest energy-producing provinces whose energy system could be served as the benchmark of energy development in Indonesia. If an energy-rich region has an unsustainable and unreliable energy system, other regions' energy systems with fewer energy sources would be doubted. Second, in Kaltim would be located the new Capital, making Kaltim is increasingly strategic for Indonesia. A sustainable and reliable energy system is a must for the Capital of the country. This study combines descriptive methodology with observations, as well as statistical and data collection and analyses. This study is expected to be an essential input for policy-makers in Indonesia in the formulation of energy policy.

2. Research Methods

This study investigates the existing electricity system in Kaltim to show how the energy policy pays less attention to the long-term, more sustainable system. The energy provision seems merely based on the abundance of energy sources, without further considering the area's geographical characteristics and the long-term effect of using a particular energy source type. The observed variables are Kaltim's geographical characteristics and population distribution, potential energy sources, energy production and consumption, existing electricity system, the adequacy level of infrastructure electricity, and electricity cost analyses consisting of electricity-generating cost and subsidy. Due to limited sources, some data and numbers in the calculations might be assumed and adjusted.

The study conducts a descriptive methodology analysis and combines observation, collection, statistical, and data processing and analysis methods, including regression analysis. Most data in this study are secondary data taken from official sources. The data are then processed to obtain patterns to be observed and analyzed. For example, population patterns in Figure 4 and Figure 5 are processed (secondary) data from BPS. The raw data from BPS are then processed to obtain the patterns. The data processing also involves statistical linear regression to obtain the relationship of GDRP and electricity consumption, as shown in Figure 6. The raw data for the regression are collected from PT. PLN, Bappenas, and BPS. The primary data resulting from this study are generating cost (GC) and subsidy, which are obtained by calculating the supporting data in Table 10 and Table 11 using the formula taken from the previous study (Asri & Yusgiantoro, 2021). All graphs in this study are resulted from data processing by the author. Figure 1 and Figure 3 are the only two pictures directly taken from BPS Kaltim.

The raw data are taken from official institutions such as the Statistical Bureau (BPS) at the regional (provincial) and national (country) level, the Ministry of Energy and Mineral Resources (MEMR), State Electricity Enterprise (PLN) as the State Own Enterprise (SOE), the Ministry of Finance (MF), The British Petroleum statistics (BP), and other related sources from domestic and international institutions, including news from electronic media about the situation in the field.

3. Results and Discussion

Kaltim is believed to have a syndrome of the energy-abundant area that exacerbates the energy paradox it experiences for years, causing the energy system is unreliable although the energy sources are abundant. This study intends to investigate this premise, reveals the reasons, provides some suggestions, and finally is expected to become the policy-makers' input in formulating the energy policy.

There are three sections of discussion. The first section would be about the overview of Kaltim, which is rich and energy-abundant. The following section discusses how the indication of the syndrome occurs. It would cover the declining energy production facing increasing demand (existing electricity system), population distribution, and the sufficiency level of infrastructure (measured by electricity consumption). The last section is the electricity cost analyses consisting of electricity-generating cost and the subsidy analyses, to show that retaining oil fuels as the primary energy source is unwise since it is expensive and unsustainable.

3.1 Kaltim Overview: Energy-abundance and Geographically Challenging

3.1.1 Kaltim: Post-fossil threat?

Katim (Figure 1) is an Indonesian province located on Borneo Island and crossed by the Equator. It occupies a 127,346.92 km^2 area and is inhabited by 3,501,232 population with an average population growth of 3.6% per year. Kaltim consists of seven Regencies and three cities. The Regencies are Paser, Kutai Barat (KB), Kutai Kartanegara (KK), Kutai Timur (KT), Berau, Penajam Paser Utara (PPU), and Mahakam Ulu (MU), while the Cities are Balikpapan, Samarinda, and Bontang (BPS Kaltim, 2017). Kaltim is the fourth largest province (BPS Kaltim, 2017) and the eighth largest economy in Indonesia (BPS, 2017). The province relies heavily on the oil industry. For example, Balikpapan, whose economy comes from the oil, mining, and manufacturing sector, becomes one of Indonesia's most important cities (Tarigan *et al.*, 2017). However, due to the decrease in oil production and global oil prices, economic diversification is a must, a preparation to enter the post-fossil industry era (Tarigan *et al.*, 2017). The impact of the end of the fossil industry era is more pronounced, as Kaltim GDRP (Gross Domestic Regional Product) grows negatively if oil and gas are included, and vice versa positive if oil and gas are excluded from the calculation. In 2016, Kaltim's GDRP grew negatively by -0.38% with oil and gas and 1.67% without oil and gas. The previous year was -1.21% with oil and gas and 4.64 % without oil and gas (BPS Kaltim, 2017).

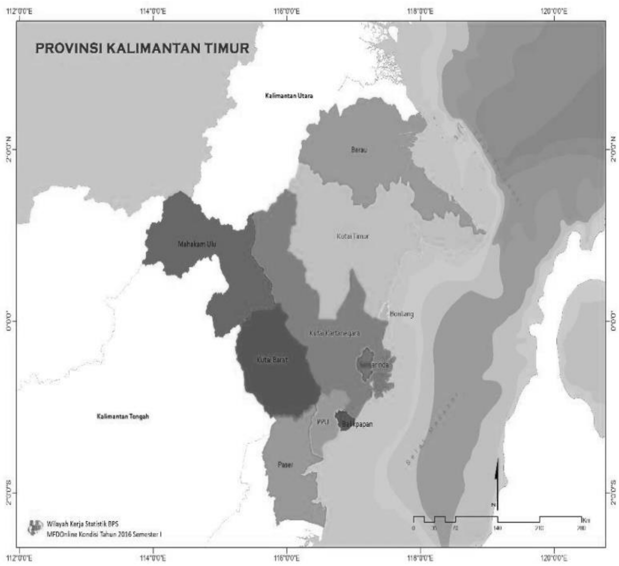
3.1.2 Area characteristics: forested, with many rivers

Kaltim's geographical landscape is forest-dominated with many rivers and wavy topography. Kaltim has hundreds of rivers as the main transportation line beside the land transportation. The longest river is the Mahakam River, with 920 km in length (Table 1).

The forest-dominated Kaltim's characteristics (Table 1) cause the absence of electricity under the electricity surplus since developing the transmission is challenging (Prokal.co, 2020). Land acquisition (Prokal.co, 2019b) is another problem PLN must face to develop the transmission. Since the electricity provision is still oriented on the grid extension, it would be difficult to electrify the unreachable areas for there is a minimum required voltage of electricity to be generated. On-grid transmission requires relatively more land and population than off-grid transmission (Purba, 2016). On-grid development is also more costly, thereby took a longer time than off-grid (Satrianegara, 2018). If the orientation is still on-grid and is not changed, electrifying the entire Kaltim would be challenging. There is an incompatibility between the geographical characteristics and the designed electricity system.

3.1.3 Potential energy sources: fossil and NRE

Kaltim is rich in energy, both in type and quantity. As an energy-rich area, Kaltim deserves to be the national energy barn. Kaltim's coal reserve and production account for 46.6% and 52.2% of national reserves and production, respectively, while its oil and gas productions are 10% and 18% of national oil and gas productions (East Kalimantan Provincial Government, 2019a). Kaltim has almost all types of energy sources, i.e., NRE and non-NRE (Table 2). However, the considerable potency of NRE has not been optimally utilized. The basic-cost of generating electricity from NRE is relatively higher than fossil (Table 3). The sparse population (Figure 4) also makes NRE difficult to reach economies of scale and even escalates the initial investment, which is avoided under financial constraints. Thus, fossil energy is preferable. However, NRE also has some advantages. It offers a long life-time as it is renewable. NRE also has zero (low) annual cost, as it requires no fuel. Fuel cost ranges from 48%-70% (Partridge, 2018), even 80% of the total generating cost (Asri & Yusgiantoro, 2021). The absence of a significant fuel cost component in NRE utilization is an attractive offer that cannot be ignored.



