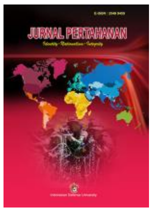
Jurnal Pertahanan

Media Informasi tentang Kajian dan Strategi Pertahanan
yang Mengedepankan *Identity*, *Nationalism* dan *Integrity*
e-ISSN: 2549-9459
http://jurnal.idu.ac.id/index.php/DefenseJournal



THE ENERGY PROVISION DILEMMA OF COAL VERSUS WIND FROM THE ECONOMIC, ENVIRONMENTAL, AND SOCIAL PERSPECTIVE WITHIN THE ENERGY SECURITY FRAMEWORK

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Article Info

Article history:
Received 15 November 2020
Revised 4 December 2020
Accepted 26 December 2020

Keywords:
Electricity generating cost,
Energy security,
Energy provision dilemma,
Environmental and social impacts,
Externalities

DOI:
http://dx.doi.org/10.33172/jp.v6i3.1049

Abstract

The energy security principle demands the fulfillment of availability, acceptability, affordability, accessibility, and sustainability. Under the financial constraints, it is very challenging to achieve. As a result, immediate decisions, often only based on the lowest cost neglecting the overall impacts, are taken. This study aims to reveal the energy provision dilemma through a literature review method and simple calculation analysis. This study intends to exemplify how to conduct an equitable analysis by comparing wind and coal power plants' impacts from the economic, environmental, and social perspectives. This study finds that the mutually complement characteristics of NRE (New and Renewable Energy) and non-NRE (fossil energy sources) raise a dilemma in selecting the energy source, where the financial constraints exaggerate the dilemma. The study also finds that the electricity generating cost of coal is cheaper than wind, but the external costs turn over the result. Coal damages the environment more than wind, but the impacts are often neglected, and society bears the cost. A simple adsorption method could minimize the impacts, but it depends on the producers' willingness to conduct, which eventually by the consumers' willingness to pay the higher price. In the social aspect, both power plants have relatively more equal indirect impacts, but coal's direct impacts are more detrimental than wind. While an energy source may excel the other, considering the specific circumstances is a must. Financial constraints aggravate the developing countries' dilemma between achieving energy security or fulfilling the basic needs and pursuing economic growth.

INTRODUCTION

The energy security principles, which demand the fulfillment of availability, acceptability, affordability, accessibility, and sustainability elements (Ang et al., 2015; APERC, 2007; Narula & Reddy, 2016), are challenging to achieve. While its definitions are diverse, energy security, in general, could be defined as securing the energy sources for the continuity of life, which covers the fulfillment of its all elements. Availability refers to the availability of energy sources in its utilization. Acceptability refers to the public acceptance of the use of an energy source. Affordability is related to how affordable an energy source for the people. Accessibility relates to the access and infrastructure to facilitate the utilization of an energy source. Sustainability is associated with how sustainable an energy source is in its utilization to support life and maintain the environment healthy. To achieve energy security means to achieve the fulfillment of its all elements.

Thus, the energy provision should no longer focus only on the availability but should pay attention to the overall elements equally. As each energy source has advantages and disadvantages, its utilization has its challenges that need to be overcome. NRE (New and Renewable Energy) and non-NRE (fossil energy sources) complement each other, where the latter's disadvantages become the former's advantages, and vice versa. For example, fossil energy sources have an established infrastructure that NRE does not have, allowing rapid development of massive energy provision. On the other hand, NRE enables implementing an off-grid electricity system that is more suitable for an archipelagic country like Indonesia (Asri & Yusgiantoro, 2020b; Hiendro et al., 2013; Shi et al., 2016; Veldhuis & Reinders, 2015). However, as the budget deficiency is still the major constraint, energy provision tends to prioritize the cheaper one, fossil energy (MEMR, 2012; PT PLN, 2018) with less capital-intensive production (Ekholm et al., 2013). In an archipelagic country like Indonesia, the small population in remote islands also makes it difficult for NRE to reach economies of scale. Thus, to immediately fulfill energy needs, fossil energy is more preferred.

However, the thought seems unequal because the selection of energy sources only takes the (lowest) price as the primary consideration due to the financial constraints. Without considering the impacts of its utilization, fossil energy utilization is cheaper than NRE. The electricity generating cost from a coal-fired power plant, for example, is the cheapest among those from diesel, oil, NRE, and nuclear. However, by including the environmental and social impacts due to its use, coal no longer the cheapest (Rhodes et al., 2017; Vujić et al., 2012). Internalizing the externalities doubles and triples the electricity generating cost from diesel and coal-fired power plants, respectively (Asri & Yusgiantoro, 2020a).

