Application of the delphi method to new renewable energy assessments in power plants in North Sumatra province

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Abstract. New renewable energy assessment on power plants is one of the solutions that can be developed in order to increase the utilization of new renewable energy as a source of electrical energy in electricity generation and also to realize national energy security. Before conducting a new renewable energy assessment on a power plant, the steps that must be taken are determining the criteria and subcriteria. Determination of criteria and criteria for new renewable energy assessment at the power plant is carried out using the Delphi method. The Delphi method is a systematic and interactive method, which depends on a panel of independent experts. Delphi is based on the principle that estimates from expert structured groups are more accurate than those from unstructured or individual groups. In this study the Delphi questionnaire was distributed. Where the contents of the questionnaire are to determine the criteria and subcriteria in new renewable energy assessment at the power plant. The questionnaire was distributed to 3 respondents who were considered experts in their fields, namely new renewable energy at the power plant. The results of the distribution of the questionnaire are the criteria for evaluating new renewable energy used in the study consisting of 4 criteria namely technological aspects, economic aspects, environmental aspects, and social and political aspects developed into 16 subcriteria namely energy efficiency, security risk, energy production capacity, investment costs, operating and maintenance costs, financial risk, payback period, methane gas emissions, CO2 emissions, CO emissions, land use, ecosystem impacts, labor, political support / policy, human health impacts, social benefits.

1. Introduction

Renewable energy is energy derived from renewable energy sources (Law No. 30/2007). A more detailed definition is a source of energy produced from energy resources that naturally will not run out and can be sustainable if managed properly, including: geothermal, biofuel, river water flow, solar heat, wind, biomass, biogas, ocean waves and depth of the sea (PerPres No.5 / 2006). [1-5]

In the past two decades, consumption of fossil fuels throughout the world has significantly increased the lack of energy sources, rising energy prices and increasing amounts of pollutants released into the environment. For this reason, developing alternative energy sources is very important to reduce the future of the energy crisis and reduce the negative effects of pollutants on the environment. One popular class of alternative energy sources is renewable energy sources. Especially in Indonesia, renewable energy is available in the form of solar power, hydropower, geothermal energy, wind energy and biomass. Each type of renewable energy source has advantages and disadvantages, so the most appropriate selection of the sources between them is very important to get optimal benefits [6-10]. The following can be seen in the development of the installed power of PLN power plants according to the power plant (MW), from 2015 to 2017 in table 1.
Table 1. Development of the installed power of PLN power plants (MW) in 2015 – 2017.

| Year | Diesel power | Steam power | Steam Gas Power | Mini Hydropower | Hydropower | Total |
|------|--------------|-------------|-----------------|-----------------|------------|-------|
|      | Isolation system | Interconnecton System |                |                  |            |       |
| 2015 | -            | 229.36      | 1.150           | 340.2/3         | 817.88     | 7.50  | 246.00 | 2.791,37 |
| 2016 | -            | 396.00      | 1.370           | 243.0/0         | 818.00     | 7.50  | 246.00 | 3.080,00 |
| 2017 | -            | 396.00      | 1.370           | 245.0/0         | 818.00     | 7.50  | 246.00 | 3.083,00 |

Source: Indonesian Statistics Agency

Based on these data, it can be seen that for the electric power owned by North Sumatra Province, it is sufficient to meet the electricity needs in North Sumatra Province. Behind that all the North Sumatra Province PLN Power Plant still relies on energy in the form of Diesel Power, Steam Power, Gas Power and Steam Gas Power in meeting the electricity needs in North Sumatra Province. Therefore, the PLN of North Sumatra Province is still little in terms of exploration of new renewable energy so it is necessary to use new renewable energy in North Sumatra Province to reduce the effects of emissions and pollutants generated from non-renewable energy power plants.