Source: (BPS Kaltim, 2017)

Fig. 1 Kaltim Province map

Table 1
The geographical landscape of Kaltim

Natural/Artificial Landscape	Numbers	Length /Width	% to Total Area
River	157	2-920 km	
Lake	18	24-13,000 acres	0.10%
Forest	-	8,339,151 acres	65.48%
Plantatio	-	1,312,977 acres	15.74%
Others*	-	1,145,932 acres	9.00%

**) wetland, dry field/garden, shifting cultivation & temporarily unused lands*
Source: (BPS Kaltim, 2017), processed

Table 2
The primary energy (fossil and NRE) sources of Kaltim

Primary energy	Reserve/Potential	Status
Coal	25 billion ton	Production
Gas	46 TSCF	Production
Oil	985 MMSTB*	Production
Coal Bed Methane	108 TSCF	Potential
Hydro	6.969,9 MW	Potential
Biomass	4,170 MW	Potential
Geothermal	10 Mwe	Speculative
Solar	13,479 MW	NA
Bioenergy	1,086.14 MW	NA
Wind	212 MW	NA

**) MMSTB: Million Stock Tank Barrels*
Sources: (Bappenas, 2015; East Kalimantan Provincial Government, 2019b; MEMR, 2015; PT PLN, 2016), processed

Table 3
Basic-cost of electricity provision, 2015

Power plants (NRE/Fossil)	Basic-cost (IDR/kWh)
Solar	8,786
Geothermal	1,058
Hydro	388
Diesel	3,992
Gas/Steam	1,843
Gas	806
Steam	661

Source: (East Kalimantan Provincial Government, 2019b)

While NRE and non-NRE (fossil) are available in Kaltim, fossil seems to be preferable. The significant initial investment, advanced technology, and underdeveloped infrastructures make NRE less desirable (Ghimire & Kim, 2018; Gómez-navarro & Ribó-pérez, 2018; Kennedy, 2018). This study recognizes the presence of an energy provision dilemma caused by a budget constraint (Asri & Yusgiantoro, 2020). As NRE's initial investment is more costly than fossil's, fossil becomes the preferable choice. Fossil also has an established infrastructure making it easier to meet the economies of scale when the development is continued. However, NRE's infant infrastructures make its initial cost more expensive, and the electricity-provision will take a longer time. The government would not sacrifice the economic performance only to have a more sustainable NRE-based electricity. Instead, they would prefer those allowing them to provide electricity immediately because the length of time in electricity provision significantly impacts the economic performance (Afful-Dadzie *et al*., 2017).

3.2 The Indication of the Syndrome?

3.2.1 Primary energy production – declining

Oil, gas, and coal are the primary energy sources upon which Kaltim relies. Although the potential is plenty, the production is declining (Figure 2). From 2012 to 2018, there was only one increase, which was in 2015 for oil (Figure 2, solid line) and gas (Figure 2, dashed line) and in 2017 for coal (Figure 2, dotted line). Production in 2013 decreased by -8% for oil and -13% for gas from 2012 production. It then further decreased by -10% and -15%, respectively, for oil and gas. The increases of 4% and 1% in 2015 could not exceed the production in 2012, which were about 36.61 million barrels of oil and 605.58 million mmbtu of gas. It then continued to decline until 2018, where the production only reached 23.72 million barrels for oil, 296.83 million mmbtu for gas, and 192.96 million tonnes for coal. It decreased by -44%, -64%, and -24%, for oil, gas, and coal, respectively, of the 2012 production.

This situation is precarious. While Kaltim heavily dependent on fossil, production continues to decline. Moreover, the Indonesian government has planned to move the country's Capital from DKI Jakarta (Java island) to Kaltim (Kalimantan/Borneo island). The energy policy should not only fulfill energy needs (for example, reach a 100% electrification ratio) but, more importantly, also establish a more reliable and sustainable energy system. Thus, NRE development is a must, and the government should start to implement a more appropriate energy policy focusing on NRE development for Kaltim.

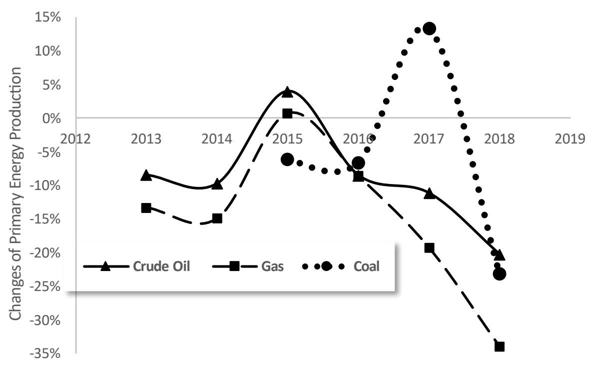
3.2.2 Electricity system – fossil domination versus un(optimally)tapped NRE

Kaltim electricity system (Figure 3) is concentrated in three cities, i.e., Samarinda, Balikpapan, and Kutai Kartanegara. Those three cities are the most populated areas and the center of economic activities in Kaltim. Thus, the electricity needs in these three areas are large.

The electricity system consists of a 150 kV interconnection system and an isolated 20 kV system for remote areas with small populations. Installed capacity is the planned capacity or the output electricity a power plant is designed to produce. Maximum capacity is the output generated when a power plant operates continuously in a stable state after deducting its own-use. Peak load is the highest electricity-load demand. In the Berau system, peak load is higher than the maximum capacity, which means a risk of shortage (electricity disruption) when the peak load occurs, for the maximum capacity is lower than the demanded load (Table 4). The most developed system is the Mahakam system that provides electricity in Balikpapan, Samarinda, and Bontang. However, due to the insufficient backup capacity, the system would encounter a power deficit when maintenance is undergone, or a large power plant unit is disrupted (PT PLN, 2016). In 2013, the power deficit reached 39.6 MW (PT PLN, 2013).

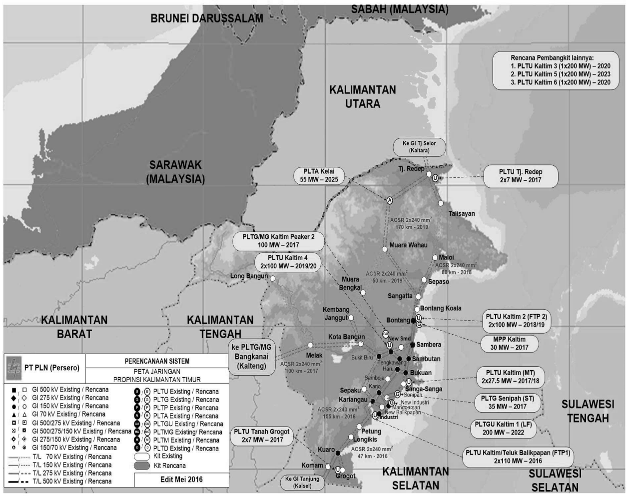
According to the 1945 Constitution, electricity management should be conducted by the State through PLN as SOE, as electricity is a strategic commodity. Thus, electricity supplied by PLN includes the electricity from third parties from which PLN rent the power plants or buy the electricity, also the captive power (electricity generated by private sectors for their own needs). In 2018, the total capacity of coal-, gas-, and oil-fueled power plants were 339, 326, and 280 MW, each (Table 5).

Total captive power in Kaltim is 1.36 GW, of which 10% comes from NRE-based power plants, i.e., biomass and biogas (Table 6). In 2015, 281 thousand kiloliters of diesel oil had been consumed by diesel-power plants, while gas- and steam-power plants were 81.6 and 9.2 thousand kiloliter diesel oil, each. Oil also dominates the Kaltim energy mix in 2015 by 67.71%, followed by gas (24%) and coal (5.16%), while NRE only 3.13% (East Kalimantan Provincial Government, 2019b). It shows how Kaltim relies heavily on fossil, especially oil fuels.



Source: (East Kalimantan Provincial Government, 2019b), processed

Fig. 2 The pattern of changes in the primary energy production (oil, gas, and coal) – the three of Kaltim's primary energy sources



Source: (PT PLN, 2016)

Fig. 3 Simple electricity map of Kaltim

Table 4
Kaltim electricity system (PLN), 2018

Electricity system	Installed capacity (MW)	Maximum capacity (MW)	Pak load (MW)
Kalimantan (Mahakam +Petung + Tanah Grogot + Sangatta)	872.9	592.1	481.2
Melak	17.2	14.3	11.8
Berau	27.5	21	22.2
TOTAL	917.6	627.4	515.2

Source: (East Kalimantan Provincial Government, 2019a)

Table 5
The electricity supplied by PLN

Power plants location	Fuel	Capacity (MW)
Bontang	Gas	2x7
Bontang	Gas	30
Kutai Kartanegara	Gas	2x20
Kutai Kartanegara	Gas	2x50
Kutai Kartanegara	Gas	60
Kutai Kartanegara	Gas	2x41
Kutai Kartanegara	Coal	50
Kutai Kartanegara	Coal	2x27.5
Balikpapan	Coal	2x110
Berau	Coal	2x7
Berau	Diesel	14.8
Samarinda	Diesel	33.6
Samarinda	Diesel	31.8
Kutai Kartanegara	Diesel	10
Balikpapan	Diesel	12.6
Balikpapan	Diesel	24
Balikpapan	Diesel	83.3
Isolated (spread)	Diesel	23.7
Isolated (spread)	Diesel	46.2
TOTAL		944.8