NRE is notoriously expensive and technologically advanced (Ghimire & Kim, 2018; Gómez-navarro & Ribó-pérez, 2018; Kennedy, 2018). Those two factors are also the leading cause of NRE utilization in developing countries to be very slow (Dutu, 2016; Martosaputro & Murti, 2014). However, the impacts of the lower-cost fossil energy utilization are too risky to ignore. Please also note that while NRE is very expensive in its initial development, its annual cost is cheaper than non-NRE, as it does not contain fuel cost. Fuel is the crucial component in electricity generating cost as it accounts for 48% to 70% (Partridge, 2018) and even 80% (Asri & Yusgiantoro, 2020a) of the cost. The absence of the fuel cost will considerably decrease the annual cost. It shows how NRE and non-NRE are complementary, where the former's weakness becomes the strength of the latter and vice versa. NRE seems to be superior in abundance (availability) and long, healthy life (sustainability) aspects. However, its utilization may not be optimal caused by inadequate infrastructure (accessibility), unaffordable price (affordability), and its unpopularity (acceptability). Vice versa, the advantages of non-NRE in the other three elements make its utilization more preferable. However, by considering other influential factors such as environmental and social impacts and conducting the overall impact analysis, the decision regarding which energy to use would be more equitable.

As NRE and non-NRE have mutual complementary traits, the dilemma of energy provision arises, prompted by the energy security principle's fulfillment. In developing countries, the dilemma is aggravated by financial constraints. While they are still surviving in fulfilling the more basic needs (malnutrition, well-being, etc.), things beyond these areas tend to be low prioritized (Siddayao, 1992). They, then, favor the production method with low capital cost (Ekholm et al., 2013). They tend to choose those with lower initial cost but higher annual cost, to immediately fulfill electricity needs as electricity is essential for economic activities (Afful-Dadzie et al., 2017). These phenomena are shown by the slow NRE utilization in developing countries (Dutu, 2016; Kennedy, 2018; Martosaputro & Murti, 2014) and by the domination of coal (more than a half) in the Indonesia electricity mix (MEMR, 2012; PT PLN, 2018). The dilemma of energy provision becomes greater as there are financial constraints on one side and the demand for energy security compliance on the other side.

The energy security issue is crucial as energy relates to national defense and national security. In Indonesia, it is as stated in Law on National Resource Management for National Defense (23/2019) and Energy Law (30/2007). Law No. 23 of 2019 states that natural resources are the 'Supporting Components' to strengthen the Main Component in conducting national defense tasks. Energy sources are one type of natural resource. Meanwhile, article 2 of the Energy Law states that energy is managed based on the national resilience's principle. The Elucidation Section of the Law also states:

> Energy resources ... are strategic natural resources and essential for the people's livelihoods, especially … for economic activity … and national security (Law No. 30 of 2007).

It shows how essential energy security is for national security. Its fulfillment is crucial for all countries in the world. The better the energy security performance, the more guaranteed the national security would be (*cet. par*). Thus, in terms of defense and security, deciding which type of energy source to use is also essential, as it in the other sectors. In the defense and security sector, NRE would be ideal and thus be more favored than fossil energy sources, but it would depend on each country's capability to conduct when it comes to reality.

This study hypothesizes that the mutually complement characteristics of NRE and non-NRE cause a dilemma in selecting the energy source, and financial constraints exaggerate the dilemma. This study brought the issues of conducting a more equitable, impartial consideration before deciding which type of energy source to use. The decision-makers should consider the overall impact analysis, which this study exemplifies, by considering as many aspects as possible about power plant options. Thus, the decision regarding which energy type to use will be more impartial.

While many review studies compare and contrast the two types of energy sources in power plants (Katsaprakakis, 2012; Partridge, 2018; Porate et al., 2013; Thomson & Kempton, 2018), there is a gap in connecting it with the energy security aspects. Moreover, to see it from the viewpoint of a less developed country like Indonesia. On the other side, energy security is studied separately and mainly focuses on defining, indexing, and measuring its performance (Ang et al., 2015; APERC, 2007; Narula & Reddy, 2016). Thus, this study tries to fill the gap by conducting a comparison analysis while connecting it with energy security principles. This study also sees a dilemma that developing countries must face in energy provision. On one side, they are forced to fulfill energy needs immediately (pursuing a 100% electrification ratio, meeting economic growth target). However, on the other side, there is also a demand for the energy security principle to fulfill (maintaining a healthy environment and achieving sustainability). It is a dilemma since achieving energy security targets takes a long time and costly, while fulfilling energy needs cannot wait longer for it is the prerequisite of economic activities. To see from the less-developed countries' viewpoint is essential to understand better why providing cleaner, more sustainable energy is hard to conduct.

Many insist on fulfilling the energy security principles in energy provision, but why it is challenging to achieve, especially in developing countries, is rarely investigated. While many only demands energy security to fulfill, this study tries to reveal how difficult it is to achieve under financial constraints. This study is a review study trying to find the reason for the dilemma by assessing the economic, environmental, and social aspects of power plant utilization.

METHODS

This study is a literature review study that compares and contrasts two power plants representing NRE (wind) and non-NRE (coal) sources from the economic, environmental, and social perspective. Numbers and data are taken from previous studies and other related sources, with some adjustments and assumptions, if necessary.

