Energy pricing and policies development for geothermal energy in Indonesia

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Abstract

The electricity needs in Indonesia is estimated to be increased per year in the next couple of years. The Indonesia State Electricity Company (PLN) mostly supplies electricity for Indonesia from fossil power plants. Stock of fossil raw material for energy is very limited and will be depleted within a certain period. On the other hand, the use of fossil fuels is also contributing to the greenhouse gas emissions in the world. Alternatively, Indonesia has several renewable energy resources that can provide sustainable reserve energy and more eco-friendly as well. However, presently, utilization of renewable energy is very low. Therefore, this research is conducted to estimate the energy pricing of geothermal, diesel, and coal power plant that has internalized its external cost using effect of production and benefit transfer method. A Multi Criteria Decision Making (MCDA) method is also used for policy analysing to encourage the development of geothermal power plant as a substitution alternative of diesel and coal energy. The results show that the estimated energy price of each source with internalizing the external cost are coal power plant (9,94 cents/KWh), diesel power plant (7,63 cents/KWh), and geothermal power plant (1,18 cents/KWh) respectively. Furthermore, based on MCDA for policy designing, after considering environmental, social, and economic criteria of power plant development, geothermal power plant has the highest score (*business as usual and feed in tariff + internalization of external cost*) compared to coal and diesel power plant. Based on the results, the power plant that should be prioritized to be developed is geothermal power plant in substituting diesel and coal power plant. This could be a solution to fossil resources depletion and environmental degradation caused by fossil power plants. Geothermal energy indeed cannot replace the whole coal and diesel energy supply due to its limited capacity. Technology and science development for geothermal energy are the important things to raise the use of this power plant source as well as to reduce emission and to arrange the stock of diesel and coal energy.

Keywords: *Energy pricing, geothermal, externality, effect on production, multi criteria decision making*

1. Introduction

Indonesia's demand for energy, particularly electricity is expected to increase by 8.4 percent per year [1]. Almost 90 per cent of the electrical energy used in Indonesia is produced from fossil power plants such as coal, diesel, and gas [2]. The dependence on fossil energy as power plant source will be a problem in the future. Petroleum potential is predicted to run out within the next 23 years, whereas approximately 83 years for coal, and 55 years for natural gas, assuming no new fossil fuel resources are found and the production rate is constant [3]. Besides, the fossil energy use also contributes to global greenhouse gas emissions by 57 percent. The impact of that emissions are related to disruption in human health , the decline in the availability of water and increase drought in the latitude , food threat , an increase in the coral bleaching , an increase in morbidity and mortality due to heat waves , flood and dryness [4]. Environmental impact can produce costs for other people outside electricity generating activity. This case is called Externality Cost [5] Fossil energy limitations forces the parties to seek alternative energy sources such as geothermal, wind, nuclear, sun, waves, and water. Geothermal is one of the renewable energy sources that has huge potential (28.5 GW), but the utilization ratio reached only 4.17 per cent of its potential [2].

The increase in geothermal energy utilization is relatively slower compared to coal energy. The average growth rate of geothermal electrical energy production in Indonesia is 2.49 per cent per year while coal reaches 5.59 percent per year [2]. The slow development of geothermal energy utilization is related to the lack of investors' interest due to the high investment cost, the complexity of bureaucracy, the disparity in operating costs and high selling prices compared to fossil energy, and lack of incentives [6]. In order to meet the electricity needs in the future, thus it's important to design policy formulations for electrical energy development. The considerations that were used in making policy of electrical energy development are the economic aspect , social and environmental aspect where the policy made should take into account (internalization) the environmental cost (external cost) from electricity production activity. Based on the problem description, the objectives of this research are:

1. To estimate the electrical energy pricing of geothermal power plant, diesel power plant, and coal power plant after internalization of external cost.
2. To analyse the proper policy for developing geothermal power plant as alternative electricity energy source instead of diesel and coal power plant.