Source: (East Kalimantan Provincial Government, 2019a)

Table 6
Captive power in Kaltim

Regency/City	Power plant capacity (MW)		
	Biomass/Biogas	Diesel/Gas	Total
Samarinda	24.0	50.5	74.5
Balikpapan	-	240.5	240.5
Bontang	-	468.7	468.7
Kutai Kartanegara	37.0	197.5	234.5
Kutai Timur	34.7	187.3	222.0
Berau	12.7	48.5	61.2
Kutai Barat	4.8	18.3	23.1
Paser	21.7	8.5	30.2
Penajam Paser Utara	7.4	0.5	8
Mahakam Ulu	-	0.7	0.7
TOTAL	142.4	1,221.2	1,363.6

Source: (East Kalimantan Provincial Government, 2019a)

Table 7
NRE utilization in Kaltim electricity

Regency/City	Solar (kWp)	Hydro (MW)	Biomass (MW, plan)
Samarinda	-	-	-
Balikpapan	-	13.6	-
Bontang	75	-	-
Kutai Kartanegara	44	851.9	-
Kutai Timur	107	102.5	-
Berau	552	598.6	3.0
Kutai Barat	629	-	-
Paser	297	36.9	1.0
Penajam Paser Utara	73	-	-
Mahakam Ulu	627	-	-
Spread	-	-	31.5
TOTAL	2,403	1,603.5	35.5

Source: (East Kalimantan Provincial Government, 2019a)

Table 8
The 2016-2025 plan of Kaltim power plant development

Project	Power plant type	Capacity (MW)	%
Teluk Balikpapan	Steam coal	2x110	9.51%
MPP Kaltim	Dual gas/diesel	30	1.30%
Tanjung Redep	Steam coal	2x7	0.61%
Kaltim Peaker 2	Dual gas/diesel	100	4.32%
Kelai	Hydro	55	2.38%
Spread	Hydro	200	8.65%
Tanah Grogot	Steam coal	2x7	0.61%
Senipah	Steam gas	35	1.51%
Spread	Biomass	21.6	0.93%
Kaltim	Steam coal	2x27.5	2.38%
Kaltim	Steam coal	2x100	8.65%
Spread	Waste	18	0.78%
Kaltim 4	Steam coal	2x100	8.65%
Kaltim 3	Steam coal	1x200	8.65%
Kaltim 6	Steam coal	1x200	8.65%
Spread	Hydro	350	15.13%
Kaltim 1	Steam gas	200	8.65%
Kaltim 5	Steam coal	1x200	8.65%
TOTAL		2,313	100%

Source: (PT PLN, 2016)

While the potency is enormous, NRE is not optimally utilized. In 2018, solar and hydro utilization was 2,403 kWp and 1.6 GW, respectively, while biomass would be utilized around 35 MW (Table 7). Until 2020, according to the manager of UP2B Kalimantan PT PLN as stated in Procal.co, NRE only supplies 3% of total Kaltim's electricity (Prokal.co, 2020).

In the 2016-2025 power plant development plan, there is an initiative to reduce fuel oil domination in the Kaltim electricity mix. However, the substituent is also fossil, which is coal that would generate 56% of 2,313 MW electricity. In total, oil, gas, and coal would provide 62% while NRE only 28% of electricity generated (Table 8). It shows how challenging it is to escape the fossil-dependency mindset, although the regulations have mandated considering the regional characteristics and energy sources' potential with sustainability principles.

3.2.3 Population distribution – scattered households

The population's distribution is analyzed by observing the population density (Eq. 1) of each area.

$$\rho_{pop} = \frac{n}{A} \tag{1}$$

Where ρ_{pop} is population density, n is population, and A is the area (km^2) of each area. The data are taken from the Statistics Bureau (BPS Kaltim, 2017).

Samarinda, KK (Kutai Kartanegara), dan Balikpapan are the most populated areas, with 24%, 21%, and 18% of the province population, respectively (Figure 4, vertical axis). Population density indicates how dense a population in an area, shown by the bubbles' size, where the more significant the bubble's size, the denser the population is (Figure 4, horizontal axis). The three densest areas are Balikpapan, Samarinda, and Bontang, with 1,222, 1,156, and 1,023 people per km^2, respectively. It shows that the Kaltim population is unevenly distributed with an extensive density range between 1.34 to 1,222 people per km^2. As a comparison, the analysis is also conducted to the Indonesian Capital, DKI Jakarta, as the extreme point or the densest area (Figure 5). Kaltim population is only about a third (3.5 million) of Jakarta's population (10 million). Interestingly, Jakarta's 2015 electrification ratio almost reached 100%, while Kaltim was still around 90% (Directorate General of Electricity, 2015).

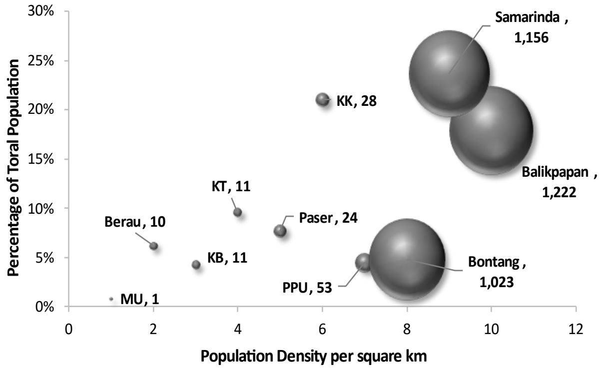


Fig. 4 The percentage of total population (vertical, the height of the bubbles) and population density per km^2 (horizontal, the size of the bubbles) of Kaltim, 2016

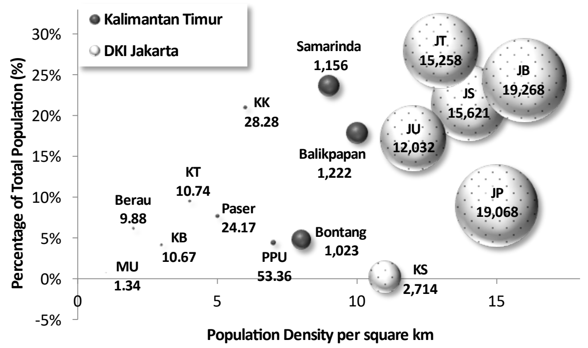


Fig. 5 The comparison of the population distribution of Kaltim and DKI Jakarta

The DKI Jakarta Capital consists of six cities, i.e., Kepulauan Seribu (KS), Jakarta Selatan (JS), Jakarta Timur (JT), Jakarta Pusat (JP), Jakarta Barat (JB), and Jakarta Utara (JU), with a total population 10,277,628 in 2016 (BPS Jakarta, 2017). Each area's proportion population ranges from 0.23% to 28% of the total population, and the population is evenly distributed, between 12 to 19 thousand people per km^2. The only area with the sparsest population is KS, with a density of only 2.7 thousand per km^2. KS is the islands in the north of Jakarta separated by the sea from the main Java island where Jakarta is located. Jakarta population's characteristic is evenly distributed, where the six bubbles (white, with dots) are on the right side of the X-axis. Kaltim's characteristic, on the other hand, is scattered. The bubbles are spread from the left to the middle of the X-axis (Figure 5). Although the area is much smaller, Jakarta's population is more numerous, so that its population is denser than Kaltim's.

Electricity provision is crucial for the economy, as its delay leads to a 1.5% decline in GDP (Afful-Dadzie et al., 2017). Thus, the government tends to prioritize the option that offers more immediate electricity provision, although by neglecting the sustainability principles like considering the compatibility between energy type and area's characteristics and optimizing NRE utilization to establish a more reliable and sustainable electricity system. For developing countries, implementing sustainability principles means a delay in the electricity provision as there is a financial constraint (Asri & Yusgiantoro, 2020). Thus, fossil energy is preferable, as it can offer a faster electricity provision than NRE.