As there is a limitation, there are only three aspects investigated, which are economic, environmental, social. These aspects are selected based on the previous studies' findings, which show that the power plants' utilization considerably impacts these three aspects. In the economic aspect, fuel price contributes 48% to 70% (Partridge, 2018) and even 80% (Asri & Yusgiantoro, 2020a) of the generating cost. In the environmental aspect, externalities due to power plants utilization are inevitable and considerable (Rewlay-ngoen et al., 2014; Sundqvist, 2004), but its internalization is not certainly conducted as it affects the producer's and consumer's welfare (Ding et al., 2014; Krishnan C & Gupta, 2018; Yusgiantoro, 2000). In the social aspect, the operation of power plants indirectly boosts the economy (J. P. Brown et al., 2012; Colombo et al., 2018) while at the same time negatively impacts social life (Gupta & Spears, 2017; Rewlay-ngoen et al., 2014). This study intends to exemplify how to conduct an equal, thorough analysis of two power plant types, which are coal and wind, while at the same time noting that there are financial constraints.

The economic aspect would be a simple calculation of electricity-generating costs from both power plants to show the difference in the generating cost, with and without considering the overall impacts. Please note that the focus is not the calculation, but the resulting cost, before and after considering the externalities. The environmental and social aspects analyses are pure literature review, which review previous studies related to the aspects. While it is essential to calculate the energy security's performance, measuring each energy security element's level in the three aspects is beyond this study's scope. Further study is required to conduct such an investigation.

RESULT AND DISCUSSION

This study compares and contrasts the wind and coal power plant from the economic, environmental, and social perspective based on the hypothesis that NRE and non-NRE are complementary. For example, while NRE to be superior in the availability and sustainability elements, non-NRE excels in the other three (acceptability, affordability, accessibility). However, please note that the superiority of the one over the other is relative, according to the other circumstances. This study tries to provide a more equitable analysis of the pros and cons of both energy types.

As this study is a review, most of this study is conducted qualitatively, except the economic aspect analysis. However, it does not mean that this study is subjective since the discussion and the analyses are conducted based on the evident findings from the previous studies.

The Analysis of Economic Aspect

The economic aspect meant here is the per kWh electricity generating cost (GC). The analysis compares the GC of non-NRE (coal) and NRE (wind) power plants. Within the framework of energy security, the economic aspect is related to affordability, accessibility, and availability. The level of costs determines the price paid by the consumers. The generating cost of NRE is more expensive than of non-NRE. Thus, it requires a subsidy from the government to be more affordable. The same is true of non-NRE, where externalities increase the generating cost. Here is where the affordability lies. Accessibility is related to providing access and supporting infrastructures, such as grids and roads, for electricity transmission and distribution. The development of such infrastructures is included in the initial investment, which will affect the resulting GC. Availability is related to the resources. Following the law of supply-demand, the scarcer supply will increase the price. As coal is non-renewable, coal prices will likely increase in the future.

The Electricity Generating Cost of a Coal Power Plant

Three components of GC in a non-NRE (in this case is coal) power plant are investment cost, fuel cost, and operational & maintenance cost. The cost and calculation method are taken from the previous study (Asri & Yusgiantoro, 2020a). The cost is the average GC from the lowest (57.14 US$/ton with CV 4,200 kcal/kg) and highest (89.40 US$/ton with CV = 6,000 kcal/kg) coal prices (British Petroleum, 2017; MEMR, 2017). By using the formulas used in the previous study (Asri, N.D., 2020b), the calculation obtains the GC from the coal power plant is 5.54 cents US$/kWh (the average of 5.435 and 5.672 cents US$/kWh).

The Electricity Generating Cost of a Wind Power Plant

Instead of three, there are only two components of GC in an NRE (in this case is wind) power plant. Those are investment costs and operational & maintenance costs. As the plant requires no fuel to operate, there is no fuel cost component in GC calculation. The initial cost of a 10kW wind power plant is 24,000-35,000 US$ (the cost decreases as the power plant’s capacity increases). The operational & maintenance costs are about 3% of the initial cost. The power plant’s capacity is assumed to be 10 x 10kW with a fan diameter of 50 m, a-12 years lifetime, and a wind velocity of 6 m/s. Using the formula and adjusted data from the previous studies (Nashar, 2015; Porate et al., 2013; Shaahid et al., 2013; Yusgiantoro, 2000), the calculation (Appendix) obtains a GC of 7.32 cents US$/kWh.

The Comparison of Generating Cost from both Power Plants

The per kWh GC from a coal-fired power plant is 5.54 cents US$/kWh and is cheaper than a wind turbine, which is 7.32 cents US$/kWh. However, the calculation disregards environmental costs or externalities. The externalities consist of external cost and carbon tax, which are about 0.18-2.34 cents US$/kWh (Sugiyono, 2005) or 1.26 cents US$/kWh on average and 44.1 US$/ton (Nasrullah & Suparman, 2010) or 3.396 cents US$/kWh, respectively. By internalizing the environmental cost, the GC from coal increases to be 10.196 cents US$/kWh, which is higher than the GC from the wind.