2. Methodology

2.1 The estimation of power plant production cost

The cost of power plant generation per KWh is estimated by the amount of costs that have been or expected to be incurred, and then is divided with the production or the amount of power generated during a period. The elements of power plant production cost generally consist of some specific costs, presented in table 1:

Table 1 Production cost of generating electricity

Production Cost	Elements
Capital Cost	Investment cost
	Labour cost
	Raw material cost
Operational & Maintenance	Maintenance cost
	Licences Fee
Other Cost	Depreciation cost

The capital cost is the cost of investment for power plant construction. Operating and maintenance costs consist of labour costs, raw material cost, and maintenance costs. Maintenance costs refer to the payments of power plant generation maintenance. labour costs refer to the all transport payments of the power plant generation employees include salaries, wages, health care, and others.. A mathematical model for the electricity production costs can be written as follows [7,8]:

$$AC = \frac{TC}{Q} \quad (1)$$

$$TC = C_1 + C_2 + C_3 \quad (2)$$

Description:
AC = the average production cost of generated electricity per kWh (IDR / KWh)
Q = the amount of electricity produced in a given time unit (KWh)
TC = total cost of electricity production (IDR)
C1 = the capital cost (capital cost) (IDR)
C2 = the operation and maintenance cost (O & M cost) (IDR)
C3 = other cost (IDR)

2.2 Energy pricing estimation by internalizing the external cost

Generally, any costs incurred by the producer such wages, cost of raw materials, machinery, energy, and the other are well known as the private cost and will be stated and be counted on the profitability statement of the company. However, there are several types of costs while producing goods/services that do not appear in the company's profitability statement i.e. the actual costs borne by society, or called as *external cost*.

To estimate the negative externalities costs of air emission from power plants, a benefit transfer approach is used. The health damage cost that is cited from the research results of Wijaya [9] and Widiyanto et al [10] is employed for the benefit transfer value. The specific of air emissions considered in this study are SO_2 and CO_2. The equation used is as follows [9,10]:

EC = TE x UD (3)

Description:
EC = External Cost (Cents/KWh)
TE = Emission level of SO_2 and CO_2 (gr/KWh)
UD = Unit damage cost of SO_2 and CO_2 (Cents /gr)

To estimate the output level that socially efficient, then the decisions on resource use should be included in the calculation of both types of fees i.e. private costs and external costs. The estimation of social cost is shown as follows [5, 11]:

Social Cost = Private Cost + External (Environmental) Cost (4)

2.3 Policy formulation of geothermal power plant

Making decision of any problems with the various determination criteria is often involved the competition among groups, the conflict of goals, and different types of information [12]. Problems with those various criteria can be solved by applying the Multi Criteria Decision Analysis (MCDA) through the Technique for Order Preference by Similarity to Ideal Solution (TOPSIS) approach. The simple principle in determining the choice by TOPSIS is the alternative options refered to the closest option of the positive ideal solution and farthest from the negative ideal solution [13]. The steps in applying TOPSIS approach is as follows [14,22]:

1. Build a Decision Matrix

It is assumed that there are *m* number of alternative $A_i(i = 1,2, \dots, m)$ which will be evaluated against *n* number of criterias $C_j(j = 1,2, \dots, n)$. The criteria and sub-criteria that are used in policy analysis are shown in Table 2.

Subjective assessment is gathered from the policy makers (decision maker) in the determination of the vector weights $W = (w_1, w_2, \dots, w_j, \dots w_j)$. Vector weight (W) represents the relative importance of *n* criteria $C_j(j = 1,2, \dots, n)$ of the decision. The decision matrix is shown in the following matrix:

$$D=\begin{array}{c} \\ A_1 \\ A_2 \\ \cdots \\ A_m \end{array}\begin{array}{c} \begin{array}{cccc} C_1 & C_2 & \dots & C_n \end{array} \\ \begin{bmatrix} X_{11} & X_{12} & \dots & X_{1n} \\ X_{21} & X_{22} & \dots & X_{2n} \\ \vdots & \vdots & \ddots & \dots \\ X_{m1} & X_{m2} & \dots & X_{mn} \end{bmatrix} \end{array} \quad (5)$$
$$W = W_1 \quad W_1 \quad \dots \quad W_n$$

Table 2 Criteria(s) and Sub-criteria(s) of the policy decision

Criteria	Sub Criteria	Unit
Economy (Eco)	Price (C1)	Cents/KWh
	Cost (C2)	Cents/KWh
	Stock (C3)	Years
Social (Soc)	Land Conflict (C4)	Likert scale (1-5)
	Employment (C5)	Person/KWh
	Cultural Changed (C6)	Likert scale (1-5)
Environment (Env)	Air (C7)	Kg/MWh
	Noise (C8)	dBA/KWh
	Water (C9)	Ph