In Jakarta's case, the province is populous and dense, suitable for the fossil-based electricity system preferred by most governments in developing countries who face financial constraints but demand immediate electricity provision. It explains why electrifying Jakarta (and other dense provinces in Java island) is much easier than electrifying Kaltim. In the Kaltim case, the province is rich in fossil energy, so fossil-based electricity provision is much more preferable. Its populous cities use the fossil-fueled on-grid system, while remote and geographically challenging areas use the diesel-fueled off-grid system. Unfortunately, it leads to a disastrous, paradox situation, where the electricity system proved unreliable (daily shortage) and very difficult to electrify the entire Kaltim, despite electricity production is surplus (Lestari, 2020; Prokal.co, 2019a, 2019b, 2020). According to the manager of PT. PLN Samarinda, to generate the electricity with a-

300 kWh diesel power plant requires voltage at least 90kVA (Prokal.co, 2019b), a very challenging job for the areas with small and scattered populations. If the house and the power plant is too far, the electricity will be lost during the transmission. NRE is more compatible than fossil, but its development is also challenging. For the sake of convenience, oil is preferable to NRE. However, for the sake of sustainability, the off-grid electricity system should be implemented for NRE (Kosai & Yamasue, 2018; McFarlan, 2018).

3.2.4 Energy infrastructure – insufficient

The electricity sufficiency level is indicated by the electrification ratio (ER), which is the ratio of electrified households to total households. Despite energy-abundance, Kaltim presumably has insufficient electricity (Table 9). Samarinda, Balikpapan, Bontang as the densest areas (Figure 4), have the highest (above 90%) ER. This finding follows the hypothesis (explained in the previous paragraph) that fossil-based system is preferable. Electrifying the densest areas has no significant difficulties as the population number meets the minimum electricity requirement. Categorized into three groups, Kaltim has three cities, three regencies, and four regencies with more than 90%, 80%, and 60% ER each. Three cities represent 1.7 million (48.7%), which means that only about half of Kaltim population has been more than 90% electrified, while other 1.13 million only 60% electrified. Only 716,215 population has been 80% electrified.

ER indicates the level of electricity consumption, which can indicate the sufficiency level of infrastructure. As measuring the infrastructure level is challenging, the most likely approach is to compare all provinces' infrastructure to obtain the relative value (level) through a linear regression method. There is a relationship between electricity and the economy, where the electricity demand is increasing as the economic activities are growing (Best & Burke, 2018; Riva *et al.*, 2018). Thus, the regression is conducted between GDRP (Bappenas, 2015; BPS, 2018) and electricity consumption (PT PLN, 2015) of all provinces in Indonesia (Figure 6).

Table 9
The Electrification Ratio (ER) of each area in Kaltim, 2018

Regency/City	Population	ER (%)
Samarinda	857,612	92.38
Balikpapan	767,616	98.60
Bontang	126,361	98.55
Population of 3 cities	*1,751,589*	*(48.7% pop)*
Kutai Timur	322,858	80.84
Berau	208,293	82.37
Penajam Paser Utara	185,064	81.94
Population of 3 regencies	*716,215*	*(19.91% pop)*
Kutai Kartanegara	653,783	63.41
Paser	288,847	67.09
Kutai Barat	159,864	67.20
Mahakam Ulu	26,499	65.41
Population of 4 regencies	*1,128,993*	*(31.39% pop)*

Source: (East Kalimantan Provincial Government, 2019a), processed

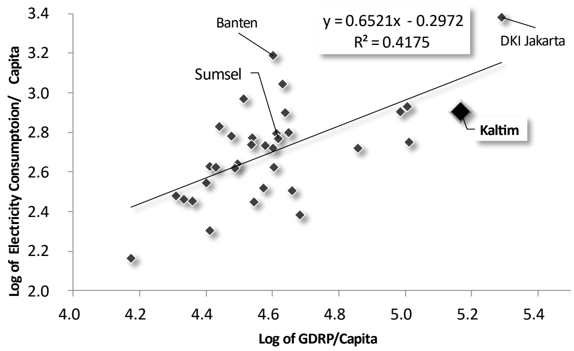
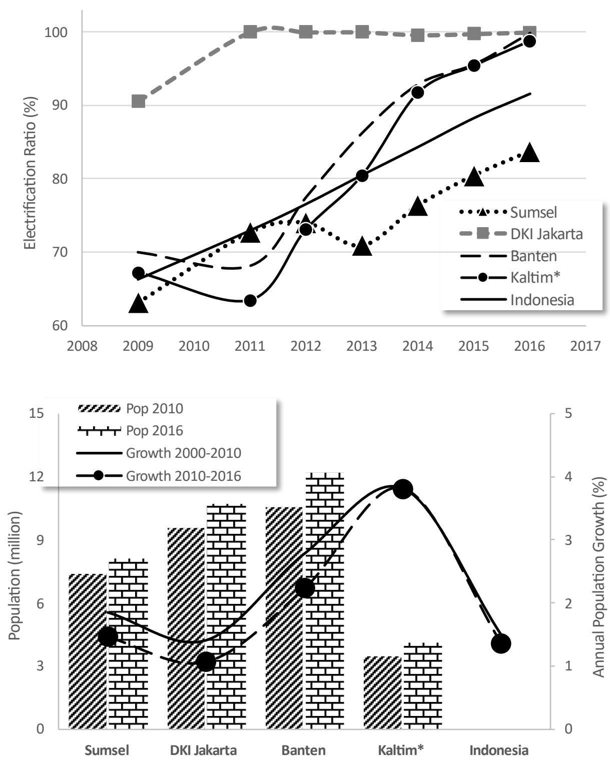


Fig. 6 The linear regression plot of electricity consumption and GDRP of all Indonesia provinces



Source: (BPS, 2017; Directorate General of Electricity, 2015), processed

Fig. 7 The electrification ratio (above) and population patterns (below) of Kaltim and some regions in Indonesia

The regression line shows the average performance of electricity consumption and the economy that can be used as the standard (minimum level) of electricity consumption of a province with a certain level of GDRP. The economic performance (the independent variable) would determine how much electricity should be consumed (the dependent variable). At least two pieces of information could be obtained, according to the graph's behavior. The first is the slope direction, whether facing upwards or facing downwards, to the line's starting point. If the slope direction is facing up, the relationship between electricity consumption and GDRP is linear and positive. It means that the economy positively affects the electricity consumption, and vice versa if the slope direction is facing down. The second is the dots' positions (represent each province's performance), whether above or below the regression line. Suppose the dot's position is above the regression line. In that case, the economy's positive effect on the electricity consumption is above the average, and vice versa if the dot's position is below the regression line.

Figure 6 shows a positive relationship between electricity consumption and GDRP, as the graph has a positive slope. It proves that economic performance determines electricity consumption positively. The higher the regional income (per capita GDRP), the larger the province's electricity consumption. However, it does not indicate how efficiently the energy is consumed. To measure energy consumption efficiency requires an energy intensity indicator, which is not provided here due to the limitation.

Kaltim GDRP is the second largest (the dot is on the second far right). However, its electricity consumption (804.4 kWh/capita) is relatively lower than it should be, given its economic performance (146,992,800 IDR/capita or about 10,499 USD/capita, assuming 1 USD = 14,000 IDR). As a comparison, Banten with 40,027,960 IDR/capita GDRP consumes 1,543,50 kWh/capita of electricity. In Figure 6, Banten's dot is to the left of Kaltim's (lower GDRP than Kaltim's) but is above the line (higher electricity consumption than Kaltim's). The relatively lower electricity consumption could also indicate the efficiency (the lower the electricity consumption to produce one unit of output, the more efficient it is). Another comparison is Banten and Sumsel, with the dot is slightly above the line. With 41,341.24 IDR/capita and 588.30 kWh/capita, Sumsel's GDRP is slightly higher than Banten's, but with much lower (almost a-third of Banten's) electricity consumption. It could also indicate a more efficient consumption as Sumsel, with lower electricity consumption, has a better economic performance than Banten. Unfortunately, there is a limitation to obtaining data and information to prove infrastructure insufficiency or electricity efficiency. However, the facts (daily electricity shortage and unelectrified areas despite electricity-surplus) point to the unreliable electricity system. Thus, the relatively lower Kaltim energy (electricity) consumption that is incomparable to its economic performance (GDRP) may indicate infrastructure insufficiency. Kaltim seems to experience electricity infrastructure insufficiency rather than efficient electricity consumption.

Kaltim's population is only about a-half, a-third, and a-quarter of Sumsel's, DKI Jakarta's, and Banten's, respectively (Figure 7 below, bar charts, right-hand scale), with higher growths (Figure 7 below, lines, left-hand scale). Thus, Kaltim may consume lower electricity than those three. Refuting a lower population leads to lower electricity consumption, a comparative analysis of the ER between Kaltim and three provinces is conducted. ER can provide a more objective analysis as it measures the electrification level of a province towards itself. Kaltim's ER is low, only about 65% in 2009 (Figure 7 above, black dotted line with circle marks) and under the average (national) ER until 2013 (Figure 7 above, black line). It was also under Sumsel's (Figure 7 above, black, dotted line with triangle marks), whose GDRP is only a-third of Kaltim's (Figure 6). These findings strengthen the indication that Kaltim's electricity infrastructure is relatively insufficient. Kaltim's ER increased significantly after 2012 (Figure 7 above). However, it could be due to the splitting of Kaltim's area into a new province (North Kalimantan), according to Law No. 12 of 2012, instead of due to the infrastructure development.