Externalities are the external impacts due to a production or consumption process that affects an individual, a party, a society, or a community that is not involved in the production and consumption activities. Since its impacts are beyond or do not directly affect the involving parties, the producers and consumers do not consider it. There are positive and negative externalities that could emerge in the production or consumption activities. CSR is positive externalities, while environmental damage a negative externality. While positive externalities benefit the external parties, negative externalities are the opposite. The producers bear the externalities if they conduct a treatment to prevent the waste from polluting the environment. The cost can then be transferred to the consumers, as indicated by the increasing price of a product. In this study, the externalities are negative and caused by electricity production, where neither the producers nor the consumers are willing to bear the cost. Negative externalities are real and detrimental, but it is not accounted for in CG calculation. As neither the producer nor the consumer borne the cost, the society or people living around, who do not produce or consume the electricity, will bear it. Thus, environmental impacts' internalization is essential because it represents the real cost of energy provision (Ding et al., 2014; Rhodes et al., 2017; Yusgiantoro, 2000).

The additional costs, which are the external cost and carbon tax, reflect the damage's magnitude. In practice, the additional costs are used to revitalize the damage caused by electricity generation from coal. On the other hand, a wind turbine may emit pollutants or cause environmental damage, but the impacts are not as considerable as a coal-fired power plant. This observation shows how the inclusion of externalities has increased the GC of coal considerably. As a result, energy security in coal utilization may decrease due to the affordability element's decrease.

The economic aspect evaluation raises a dilemma to select a cheap but dirty or a pricey but clean energy source. While the former is more affordable, has better access but dirty, the latter has a more lasting availability, clean but costly. Considering the externalities will provide a more equitable consideration. However, is it likely to conduct in less developed countries with insufficient budgets? Taking into account the externalities is the second dilemma in selecting the power plant. It then will depend on the decision-makers to decide which one will be used.

The Analysis of Environmental Aspects

The analysis assesses the environmental impacts of both power plants. It will also provide some suggestions on how to minimize or overcome the issues. Within the framework of energy security, the environmental aspects are under the acceptability and sustainability elements. Acceptability is related to the community's acceptance of the power plants' existence. The impacts of the power plant influence the level of acceptance. The more negative the impact, the lower the level of acceptance. Sustainability is related to the fuel's lifetime and the environment's health level once a power plant is operating. A wind turbine is more sustainable than a coal-fired power plant.

The Environmental Impacts of a Wind Power Plant

A wind turbine's operation is believed to reduce human life quality and threaten wildlife (Zerrahn, 2017). Those include the impacts on birds and bats, noise pollution, flicker (turbine spin shadow), a land-competitive characteristic, electromagnetic interference, and visual disturbance.

There are cases of birds and bats hit by the spinning fans and found dead around the turbine. However, closer observations find that the local animals successfully avoid spinning fans. These accidents are common in migratory birds and bats, and the turbine is not the only cause of their deaths. Weather also contributes to accidents. There are at least two suggestions for this issue. The first is by turning off the turbine for a moment when the migration occurs. As turning off the turbine may cause restrictions from the community, socialization seems could minimize it. The second is by adjusting the turbine's height, which is different from the birds' flying altitude (Barclay et al., 2007; Kikuchi, 2008).

The second issue is noise pollution caused by spinning. The spinning fans generate noise about 95-105 dB, higher than the noise generated from human activities, about 35-100 dB. The noise is disturbing, especially if there are more than one turbine is operating. Two suggestions for this issue are selecting the right location and, more technically, modifying the installation. The noise becomes polluting if the turbines are developed around the residential area. Selecting the right location, which is far from the residential areas, is a must. Choosing the right location is also to overcome the unavoidable flicker disturbances. Although it is not detrimental, flicker disturbances are very annoying. Technically, noise could be minimized by reducing the vibration and balancing the turbine, which could be done at the installation stage (Katsaprakakis, 2012). The turbine also generates electromagnetic waves that interfere with radio, telecommunication, and television. By installing anti-magnet and anti-radiation materials in the generator, the issue is no longer a problem (Zheng et al., 2011).

The last issue is related to land use. A wind turbine development is land-consumptive that leads to land-competitive. As the development requires a wide area, there is a land allocation competition for a wind turbine or residents and agriculture. The competition is getting more challenging as the electricity demand and population increase. Moreover, if the wind is the primary energy source, a massive wind farm development will cause visual impact or landscape changes (Otero et al., 2012). The land issues could be solved, first by selecting suitable land, which is the unproductive vacant land and far from settlements. Second, by conducting an approach to the people, especially if the land area is limited. It includes socializing the power plant development and educating the people. An appropriate approach is believed to minimize resistance and increase public acceptance. The resistance emerges due to people's lack of understanding of the power plants' importance or the traditional beliefs opposing the development. The approach can also be applied to other NRE power plants, which, due to the people's unfamiliarity, often get restrictions from the community (Kim et al., 2018; Liebe et al., 2017; Scherhaufer et al., 2018).