Source:[15]

2. Estimation of normalized decision matrix

A projected value of each criterion can be generated from the calculation of the normalized decision matrix. The equation used to calculate the normalized decision matrix is as follows:

$$r_{ij} = \frac{x_{ij}}{\sqrt{\sum xij^2}} ; i = 1, \dots, m; j = 1, \dots n ; \quad (6)$$

Where:

x_{ij} : represents the intersetion of each alternative and criteria

r_{ij} : represents the normalized the intersection of each alternative and criteria

3. *Estimation of weighted normal decision matrix*

The calculation of the weighted normal decision matrix (V_{ij}) is using the following equation: $V_{ij} = w_j r_{ij}$, (7)

$i = 1, \dots, m; j = 1, \dots n$

where :

w_j : represent the weight of criterion j and the number of overall weight is 1

$$(\sum_{j=1}^{n} wj = 1) \quad (8)$$

4. Determination of positive ideal solution (A^{+}) *and negative ideal solution* (A^{-})

The calculations used to obtain a positive ideal solution (A^{+}) and negative ideal solution (A^{-}) is using the following equation:

$$A^{+} = \{v_1^{+}, \dots, v_n^{+}\}\{(\max_j V_{ij}, i \in I) | (\min_j V_{ij}, i \in J)\} \quad (9)$$

$$A^{-} = \{v_1^{-}, \dots, v_n^{-}\} = \{(\min_j V_{ij}, i \in J) | (\max_j V_{ij}, i \in I)\} \quad (10)$$

Where v_i^{+} denotes the maximum value of V_{ij} and v_i^{-} denote the minimum value of from V_{ij}. I is associated with the benefit criteria and J is associated with the cost criteria.

5. *Determination the distance of each alternative determined*

After determining the positive ideal solution and negative ideal solution, the distance of each alternative can be determined by using equation 11 for positive ideal solution and equation 12 for negative ideal solution;

$$d_i^{+} = \left\{\sum_{j=1}^{n} \left(v_{ij} - v_j^{+}\right)^2\right\}^{\frac{1}{2}}, i = 1, \dots m \quad (11)$$

Alike for a positive solution, for negative ideal solution is written as the following equation

$$d_i^{-} = \left\{\sum_{j=1}^{n} \left(v_{ij} - v_j^{-}\right)^2\right\}^{\frac{1}{2}}, i = 1, \dots m \quad (12)$$

6. *Estimation of the closeness coefficient (C_i).*

The estimation of the closeness coefficient is a measurement that is used to rank each alternative. C_i calculation has been done through the following equation:

$$C_i = \frac{d_i^{-}}{(d_i^{+} + d_i^{-})} ; i = 1, \dots, m \quad (13)$$

where C_i is a final value of an alternative in the calculation using the TOPSIS approach.

7. Sequence value determination

The sequence of values is aimed to get the best solution of the problems of the electrical energy. The alternatives to the highest closeness coefficient C_i are the best choices.

8. Sensitivity analysis

There are some changes to the weight of each criterion i.e. equal to 0.111 for each criterion (equal rate). Furthermore, there is a change in price and costs for each alternative of power plants. The amount of the increasing price is in accordance with the rules of the Ministery of Energy and Mineral Resources Indonesia Regulation No.17 Year 2014. The amount of changes in the cost criteria is in accordance with the amount of social costs contained in the results of second research objective.

3. Results

3.1 Energy pricing with the internalization of external cost

In producing the electricity, each power plant generally requires several production costs i.e. investment costs, labour wage, raw materials, maintenance, and other costs. These costs can be classified into a private cost due to not including the externalities costs. The external costs incurred and to be borne by other parties outside the company that produces the electricity. The external costs arising from electricity generation is calculated through the costs of losses due to water quality changes that causes production changes, and health costs arising from changes in the quality of the environment.

External costs / damage cost for power plant generation are obtained using the transfer benefit approach. The externality costs are shown in Table 3 is for diesel power plant (DIESEL PP), coal power plants (COAL PP), and geothermal power plants (GEOTHERMAL PP) associated with the changes in air and water quality. The study conducted by Wijaya (2010) [9] and Widiyanto et al (2003) [10] used the health damage cost to estimate the negative externalities of air pollution from DIESEL PP and COAL PP. Air emissions released by each plant then multiplied by the health cost to obtain the external costs. Air emissions are calculated by Wijaya (2010) [9] is SO_2 and CO_2. The equation used to obtain the monetary value of these externalities is shown in the Equation 3.