3.3 Electricity Cost Analysis – the Cost of Reliance on Fossil Energy

3.3.1 Generating cost of electricity

Electricity cost analysis intends to show that oil-based electricity is expensive by comparing the electricity generating cost of three fossil fuels (coal, gas, diesel) with CV and fuel price as shown in Table 10. The calculation uses the same formula from the previous study (Asri & Yusgiantoro, 2021), so it is not provided here. Due to insufficient data, the analysis of NRE is not conducted but is also taken from the previous study (Asri & Yusgiantoro, 2020), which is 7.32 cents US$/kWh (for a wind turbine).

The power plant's duration (operating time) generally determines the fuel type in electricity generation, following the electricity load pattern. There are base, medium, and peak electricity load patterns during specific periods in a day, following people's activities (Andersen *et al.*, 2017). Peak load is the highest electricity demand, which occurs for a short time, while the base-load occurs almost along the day with moderate electricity demand. Power plant utilization should be suited to the electricity load to use the fuel efficiently. Coal is usually dedicated to bearing the base load while diesel (fuel oil) for peak load. The operating time is indicated by the Capacity Factor (CF), which is the ratio of gross electricity production per year and the power plant's installed capacity (PT PLN, 2015). The calculation of generating cost is applied for the three operating times, which represents three CF's. CF 80% represents base load with the longest operating time, CF 60% represents medium load, and CF 20% represents peak load with the shortest duration (Table 11).

Electricity generating cost (per kWh total cost) is the sum of three cost components, which are investment (initial) cost, fuel cost, and operational and maintenance cost (Asri & Yusgiantoro, 2021). From the calculations, at CF 80% (longest operating time), GC for diesel, gas, and coal are 14.8, 6, and 5.4 cents US$/kWh, respectively. In the same power plant, per kWh GC would be higher if less power is generated, or GC increases as the CF decreases (Figure 8, bar chart, LHS). A previous study obtains GC of a wind power plant is 7.32 cents US$/kWh, with 8,760 hours per year (Asri & Yusgiantoro, 2020). Converted into 5,000 hours per year (Table 11), the GC of a wind turbine would be around 12.83 cents US$/kWh. Although both power plants operate for the same most prolonged duration, GC for diesel remains the most expensive. Please note that it is a rough calculation to get a rough comparison since the GC calculation for wind is only adjusted from the previous study, not directly conducted in this study.

Among the three, coal has the cheapest GCs while diesel is the most expensive (Figure 8, bar chart, LHS). However, the increase in GC coal as CF decreases is the highest while diesel is the lowest. From CF80% to CF60%, GC coal increases around 12.5%, while diesel is only 5% and gas 11% (Figure 8, dotted line, RHS). From CF60% to CF20%, GC coal increases 89%, while gas 80% and diesel only 35% (Figure 8, solid line, RHS). According to this rough calculation, fuel oil should be used only in peak hours (CF20%), as it is costly. However, by seeing Kaltim's energy consumption pattern dominated by almost 70% oil, it may lead to the premise that oil is also utilized for the base- and medium-hours or used along the day. This premise is supported by the fact that oil is abundant and easy to get, so that people tend to consume it lavishly, indicating the existence of the energy-rich syndrome.

Table 10
Caloric value and fuel prices of the three fuels

Fuel	Caloric Value (CV)	Fuel Price
Coal	4,200 kcal/kg	57.14 US$/ton
Gas	252,000 kcal/mmbtu	4.34 US$/mmbtu
Diesel	9,370 kcal/liter	93.51 US$/BOE

Source: (East Kalimantan Provincial Government, 2019a)

Table 11
Three types of load and their duration

Fuel	Load type	Duration (hr/yr)*	CF*
Coal	Base	5,000	80%
Gas	Medium	3,500	60%
Diesel	Peak	2,000	20%

**) assumed and adjusted from previous studies*

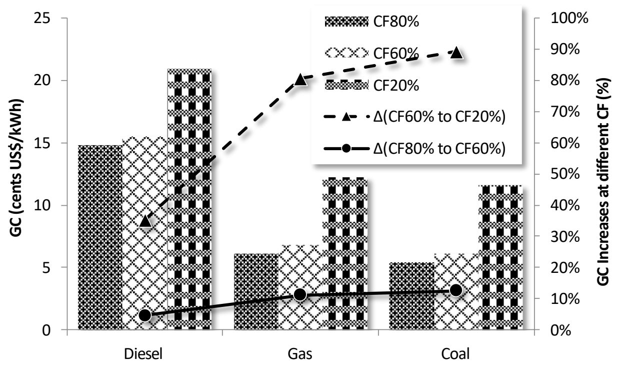


Fig. 8 GC (US$/kWh) of diesel-, gas-, and coal-fueled power plants at CF 80%, 60%, 20% (left-hand scale/LHS), and their increase (%) with CF changes (right-hand scale/RHS)

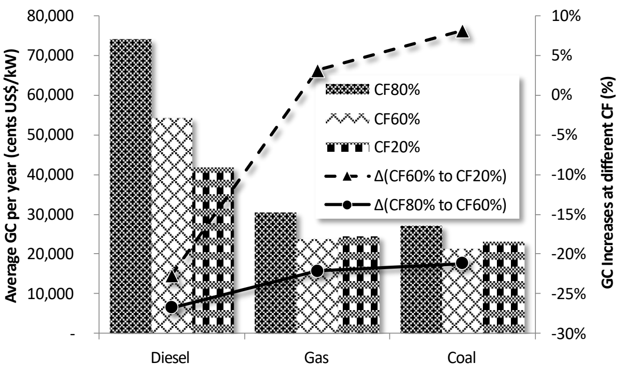
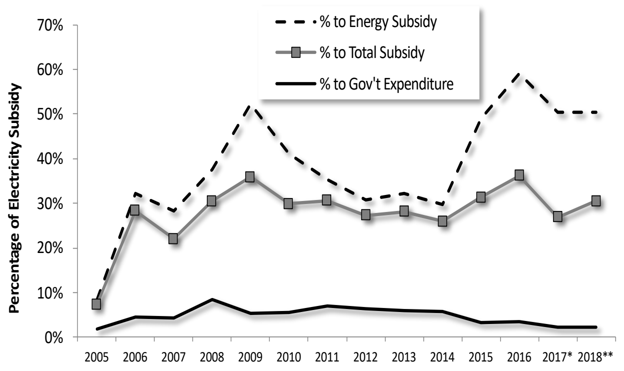


Fig. 9 GC (US$/kW) of diesel-, gas-, and coal-fueled power plants at CF 80%, 60%, 20% in a year operating time (LHS) and their changes (%) with CF changes (RHS)



Source: (MF, 2016, 2018b), processed

Fig. 10 The proportion of electricity subsidy towards energy subsidy, total subsidy, and government spending

The GC pattern observation in a year is conducted by multiplying the initial GCs (Figure 8) by the operating time (hours/year in Table 11, column 3). The results show that GC's pattern changed (Figure 9). Initially, all GC increases as CF decreases (Figure 8). Now, the pattern only applies to diesel oil (Figure 9, bar chart, LHS), while in gas and coal, GC at CF 60% is the lowest (Figure 9, bar chart, LHS). It is crystal clear that diesel should only be used for peak hours, while coal for medium- and base-hours. Reducing CF from 80% to 60% will reduce GCs by -26%, -22%, and -21%, respectively, for diesel, gas, and coal (Figure 9, solid line, RHS). Reducing CF from 60% to 20% will decrease GCs by -22% for oil but increase gas and coal by 3% and 8%, respectively (Figure 9, dotted line, RHS). The results show that diesel not only the most expensive but also the most sensitive to CF changes. While GCs of gas and coal show more minor changes as CF decreases (especially from CF 60% to CF 20%), GCs of diesel show more remarkable changes as CF decreases (Figure 9, bar chart, LHS).

Therefore, it would be wise to minimize diesel utilization, as it is costly and susceptible to load changes. This finding is consistent with a previous study, which found that the GC of oil fuel is the most expensive among the three fossil fuels (Asri & Yusgiantoro, 2021). Due to the limitation, the actual data of diesel utilization in what load (peak, medium, or base) in Kaltim's power plants is unavailable. However, by observing the energy consumption pattern, energy wasteful behavior seems to occur in Kaltim. Its abundance made oil easy and very convenient to utilize. Thus, it follows what previously hypothesized that the government prioritizes oil fuel as main energy source to immediately fulfill electricity needs.