The Environmental Impacts of a Coal Power Plant

The impacts of the coal-fired power plants are more evident and detrimental to the environment, living organisms, and people living around. The wastes or the by-products from the burning fuels pollute the ground, water, and air. Its deposit stock pollutes the ground, its wastewater pollutes the water, and its ash pollutes the air. The wastes are very harmful as it contains hazardous materials such as heavy metals and radioactive, which are very toxic and carcinogenic. It also harms humans and living organisms. These materials are diffused in the ground, water, and air, enter the food chain, and eventually accumulate in the living organisms' bodies. As humans at the top of the food chain, the human body contains the highest concentration of those materials (Goodarzi et al., 2008; Papastefanou, 2010; Sanei et al., 2010).

In the future, the impacts will be burdensome to the ecology as the pollutants are accumulated in the environment. The accumulation of the hazardous pollutant causes the decreasing of harvested crops (caused by nitrogen oxide, sulfur dioxide, and acid in the plant, waters, and air), building lifetime (due to acid rains), and life expectancy (caused by the increase of the unhealthy environment-related diseases such as respiratory diseases, heart attacks, and cancers). The emitted pollutants change the condition of soil, air, water, and seas. It also causes the air to become denser, black, and harmful to inhale and causes very destructive acid rains (Rewlay-ngoen et al., 2014; Rodgers et al., 2019; Sakulniyomporn et al., 2011).

However, the detrimental impacts of a coal-fired power plant are likely to prevent by conducting, for example, an adsorption method. The adsorbent is made by modifying materials such as zeolite, surfactant, bentonite, or chitosan. The adsorbents are then applied in the wastewater or chimney of a power plant to prevent the waste from polluting the environment. The main principle of the method is to catch and filter the pollutants (the targeted materials). Some advantages of the adsorption method are relatively inexpensive and easy to apply. Materials to be made as adsorbents are also relatively easy to find. Fly ash from the power plant is also proven to be used as an adsorbent, which means recycling the waste to be more useful (Kołodyńska et al., 2017; Tohdee et al., 2018; S. Wang et al., 2016).

However, despite its ease of use and competitive price, adsorbent's use to pre-treat the wastes before polluting the environment depends on the producers' willingness since it needs money to conduct. The use of adsorbents is an example of a positive externality by the producer. If they are willing to do that, the producers are willing to pay the extra cost, which is the externalities, to prevent the society from bearing the negative impacts. However, it not always depends on the producers. Since internalizing the external cost increases the product's price, it also depends on whether the consumers are willing to pay the higher price. If the product is successful in the market, internalizing the external cost is no longer an issue, like eco-friendly products that popular among the consumers. The problem may arise when the products are sold in a less developed country where the consumers cannot afford to pay more. It shows why it is rather challenging to include the externality into the cost calculation (Ding et al., 2014; Yusgiantoro, 2000).

The Comparison of Environmental Impacts from both Power Plants

The land is the first issue in a power plant development. A wind turbine and a coal-fired power plant development respectively require lands of 2,040 and 1290-25,200 m^2 years/GWh of produced electricity. The development of a wind turbine may demand a larger area than a coal-fired power plant, but it is relative, depending on the number of the power plant will be built (Katsaprakakis, 2012).

The second issue is GHG emission during the operation of the power plant. A Life Cycle Analysis (LCA) obtains that a wind power plant emits 19(±13) g CO_2e per kWh of electricity for every 0.060(±0.058) kWh of used energy (Arvesen & Hertwich, 2012). On the other hand, a coal-fired power plant emits about 71,352 tons of CO_2, 0.547 tons of SO_x, 0.518 tons of NO_x, and 0.165 tons of suspended materials. These particulate materials cause negative externalities (Porate et al., 2013). LCA also shows that the power generation stage generates the highest environmental cost, as of \$50.24. The resource consumption cost and environmental (external) cost during the power plant's life cycle are \$46.01 and \$22.90 per unit of MWh power, respectively (J. Wang et al., 2018).

The cost of externalities occurs in both power plants. According to the emitted pollutants, the cost of externalities of a coal-fired power plant is about 0.06-72.42 cents US\$/kWh, while a wind turbine is about 0-0.8 cents US\$/kWh (Sundqvist, 2004). Conflicts due to wind turbine development could also arise so that the external factors are essential to consider thoroughly to avoid such issues in the future (Gorayeb et al., 2018). However, there are indirect positive externalities of a wind turbine according to the observation toward Altamount Pass and Sawtooth wind turbines in the USA. The Altamount wind turbine operation could avoid a cost of about 650 million US$ to 4.38 billion US$, while Sawtooth about 18 million US$ to 104 million US$. The avoided costs are related to human health and climate change. In the per kWh unit, those externalities costs are about 1.8-11.8 cents$/kWh and 1.5-8.2 cents $/kWh, for Altamount and Sawtooth, respectively (McCubbin & Sovacool, 2013).

Besides the positive externalities, a wind power plant also has another advantage, which is less water-consumed. In utilizing a coal-fired power plant, water is necessary to neutralize the wastewater temperature and separate coal from impurities. Water is also required in the thermodynamic process of the power plant. (Saidur et al., 2011). Thus, a coal-fired power plant must be built in the water-containing areas, but a wind turbine could be anywhere, including in the dry, water-absence areas.