The COAL PP is a plant that produces carbon dioxide (CO_2) in the highest quantity among others. The highest unit damage cost is the cost of the damage caused by SO_2 emissions derived from COAL PP. The emissions level of each pollutant and unit cost of damage is shown in Table 3.

Table 3 Air emission level and unit and total damage cost of each power plant

No.	Type of power plant	Emission level (gr/KWh)		Unit damage cost (cent/gr)		Total damage cost (cent/KWh)		
		SO_2	CO_2	SO_2	CO_2	SO_2	CO_2	Total
1	GEOTHERMAL PP	0.15	27.2	1.5	0.003	0.23	0.08	0.31
2	DIESEL PP	2.01	722	1.5	0.003	3.02	2.17	5.18
3	COAL PP	4.36	922	1.5	0.003	6.54	2.77	9.31

Source: [9]

Power plant generation should include externalities costs into the electricity production costs (internalization). The objective of its external cost internalization is to achieve socially efficient output level. The calculation of production costs and external costs are presented in Table 4.

Table 4 Costs for power plant generating

Type of power plant	Private cost (Cents/KWh)						Damage cost (Cents/KWh)	Social cost (Cent/KWh)
	Investment cost	Labour cost	Raw material cost	Maintenance cost	Others cost	Total private cost		
	1	2	3	4	5	6	7	8 = 6+7
GEOTHERMAL PP	0,06	0,02	0,77	0,02	0,00	0,87	0,31	1,18
DIESEL PP	0,16	0,05	2,18	0,05	0,01	2,45	5,18	7,63
COAL PP	0,04	0,01	0,56	0,01	0,00	0,63	9,31	9,94

Source: * [2]

It can be concluded from Table 4, the highest social cost for electricity generation occurs on the coal power plants, diesel power plant, and geothermal power plant respectively. These results will show different result if we only consider the private cost, whereas the geothermal power plant has the second highest cost after diesel power plant.

In the determination of energy electricity pricing, the government should consider for social cost relating to every power plant. Power plant with low social cost must be given an incentive or premium price, because they give low impact to our environment. On the other hand, government should impose high tax especially environment tax on power plants with high social cost. For example in 1970, US President made a regulation for emission tax of 15 cents per pound of sulfur emission from large power plants [23].

3.2 Policy analysis of geothermal power plant development

The increasing population and economic growth will indeed increase the demand for electrical energy in future. The limited reserves of fossil energy resources as the primary energy source for electricity generation will cause problems for energy security, particularly electricity. Thus, a policy is needed that takes into account various aspects such as economic, social and environment in order to develop new and renewable electrical energy source for the future.

This study shows the results of the policy analysis of three type of electrical energy development which has taken into account a wide range of criteria. The detailed explanation of the criteria and sub-criteria used in this study can be seen in Table 1. The process of the decision to determine the best power plants which already considers the economic, social, and environmental criteria obtained through the following steps:

1. *The decision matrix*

A nine (9) sub criteria $C_j(j = 1,2,\ldots,9))$ as a component of the three main criteria and three alternatives$(A_i(i = 1,2,3))$ of each criteria is compiled in the decision matrix for power plant development to determine the score. The weight assessed by the policy maker (stakeholder*)* is shown in Table 5. The policy maker interviewed in this study are the key persons of National Energy Council , academics and researchers, Electrification Indonesia Society Organization, and power plant corporation represented by PT IP which has three power generation plants (GEOTHERMAL PP, DIESEL PP, and COAL PP). Each of stakeholders weights each of sub criteria. Average weight values of all stakeholders will be used as a reference in the calculation using TOPSIS. The decision matrix of best power plants is presented in Table 5.