The analysis of electricity-generating cost is an approach to get a rough description of the three fossil fuels' electricity costs since the actual cost is difficult to find. The calculation uses some assumptions and adjustments so that the results may not exactly represent the real GC. Moreover, the real GC is only known by the electricity producer. On the other hand, electricity tariff is not purely derived from a single calculation. Instead, it has already contained political decisions (Setyawan, 2014) like subsidy before its implementation.

3.3.2 Subsidy analysis

The subsidy analysis is conducted by describing the proportion of electricity subsidy to the state budget to show that high reliance on fossil energy is disastrous. A subsidy is an allocated government budget to establish more affordable prices for many people. Two kinds of subsidy in Indonesia are energy subsidy and non-energy subsidy. Energy subsidy consists of subsidies for oil, LPG, and electricity. In contrast, non-energy subsidy consists of subsidy for food, fertilizer, seeds, public transportation and public information, debt interest rate, and tax (MF, 2018a). Annually, electricity subsidy takes 2% to 9% of government spending or about 7% to 30% of total subsidy (energy and non-energy), and about 8% to 60% of energy subsidy (Figure 10).

Electricity subsidy fluctuates every year due to the fluctuation of oil price. From 2005 to 2009, the proportion of electricity subsidy to energy subsidy (Figure 10, dashed line) and total subsidy (Figure 10, solid line, with square marks) increased due to increased oil price. From 2009 to 2014, the decrease of the electricity subsidy (Figure 10, dashed line) due to the decreased, shale gas-affected global oil price. From 2014 to 2016, the subsidy increased and then decreased in 2017. The increase in 2014 was caused by oil prices recovery, while the decrease in 2017 was caused by subsidy removal in some groups of electricity users.

A subsidy is essential to trigger economic growth, boost a productive economy, or make energy more affordable for the underprivileged. However, it would be disastrous if it is wrongly allocated, like fuel subsidy for all. It will burden the budget, widen the price gap (Table 3) of NRE and fossil, and eventually hampering the NRE development. In that situation, subsidy removal is better and positively impacts the economy (Mundaca, 2017). However, subsidy removal should be carefully conducted and accompanied by supporting policies, especially in developing countries, as the removal could trigger the increase of basic-necessities' prices (Hassani et al., 2018). In Indonesia, a subsidy is dedicated to targeting the specific income groups, i.e., the poor and the low-income groups. However, to increase the effectiveness and efficiency, the energy subsidy policy should also consider the fuel type. It is the case, especially according to the previous section's findings, that a certain energy type (fuel oil) is very costly.

3.3.3 Kaltim subsidy structure

Subsidy analysis in this study is also developed from the previous study (Setyawan, 2014). For simplification, electricity user groups are categorized into five groups, i.e., Residential, Commercial, Industrial, Social, and Government & Public Road Lighting. Each group consists of subsidized and non-subsidized users (Figure 11). Please note that the percentage of subsidized and non-subsidized users is an assumption since the real data are challenging to obtain. The statistics bureaus at the regional (provincial) and national (country) level (BPS, 2018; BPS Kaltim, 2017) from which the data are taken only provide general statistics. As it is an approach, the data are presented in percentage (not in absolute numbers) to get the rough description (not analyze the exact numbers).

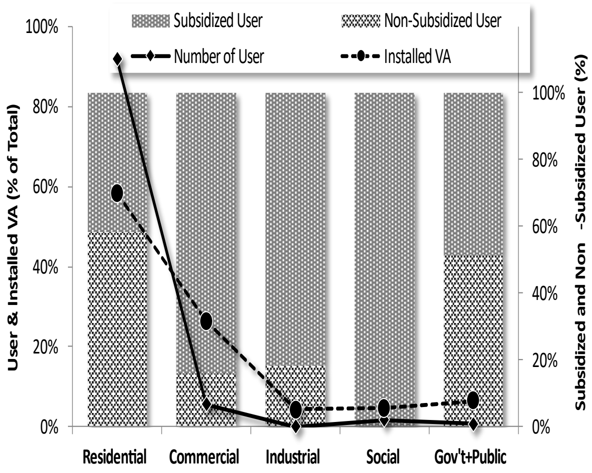


Fig. 11 The proportion of (subsidized and non-subsidized) electricity users (bar charts, RHS) and the percentage of electricity users with its installed capacity (line charts, LHS), with some assumptions and adjustments

The most user group is Residential, which covers about 91.82% of the total user (Figure 11, solid line, LHS) with around 60% of installed capacity (Figure 11, dashed line, LHS). The least users are Industrial and Government & Public Light (Gov't & Public) which constitute less than 1% (0.04% and 0.74%, respectively) of total users (Figure 11, solid line, LHS) and less than 10% (4.39% and 6.42%, each) of total installed capacity (Figure 11, dashed line, LHS). The most subsidized user is the Social group, as all users are subsidized (Figure 11, bar chart, RHS). These figures indicate at least two things about the pattern of electricity consumption and the economy of Kaltim. First, the Business and Commercial sector (export/import, banking, warehousing, trading businesses, individual business) is more active than the Industrial and Manufacturing sector. The former sector's installed capacity is higher (about 30%) than the latter, which is only about 5% (Figure 11, dashed line, LHS). However, both sectors seem under the subsidy recipients' target, as more than 80% of the users in both groups are subsidized (Figure 11, bar chart, RHS). It is common for the government to provide subsidies for the industry and commercial, primarily if both sectors produce goods and services essential for many people. Second, the Residential seems not to be the main target of electricity subsidy, as 60% of the users in this group are non-subsidized (Figure 11, bar chart, RHS).

Subsidy analysis is conducted to obtain a rough description of the subsidy pattern, given the indication of Kaltim's high dependency on expensive, unsustainable fossil fuels, especially oil. The value of subsidy (cents US$/kWh) is obtained by subtracting GC (Figure 8) with subsidized tariffs (in the regulation). The subsidized electricity tariffs have been adjusted to simplify the calculations as they involved more than thirty groups of electricity tariffs (Setyawan, 2014). The subsidy is presented as the percentage of Kaltim GDRP (Figure 12).

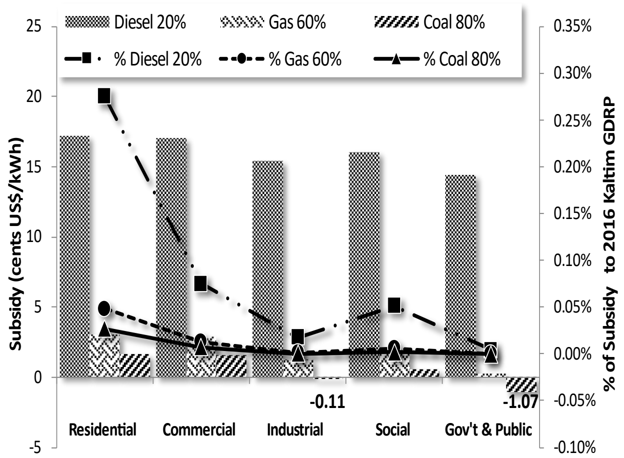


Fig. 12 Subsidy (cents US$/kWh) of five groups of users (LHS) and their percentages to Kaltim GDRP (RHS)

The calculations are applied only on representative GCs to simplify the analysis. As each fuel's actual utilization to bear which load is unknown, it then assumed that diesel is used only for peak-load or CF20% (the shortest duration), gas for medium-load or CF60%, and coal for base-load or CF80% (the longest operating time). Figure 12 (bar charts, LHS) shows that in all five user groups, the subsidy of diesel is the most remarkable, which are around 15-18 cents US$/kWh compared to gas (0.27-3 cents US$/kWh) and coal (0.5-1.7 cents US$/kWh). The minus subsidy values for Government & Public Light sector might be due to the incompatible adjustments so that the GC is less than the subsidized tariffs.

In the percentage to GDRP, subsidy for diesel in Residential group is the highest, or about 0.275%, followed by Commercial and Social, which are about 0.08% and 0.05% of GDRP, respectively (Figure 12, dashed-dots line with square marks, RHS). The highest subsidy for gas (dashed line with circle marks) and coal (solid line with triangle marks) are also on the Residential group, which about 0.048% and 0.027% to GDRP, respectively.