If the externalities are included, 50% of renewable energy should be implemented in the fossil fuel-NRE combined energy system to meet the least cost (Noel et al., 2017). Wind energy utilization would be competitive only if the capacity factor around 35% and at very high coal prices. Alternatively, a carbon price of $73/tCO_2$ would make coal and wind equally costly (Galetovic & Muñoz, 2013). Some residents near the wind turbine would pay $2.56 a month (on average) to keep it in place, whereas residents near the coal-fired power plant are willing to pay $1.82 a month (on average) to remove the facility (Thomson & Kempton, 2018).

The analysis of environmental impacts raises the dilemma between a healthy environment and the price paid. For the producer, the cheaper energy source, which is coal, seems to be more acceptable, but not for the society, as a coal power plant badly impacts the environment. However, making a coal power plant more acceptable depends on the willingness and the ability of the consumers to pay the externalities. In developing countries, it also an issue as the consumers cannot afford to pay more. It is a big dilemma for developing countries where at the same time they must provide clean and affordable energy. A wind turbine has advantages in acceptability and sustainability elements. However, its high cost makes it less preferable for the producers, though not for the society. It then will be on the government’s hand to decide which energy source will be used.

The Analysis of Social Aspects

The social aspects are related to the local economy and social life, such as livelihood, culture, local identity, demographics, and local lifestyle. Within the framework of energy security, the social aspects are related to the acceptability element. How the power plant affects social life, positively or negatively, will determine the level of public acceptance. Social impacts could be direct and indirect. The existence of a power plant allows the emergence of new economic activities such as industry. The emergence of new economic activities that subsequently affect social aspects is the indirect impact of a power plant development. Electricity delivers a positive impact on the economy. Not only the wealth of a country or a district but also the people’s well-being.

Electricity is essential for the economy (Afful-Dadzie et al., 2017). Its existence can multiply the contribution of natural resources such as mining, tourism, crops, sea catches, etc., for the local economy. In tourism, to attract more tourists to visit, the creation or improvement of the amenities is necessary. Such improvement is only possible if there is any electricity support. The establishment of an industry is only possible if there is sufficient electricity support. Once an industry – mining, tourism, agriculture, or others – is established, it will absorb many people to run, which means jobs provision for the local people and will trigger the emergence of supporting economic activities. In the mining industry, the supporting economic activities could be local stalls for the workers, supporting industries to provide raw materials, downstream industries who buy the industry's output, retail markets, etc. The establishment of an industry, which only possible by sufficient electricity support, will create a multiplier effect, through the backward and forward linkages, for the economy. Simultaneously, a power plant's development could also arise a dilemma caused by its negative impacts (Arifi & Späth, 2018; Colombo et al., 2018; Yusgiantoro, 2000).

The increase in employment may be followed by a social life change, reducing the local identity. The existence of the mining industry, for example, on one side will demand more workforce from the local people, but on the other side will entice people to leave their jobs, for instance, as farmers, fishers, or cattlemen, which eventually will change the social landscape. Such an industry may also be built on customary land, which causes conflict and erodes the local culture (G. Brown & Raymond, 2014; Erb, 2016). The development of an industry due to the electricity may emerge the local's response that tends to restrict or oppose it (low acceptability). Thus, the coal-fired power plant seems to have lower energy security than wind due to low public acceptance.

There are two suggestions for social issues. Such a policy to regulate job division with its derivative rules may hinder social change. The first derivative rule concerns the supply of workforce for the newly opened industry, while the second is strengthening traditional livelihoods. For example, if agriculture is the leading sector of the area, then regulations related to the increasing crop yields and the absorption of agriculture products must be strengthened. Strengthening the sector will make the sector more promising and retain those who previously worked in the sector. By implementing such policies, a new industry's development would not significantly change the social aspects. The conflict issue could be resolved through appropriate approaches like socialization and education to the community (Liebe et al., 2017; Scherhaufer et al., 2018). On the other side, at the same time, the industry, during their activities (operation), must be committed not to break or violate the local customs and to respect the local culture and local identity. The involvement of the government is a must during the process. There are always positive (pros) and negative (cons) sides. What should be done is to recognize it well by conducting a thorough evaluation to minimize the disadvantages and maximize the benefits.

The Social Impacts of a Wind Power Plant

There are direct and indirect social impacts of a wind turbine, which could be positive and negative. As explained before, the negative, direct social impacts of a wind turbine are visual disturbances, noise pollution, etc. The impacts become more substantial as the turbines are the primary energy source like in Europe. Its land-consumptive characteristic is another issue that may reduce public acceptance (Katsaprakakis, 2012; Otero et al., 2012). However, there is also a positive, indirect impact of a wind turbine due to its contribution to the economy. It increases total individual income by about 0.2% and job opportunities by 0.4% (J. P. Brown et al., 2012).

By comparing the positive and negative social impacts of a wind power plant, a wind turbine are relatively more acceptable, considering its benefits that exceed the drawbacks.