Table 5 Decision matrix

Alternative	**Criteria**								
	Economy			**Social**			**Environment**		
	Price (C1)	**Cost (C2)**	**Stock (C3)**	**Land conflict (C4)**	**labour (C5)**	**Culture (C6)**	**Air (C7)**	**Noise (C8)**	**Water (C9)**
GEOTHERMAL PP *(A_1)*	0,97[a]	0,87[a]	100[b]	3[c]	91[d]	3[c]	27,2[e]	56,28[g]	6,58[g]
COAL PP (A_2)	0,68[a]	0,63[a]	83[b]	4[c]	29[d]	4[c]	922[f]	62,78[h]	7,78[h]
DIESEL PP (A_3)	2,75[a]	2,45[a]	23[b]	3[c]	73[d]	2[c]	722[f]	71,70[h]	7,71[h]
Weight (W)	0,155	0,118	0,13	0,128	0,118	0,095	0,103	0,078	0,078

Source :

a : [2]	e: [17]	h : [19]
b : [3]	f: [10]	i : [20]
c : Primary Data 2015	g: [18]	j : [21]
d :[16]		

2. *Determination of decision*

The calculation for the decision matrix is normalized using Sanna Software for the analysis. The results obtained in the processing using the software shown in closeness coefficient table for each alternative which are presented in Table 6. This coefficient is the final score that is calculated to gather the best sequence of the offered alternatives. The geothermal power plant (GEOTHERMAL PP) is chosen as the best power plant generation, followed by the coal power plant and diesel power plant.

The next analysis is associated with a sensitivity analysis to recognize the effect that occurs when there are some criteria changes, especially in sub-economic criteria i.e. cost and price. There are two changes scenarios used i.e. Feed in Tariff (FIT) government policy scenario for renewable electricity generation, and the equal weight scenario for each criteria (Equal Rate/ER). The first change is the equal weight between coefficient (BAU + ER). The next analysis is based on changes in price and cost of each alternative and weighting criterion in accordance with the key person results (FIT + KP).

The results with the prices and costs changes and equal of weightage criteria for each criterion (FIT + ER) prove that geothermal power plant option be the first choice for the electricity energy development. Based on the results shown in Table 6, the government as a policy-maker should prioritize the development of geothermal power plants to fulfil the national electricity needs. If the government implements the *business as usual* (BAU) model for electricity source development based on the weight criteria affirmed by the key persons (BAU+KP), then the power plant choice beside the GEOTHERMAL PP is the DIESEL PP and then the COAL PP. Furthermore, if the government chooses the business as usual scheme with equal weighting criteria (BAU+ER), then the power plant development choice is GEOTHERMAL PP, COAL PP, and DIESEL PP respectively.

Table 6 The closeness coefficient calculation results and sensitivity analysis of the power plants development

Alternative		**With sensitivity analysis**		
	BAU + K.P	**BAU+E.R**	**FIT+K.P**	**FIT+E.R**
GEOTHERMAL PP	**0,67161**	**0,75598**	**0,69232**	**0,76977**
DIESEL PP	0,42080	0,34153	0,43104	0,35208
COAL PP	0,38004	0,36807	0,24527	0,25351

Description:
BAU+KP : price and cost based on *business as usual* and weight based on *key person*
BAU+ER : price and cost based on *business as usual* and weight based on *equal rates*
FIT + K.P : price based on *feed in tariff*, cost based on social cost, and weight based on *key person*
FIT + E.R : price based on *feed in tariff*, cost based on social cost, and weight based on *equal rates*

4. Conclusion

The energy pricing for COAL PP is the highest after considering social cost, but if only considering the private cost, then DIESEL PP has the highest energy price. Moreover, the sequence of power plant alternative that has the highest score to be developed after considering the economic, social, and environmental criteria are GEOTHERMAL PP. DIESEL PP become the second largest priority for power plant development, but when there is a change in weighting criteria be equal rate, thus the second priority for power plant development is the COAL PP. Therefore, government can encourage any policies that are able to accelerate the development of renewable energy such as the provision of incentive, removing or reducing the import duty and tax for renewable energy company, as well as conduct an internalization of external cost policy for the electricity production in Indonesia.

Particularly to optimize the potential of geothermal power plant, the government is advised to ease the licensing for exploring the geothermal source, increasing the purchasing price of electricity, and invest for the information development related to geothermal resources as well as the development of technology and human resources. This should be a concern in accordance with the Indonesia National Energy Blueprint 2006-2025 so that target of 5 per cent electrical energy from geothermal could be realized. Furthermore, it still needs a technical research on environmental quality and public health in the area around the power plant.

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