Please note that the analysis (percentage to GDRP) intends mainly to get the rough figure of the subsidy pattern, as it is not covered in GDRP, but under government spending in the State Budget. Please also note that the subsidy analysis is applied only to the representative GC with the most likely (prevalent) scenario, i.e., diesel is assumed to be used only in the peak-load, while gas in medium- and coal in base-load. However, according to the previous observations, there are indications that diesel may be used not only to bear the peak-load, given the massive amount of consumption. The analysis is also to describe the subsidy burden if Kaltim cannot escape oil. According to the results, subsidy for diesel accounts for 0.003% to 0.275% of Kaltim GDRP (Figure 12, dashed-dots line with square marks, RHS). In the money value, the subsidy would be around 17 billion to 1.55 trillion IDR (1.2 to 110 million USD, assuming 1 USD = 14,000 IDR) from the 564.7 trillion IDR 2015 Kaltim GDRP. Although it is not the exact value (given the real GC is only known to the producer), it could be used as one of the fundamental arguments to end the fossil era and start utilizing NRE optimally.

4. Conclusion

This study aims to investigate Kaltim's energy system and how energy-rich syndrome occurs. Kaltim is strategic. As the barn of national energy, its energy system is the benchmark of energy development in Indonesia. If an energy-rich province has an unreliable energy system, other provinces' energy systems with fewer energy sources would be doubted. Kaltim also where the new country's capital is located, then, a sustainable and reliable energy system is a must. However, Kaltim has a problematic electricity situation. Previously, its electricity is deficit (daily blackout and shortage electricity supply). Today, the electricity is surplus, but there are still unelectrified areas. This situation is a paradox, where energy-abundance cannot guarantee the establishment of a reliable and sustainable electricity system.

This study finds that the utilization of NRE and non-NRE is unequal, although Kaltim is rich in both. While NRE only contributes to 3% of total Kaltim's electricity, non-NRE (fossil) dominates the electricity mix by 67.71%, 24%, and 5.16%, respectively, for oil, gas, and coal. Unfortunately, the three energy sources' production, upon which Kaltim relies its economy and electricity, is declining. In 2018, oil, gas, and coal production decreased by -44%, -64%, and -24%, respectively, from 2012 production. The initiative to reduce the oil domination is unfit since the substituent is also fossil, which is coal as 56% of 2,313 MW electricity. In total, fossil would generate 62% while NRE only 28% of 2,313 MW electricity until 2026.

The investigation on Kaltim's geographical characteristics and population distribution finds the incompatibility between the utilization of energy sources and Kaltim's geographical characteristics (energy-area incompatibility). Kaltim is forested with a scattered population, which is suitable with an off-grid system. However, the electricity system is on-grid and fossil-based. The wasteful behavior is shown by the massive use of diesel-gen-sets in the unreachable areas, whereas the off-grid system should be applied to NRE. This finding is strengthened by further investigation on electrification ratio (electricity consumption) to measure infrastructure sufficiency. The investigation reveals that Kaltim electricity consumption is lower than it should be, given its incredible economic performance. Kaltim ER is under Sumsel's and Banten's with a-third Kaltim GDRPs but two and four times Kaltim's population. Low ER indicates the infrastructure insufficiency indicating the energy-area incompatibility.

Cost analyses show that coal has the cheapest GCs and diesel is the most expensive. GC diesel is also very sensitive to load changes. Diesel should only be used for peak-hours, while coal for medium and base-hours. Thus, diesel utilization should be minimized. The subsidy for diesel accounts for 0.003%-0.275% of Kaltim GDRP or around 17 billion to 1.55 trillion IDR of 564.7 trillion IDR of 2015 Kaltim GDRP. Although it is not the exact value, it could be used as the argument to end the fossil era and start to utilize NRE optimally.

To sum up, Kaltim seems to experience the paradox-energy where the abundance of energy cannot guarantee the reliable, sustainable electricity system exacerbated by the syndrome of energy-abundant area. Also, there is a post-fossil threat. High reliance on fossil energy would lead to a disastrous instead of a sustainable energy system. The initiative to consider energy-area compatibility as ordered in RUED will be challenging if the mindset based on energy-abundance syndrome still adheres.

5. Recommendation

As the recommendation, the government should optimally utilize NRE, especially in the new energy development projects. The initiative is conducted, for example, by considering as many aspects as possible, such as energy security, externality, and sustainability principles, to obtain an equal comparison between NRE and No-NRE. The analysis should be long-term oriented. It should beyond the merely tangible benefit-cost analysis limited to the money value but included the intangible values. However, to conduct such of policy is challenging, then it could be conducted in stages. The first step is to change the mindset and end the syndrome, start from the policy-maker, which is then continued to the community.

References

Aditya, N. (2016, February 17). Listrik byarpet di Penajam bikin roda ekonomi masyarakat terhambat. *Merdeka.Com*. https://www.merdeka.com/peristiwa/listrik-byarpet-di-penajam-bikin-roda-ekonomi-masyarakat-terhambat.html

Afful-Dadzie, A., Afful-Dadzie, E., Awudu, I., & Banuro, J. K. (2017). Power generation capacity planning under budget constraint in developing countries. *Applied Energy*, *188*, 71–82. https://doi.org/10.1016/j.apenergy.2016.11.090

Aliev, A. (2017, July 20). Listrik di Kalimantan Timur dan Utara byar pet, ini sebabnya! *WE Online*. https://www.wartaekonomi.co.id/read148240/listrik-di-kalimantan-timur-dan-utara-byar-pet-ini-sebabnya

Andersen, F. M., Baldini, M., Hansen, L. G., & Jensen, C. L. (2017). Households' hourly electricity consumption and peak demand in Denmark. *Applied Energy*, *208*(September), 607–619. https://doi.org/10.1016/j.apenergy.2017.09.094

Asri, N. D., & Yusgiantoro, P. (2020). The energy provision dilemma of coal versus wind from the economic, environmental, and social perspective within the energy security framework. *Defense Journal*, *6*(3), 310–327. https://doi.org/http://dx.doi.org/10.33172/jp.v6i3.1049

Asri, N. D., & Yusgiantoro, P. (2021). *Is sustainability challenging in Indonesia's energy provision? - Fuel type vs externalities in electricity cost analysis*.

Bappenas. (2015). *Regional Development Analysis of East Kalimantan Province 2015*.

Best, R., & Burke, P. J. (2018). Electricity availability: A precondition for faster economic growth? *Energy Economics*, *74*, 321–329. https://doi.org/10.1016/j.eneco.2018.06.018

Bhandari, R., & Stadler, I. (2011). Electrification using solar photovoltaic systems in Nepal. *Applied Energy*, *88*(2), 458–465. https://doi.org/10.1016/j.apenergy.2009.11.029

BPS. (2017). *Statistical Yearbook of Indonesia 2017*.

BPS. (2018). *Statistical Yearbook of Indonesia 2018*.

BPS Jakarta. (2017). *Jakarta in Figures*.

BPS Kaltim. (2017). *Kalimantan Timur Provinces in Figures*.

Carley, S. (2009). Distributed generation: An empirical analysis of primary motivators. *Energy Policy*, *37*, 1648–1659. https://doi.org/10.1016/j.enpol.2009.01.003

Directorate General of Electricity. (2015). *Electricity Statistics 2015*.

Dong, B., Zhang, Y., & Song, H. (2019). Corruption as a natural resource curse: Evidence from the Chinese coal mining. *China Economic Review*, *57*(December 2018), 101314. https://doi.org/10.1016/j.chieco.2019.101314

Dutu, R. (2016). Challenges and policies in Indonesia's energy sector. *Energy Policy*, *98*, 513–519. https://doi.org/10.1016/j.enpol.2016.09.009

East Kalimantan Provincial Government. (2019a). *The general plan of regional electricity*.

East Kalimantan Provincial Government. (2019b). *The general plan of regional energy*.