The Social Impacts of a Coal Power Plant

Like a wind turbine, a coal power plant also has direct and indirect social impacts, which could be positive and negative. The negative, direct social issues of a coal-fired power plant are human displacement and environmental degradation (Zaman et al., 2018). Environmental degradation causes a decrease in natural products (crops, sea catches), which subsequently decreases the people's livelihood. Another, as mentioned before, is pollution-related diseases, which reduce people's quality of life and life expectancy (Gupta & Spears, 2017; Rodgers et al., 2019; Sakulniyomporn et al., 2011). All of those negative impacts lead to a low level of public acceptance.

However, please note that the development of a coal-fired power plant also means the sufficiency of electricity as the prime mover for economic activities. A comprehensive, thorough analysis should be conducted to evaluate the cost and benefit. Ensure that the benefits outweigh the drawbacks so that the power plant receives good acceptance from the community. Public acceptance is essential as it also indicates the social impacts have been successfully overcome (Leipprand & Flachsland, 2018; Song et al., 2017).

The Comparison of Social Aspects of both Power Plants

Both power plants have negative impacts on social aspects as they are developed. However, their existence is also inevitable as they bring positive impacts to society and a country. As energy (in this case is electricity) is the prerequisite of economic activities, a power plant's development will provide more jobs. However, its negative impacts are also inevitable. It could change social life or local identity. While both power plants bring positive and negative impacts on society, the weight of the advantages and disadvantages are relative rather than absolute. Social aspects are also more intangible than tangible, which is difficult to measure in a unit value. For example, the development of a coal-fired power plant causes resettlements, which can also occur in wind turbine development. What happens in a new industry establishment as the indirect effect of a coal-fired power plant development also occurs in a wind turbine. While the negative impacts are specific to the power plant's type, both also deliver positive impacts, which is an economic improvement. Thus, to equally compare the impacts should consider the area's circumstances.

To sum up, two things should be noted, the aspect of energy security focused on and the area's specific circumstance where the power plant is built. For example, if the focus of energy security is sustainability and an area is windy, then a wind turbine development seems more suitable. The next consideration is the type of industry that will be developed that is suited to the area's potency.

The Dilemma under the Financial Constraints

The previous sections show how the mutually complement characteristics of NRE and non-NRE raise a dilemma in energy provision. In the economic aspect, coal excels in affordability and accessibility, while the wind in more lasting availability. In the environmental aspect, the wind has all the advantages (acceptability and sustainability) over coal. In the social aspect, coal seems to have less acceptability than wind, as its direct impacts are also more detrimental.

From the viewpoint of developing countries, the dilemma is even more remarkable. Under a limited capital, the investment of electricity provision tends to be allocated to those with less capital-intensive, although it will lead to more considerable environmental damages (Ekholm et al., 2013). There are at least two reasons why and how the dilemma arises. First is related to the national priority, which will first ensure the fulfillment of more basic needs in life, such as food, health, well-being, etc. The second is related to the national interests in economic development to improve national welfare. As their financial capabilities are limited, the less-developed countries will prioritize those under the priorities. It seems impossible to maintain environmental health when people live in unhealthy conditions (hunger, malnutrition). It is also impossible to use clean energy sources while the population lives in dirtiness without a proper sanitation system.

As Siddayao (1992) argues, there are immediate, more basic needs, such as malnutrition, health, hunger, etc., that developing countries should meet first before concerning the issues caused by energy development such as resource depletion and environmental degradation. As a result, the latter issues will get a low priority in many emerging countries. Moreover, as the capital is limited, the energy investment decision tends to consider the least opportunity cost, which is the minimum sacrifice (lost) to get the maximum benefit. Under financial constraints, the developing countries will tend to choose the cheapest energy source regardless of the impacts, as they still have more immediate problems to solve.

As electricity is essential for the economy, its provision will positively boost the economy. Vice versa, if there is a delay in its fulfillment, the economy will grow slower or minus. Thus, how immediate the electricity is fulfilled will (in general) affect how fast or high the economy will grow. In Ghana, a shortfall in electricity provision causes a GDP decline by 1.5%. There are positive and timing relationships between electricity provision and the economy. Under the financial constraints, the electricity generation planning tends to use the energy source with lower capital cost but higher annual cost, instead of delaying it (and waiting until the budget enough to pay the more expensive, cleaner energy source), as the delay time means the delay in economic performance or the reduction in GDP growth (Afful-Dadzie et al., 2017). It shows that under budget deficiency, the economy would not be sacrificed in favor of clean energy utilization or the accomplishment of energy security principles.

The Energy Security of Coal vs Wind in terms of Defense and Security

The importance of energy in national security can be classified into three levels, namely the primary (essential), secondary, and tertiary levels. At the primary level, energy plays a role in supporting maintaining the state's existence and sovereignty. At this level, energy security refers to securing the logistic chain for ongoing and unexpected military operations. Securing a logistic chain includes sufficient quantity and affordable prices of energy. At the primary level, energy security must ensure that the military can carry out its functions properly. At the secondary level, energy security includes the availability element of energy to support all domestic activities that require energy. At the tertiary level, energy security functions to maintain national economic performance (Cornell, 2009). It can be seen that energy security from a defense and security perspective is vital so that its performance must always be maintained, one of which is by selecting the right energy sources.