Friedrichs, J., & Inderwildi, O. R. (2013). The carbon curse: Are fuel rich countries doomed to high CO2 intensities ? *Energy Policy*, *62*, 1356–1365. https://doi.org/10.1016/j.enpol.2013.07.076

Ghimire, L. P., & Kim, Y. (2018). An analysis on barriers to renewable energy development in the context of Nepal using AHP. *Renewable Energy*, *129*, 446–456. https://doi.org/10.1016/j.renene.2018.06.011

Gómez-navarro, T., & Ribó-pérez, D. (2018). Assessing the obstacles to the participation of renewable energy sources in the electricity market of Colombia. *Renewable and Sustainable Energy Reviews*, *90*(March), 131–141. https://doi.org/10.1016/j.rser.2018.03.015

Handayani, K., Krozer, Y., & Filatova, T. (2017). Trade-offs between electrification and climate change mitigation: An analysis of the Java-Bali power system in Indonesia. *Applied*, *208*(August), 1020–1037. https://doi.org/10.1016/j.apenergy.2017.09.048

Hassani, H., Sattar, M., Odulaja, A., & Santoso, W. M. (2018). A statistical approach for a fuel subsidy mechanism. *Energy Policy*, *119*(May), 666–673. https://doi.org/10.1016/j.enpol.2018.04.012

Kennedy, S. F. (2018). Indonesia's energy transition and its contradictions: Emerging geographies of energy and finance. *Energy Research & Social Science*, *41*(June 2017), 230–237. https://doi.org/10.1016/j.erss.2018.04.023

Kosai, S., & Yamasue, E. (2018). Cost-security analysis dedicated for the off-grid electricity system. *Renewable Energy*, *115*, 871–879. https://doi.org/10.1016/j.renene.2017.09.024

Lestari, G. I. (2020, October 27). Puluhan ribu KK di Kaltim belum teraliri listrik meski ketersediaan setrum surplus 550 MW. *Kaltimkece.Id*. https://kaltimkece.id/warta/terkini/puluhan-ribu-kk-di-kaltim-belum-teraliri-listrik-meski-ketersediaan-setrum-surplus-550-mw

López-González, A., Domenech, B., & Ferrer-Martí, L. (2018). Lifetime, cost and fuel efficiency in diesel projects for rural electrification in Venezuela. *Energy Policy*, *121*(March), 152–161. https://doi.org/10.1016/j.enpol.2018.06.023

Majumder, M. K., Raghavan, M., & Vespignani, J. (2020). Oil curse, economic growth and trade openness. *Energy Economics*, *91*, 104896. https://doi.org/10.1016/j.eneco.2020.104896

Marquardt, J. (2014). A Struggle of Multi-level Governance: Promoting Renewable Energy in Indonesia. *Energy Procedia*, *58*, 87–94. https://doi.org/10.1016/j.egypro.2014.10.413

Martosaputro, S., & Murti, N. (2014). Blowing the wind energy in Indonesia. *Energy Procedia*, *47*, 273–282. https://doi.org/10.1016/j.egypro.2014.01.225

McFarlan, A. (2018). Techno-economic assessment of pathways for electricity generation in northern remote communities in Canada using methanol and dimethyl ether to replace diesel. *Renewable and Sustainable Energy Reviews*, *90*(March), 863–876. https://doi.org/10.1016/j.rser.2018.03.076

MEMR. (2015). *Kebijakan dan Strategi Pengembangan EBTKE untuk Memenuhi Target Kebijakan Energi Nasional*. The Ministry of Energy and Mineral Resources.

MF. (2016). *State Budget Information 2016*.

MF. (2018a). *Financial Note and the 2018 State Budget*.

MF. (2018b). *State Budget Information 2018*.

Mundaca, G. (2017). Energy subsidies, public investment and endogenous growth. *Energy Policy*, *110*(October 2016), 693–709. https://doi.org/10.1016/j.enpol.2017.08.049

Necolsen, G. (2018, January 3). Genset 10x1 Megawatt sudah terpasang. *Tribunkaltim.Co*. http://kaltim.tribunnews.com/2018/01/03/genset-10x1-megawatt-sudah-terpasang

Nielsen, H., Warde, P., & Kander, A. (2018). East versus West: Energy intensity in coal-rich Europe, 1800 – 2000. *Energy Policy*, *122*(July), 75–83. https://doi.org/10.1016/j.enpol.2018.07.006

Nouni, M. R., Mullick, S. C., & Kandpal, T. C. (2008). Providing electricity access to remote areas in India: An approach towards identifying potential areas for decentralized electricity supply. *Renewable and Sustainable Energy Reviews*, *12*(October 2006), 1187–1220. https://doi.org/10.1016/j.rser.2007.01.008

Oniemola, P. K. (2016). Why should oil rich Nigeria make a law for the promotion of renewable pnergy in the Power sector ? *Journal of African Law*, *1*(August 2015), 29–55. https://doi.org/10.1017/S0021855315000212

Partridge, I. (2018). Cost comparisons for wind and thermal power generation. *Energy Policy*, *112*(September 2017), 272–279. https://doi.org/10.1016/j.enpol.2017.10.006

Poudineh, R., Sen, A., & Fattouh, B. (2020). An integrated approach to electricity sector reforms in the resource rich economies of the MENA. *Energy Policy*, *138*(January), 111236. https://doi.org/10.1016/j.enpol.2019.111236

Prokal.co. (2019a, May 5). Deritanya eh..!! Setrum di 298 desa masih dilayani Genset. *Kaltim Post*. https://kaltim.prokal.co/read/news/355069-deritanya-eh-setrum-di-298-desa-masih-dilayani-genset

Prokal.co. (2019b, May 5). Di kabupaten ini, masih ada 40 desa yang gelap: 2023 semua teraliri. *Kaltim Post*. https://kaltim.prokal.co/read/news/355068-di-kabupaten-ini-masih-ada-40-desa-yang-gelap

Prokal.co. (2020, October 27). Daya surplus, Kaltim distribusikan setrum ke provinsi tetangga: 69 ribu rumah di Kaltim belum teraliri listrik. *Prokal.Co*. https://kaltim.prokal.co/read/news/378620-69-ribu-rumah-di-kaltim-belum-teraliri-listrik

PT PLN. (2013). *Sistem Ketenagalistrikan Kalimantan Timur dan Utara*.

PT PLN. (2015). *General Plan of Electricity Draft 2015-2034*.

PT PLN. (2016). *The Power Supply Bussiness Plan of PT. PLN 2016-2025*.

Purba, E. N. N. (2016). *Solar power plant application for fisherman's housing in Arungkeke Village, Jeneponto District, South Sulawesi*. Universitas Indonesia.

Riva, F., Ahlborg, H., Hartvigsson, E., Pachauri, S., & Colombo, E. (2018). Electricity access and rural development: Review of complex socio-economic dynamics and causal diagrams for more appropriate energy modelling. *Energy for Sustainable Development*, *43*, 203–223. https://doi.org/10.1016/j.esd.2018.02.003

Sahin, E. S., Bayram, I. S., & Koc, M. (2019). Demand side management opportunities, framework, and implications for sustainable development in resource-rich countries: Case study Qatar. *Journal of Cleaner Production*, *241*, 118332. https://doi.org/10.1016/j.jclepro.2019.118332

Salahuddin, M., & Gow, J. (2014). Economic growth, energy consumption and CO2 emissions in Gulf Cooperation Council countries. *Energy*, *73*, 44–58. https://doi.org/10.1016/j.energy.2014.05.054

Sarita, M. (2018, April 16). Terpaksa pakai Genset karena listrik PLN tak kunjung terpasang, Alkes RSUD banyak yang rusak. *Tribunkaltim.Co*. http://kaltim.tribunnews.com/2018/04/16/terpaksa-pakai-genset-karena-listrik-pln-tak-kunjung-terpasang-alkes-rsud-banyak-yang-rusak?page=all

Satrianegara, R. (2018, February 14). Menteri Jonan: Pembangkit listrik off-grid cocok untuk Papua. *CNBC Indonesia*.

Setyawan, D. (2014). Assessing the current Indonesia's electricity market arrangements and the opportunities to reform. *International Journal of Renewable Energy Development*, *3*(February), 55–64. https://doi.org/10.14710/ijred.3.1.55-64

Slough, T., Urpelainen, J., & Yang, J. (2015). Light for all? Evaluating Brazil's rural electrification progress, 2000 – 2010. *Energy Policy*, *86*, 315–327. https://doi.org/10.1016/j.enpol.2015.07.001

Suárez, J. A., Beatón, P. A., Escalona, R. F., & Montero, O. P. (2012). Energy, environment and development in Cuba. *Renewable and Sustainable Energy Reviews*, *16*(5), 2724–2731. https://doi.org/10.1016/j.rser.2012.02.023

Tarigan, A. K. M., Samsura, D. A. A., Sagala, S., & Wimbardana, R. (2017). Balikpapan: Urban planning and development in anticipation of the post-oil industry era. *Cities*, *60*, 246–259. https://doi.org/10.1016/j.cities.2016.09.012

Veldhuis, A. J., & Reinders, A. H. M. E. (2015). Reviewing the potential and cost-effectiveness of off-grid PV systems in Indonesia on a provincial level. *Renewable and Sustainable Energy Reviews*, *52*, 757–769. https://doi.org/10.1016/j.rser.2015.07.126