The importance of energy for defense and security is vital, as also stated in Laws. Ideally, it is crystal clear that NRE (in this case, Wind) is favored more than coal, especially for its availability and sustainability in supporting military operations. Coal is risky, especially in terms of availability, which cannot last longer (nonrenewable). However, each country will assess and adjust its capability in selecting which energy source to use for this vital sector when it comes to reality. Thus, just like the energy policy for other sectors, selecting the type of energy sources in the defense and security sectors is also essential but, at the same time, creates a dilemma. Careful considerations that examine all aspects are required before deciding which energy sources to use for the defense and security sectors.

CONCLUSIONS AND RECOMMENDATIONS

An immediate energy (electricity) provision is a must, but neglecting the overall impacts is too risky. This study tries to provide a more equitable analysis of the comparison between wind and coal power plants considering the energy type to use. This study has successfully revealed that the complementary characteristics of NRE and non-NRE raise a dilemma in energy provision, and the financial constraints aggravated the dilemma.

The economic aspects are related to the elements of affordability, accessibility, and availability. The electricity generating cost of a coal-fired power plant is cheaper than a wind turbine, but they become more comparable when the externalities are internalized. The dilemma arises whether to use more affordable but dirty energy or a longer available and clean but pricey energy. The second dilemma arises as there is the externality, whose internalization will change the cost.

The environmental aspects are under the elements of acceptability and sustainability. The utilization of a coal-fired power plant negatively impacts the environment and living organisms. However, such a method as adsorption is likely to apply to minimize the impacts. A wind turbine also negatively impacts the environment, but the negative impacts are relatively not as significant as those of a coal power plant. By conducting socialization, installing some technical tools, and locating it in the right location, the issues are likely to solve. In a coal-fired power plant, to solve the issues are more complicated since it involves the producers' willingness to consider the externalities, which depends on the consumer's willingness to pay the higher price. The environmental aspect analysis shows the dilemma of maintaining a healthy environment, and the price must be paid.

The social aspects are closely related to acceptability. As electricity is the prerequisite of economic activities, power plants do not always deliver negative impacts. The development of a power plant leads to multiplier effects that positively affect the economy. However, it may also change the social landscape. Some companion policies are required to ensure that the benefits outweigh the drawbacks.

Financial constraints exacerbate the dilemma for two main reasons. First is the dilemma between fulfilling the more immediate, basic needs (food, health, well-being) or investing in more expensive, clean energy technologies. Second is the dilemma between providing a more sustainable energy system (developing eco-friendly, less harmful power plants) in a longer waiting time with a risk of slowing economic growth or providing the powerplants soon following current financial capabilities (regardless of its impacts to the environment) to maintain the economic performance.

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Appendix

This study calculates the GC of a coal power plant by using the equations used in the previous study (Asri & Yusgiantoro, 2020a). The equations and the calculation are not presented here as it already refers to the previous study and to avoid repetition.

GC of a wind turbine is obtained by dividing the annual cost with annual energy output. The annual cost is the sum of the annual operating cost and the ratio of initial cost and expected life, while the annual energy output is the multiplication of power with operating time. Power is calculated by using the formula in Equation 1.

$$P = 0{,}5 \text{ x } \pi r^2 \text{ x } \rho \text{ x } v^3 x\ \eta \quad \dots\dots\dots\dots\dots \quad (1)$$

Where:
P : Power
r : radius of fan (m)
ρ : air density (1,23 kg/m^3)
v : wind velocity (m/s)
η : power plant's efficiency (± 21 %)

Table 1. The Components of Generating Cost of a Wind Turbine

Costs Components	US$
1. Investment Cost	
- Investment of the instruments	
a. Turbine	24,000
b. Tower	1,000
c. Inverter	9,000
d. Battery	950
e. Power cable	63
Sub Total of the Instruments costs	*35,013*
- Installation Cost	
f. Foundation	421
g. Installation cost	211
Sub Total of the Installation costs	*632*
Total of the Initial Investment	***35,645***
2. Annual Cost	
a. Field operator	253
b. Operational materials	63
c. Regular maintenance	105
d. Spare parts	105
e. Depreciation*	2,918
Total of the Annual Cost	***3,444***

Source: Processed by Authors, 2020

*) Straight-line depreciation (Yusgiantoro, 2000):
Depreciation rate = 100 %/lifetime of the tool
= 100 %/12
= 8,33 %
Thus, depreciation/year = 8,33 % x USD 35,013
= USD 2,918
(assuming 1 US$ = Rp 14,000)

The calculation obtains GC of the wind turbine is 7.32 cents US$/kWh **.

**) the per kWh cost is calculated for a turbine with a power of 10 kW. The results are the same for ten power plants with a total power of 100 kW.