Measuring the sustainability of the energy supply system is a major problem and the driving force of discussion in sustainable development. Developing reliable evaluation criteria and methods to measure sustainability is a prerequisite for choosing the best alternative, identifying unsustainable energy supply systems, informing design makers that integrate alternative performance and the impact of monitoring on the social environment. The many criteria and measures of tools developed in this fast-growing field show the importance of conceptual and methodological work in this area. The development and selection of criteria requires parameters related to reliability, appropriateness, practicality and measurement limits. Criteria used to evaluate new renewable energy at power plants.

![Conceptual framework](image)

Figure 1. Conceptual framework.

Based on these issues regarding the lack of utilization of renewable energy resources in North Sumatra Province, the government must take action regarding the utilization of new renewable energy.
in North Sumatra Province. Where, the determination of criteria and sub-criteria for assessment will be considered so that non-renewable energy power plants in North Sumatra Province can be replaced with renewable energy plants that are more environmentally friendly, so that they can reduce das and pollutant emissions which are the effects of energy power plants non-renewable and can also improve existing environmental conditions by building environmentally friendly power plants. The purpose of this study is to determine the criteria for conducting a new renewable energy assessment at a power plant in North Sumatra Province based on the consensus of experts.

2. Research methodology
Based on its nature, this research is classified as descriptive research. Descriptive research is research that seeks to explain problem solving to a problem that is now systematically and factually based on data or provide a more detailed description of the symptoms or phenomena. So this research includes the process of collecting, presenting, and processing data, as well as analysis and interpretation. This research is also called survey research because the data used are collected by interview techniques which are supported by the questionair.

The steps taken in carrying out this research are as follows.
1. Observation
The study was conducted by direct observation of the circumstances, desires, ways of working and recording.
2. Distribution of questionnaires
A list of written questions that are given directly to customers to obtain information about new renewable energy assessments at power plants in North Sumatra Province
3. Literature review
The need for literature review for information other than research that is in the field and from books, journals, or other information. Literature review can
4. Data collection
Data collected for use in this study are as follows:
   a. Primary data is data obtained by direct observation or descending directly into the field to collect information / data needed. The primary data collected is the respondent's answer from the interview in the form of a questionnaire regarding new renewable energy assessment at a power plant in North Sumatra Province.
   b. Secondary data is data obtained from literature searches on new renewable energy assessment at power plants in North Sumatra Province.
5. Data processing
Processing was carried out using the Delphi method where the Delphi questionnaire was distributed which was distributed to determine the desired criteria and sub criteria in the new renewable energy assessment at the power plant in North Sumatra province.

3. Delphi Method
The Delphi method is a systematic method of gathering opinions from a group of experts through a series of questionnaires, where there is a feedback mechanism through ‘rounds’ / round questions held while maintaining the anonymity of respondents' responses (experts). The Delphi method is a modification of brainwriting and survey techniques. In this method, the panel is used in communication movements through several questionnaires contained in the writing. The Delphi technique was developed in the early 1950s to obtain expert opinion. Most delphi policies are related to statements, arguments, comments, and discussions. To develop several ways of evaluating ideas expressed by the group of respondents, and also have to set the rating scale for the selection of these policies, such as ideas of interest, desires, beliefs, and the feasibility of various policies and issues [12].

The Delphi procedure has characteristics, namely:
1. Ignore the name
2. Controlling and controlled feedback
3. Statistical group response

The number of iterations of the Delphi questionnaire can be three to five depending on the degree of suitability and the amount of additional information as long as it applies. Generally the first questionnaire asks individuals to respond to questions in outline. Each subsequent questionnaire is built based on the preliminary questionnaire response. The process will stop when the consensus approaches the participant, or when the change of information is valid enough.

The procedure of the Delphi method is as follows:

1. Develop the delphi question. This is the key to the Delphi process. This step begins with formulating an outline of the questions by decision making. If the respondent does not understand the outline of the question then the input process is futile. The key element of this step is to develop questions that can be understood by respondents. Staff members must interview the decision maker clearly about the question in question and how the information will be used.

2. Selecting and contacting respondents. The participants should be selected on a basis of; the respondent personally knows the problem, has the right information to share, transforms to complete Delphi and the respondent feels that the aggregation of the respondent's panel opinion will include information that they value and they do not access it in other ways. The actual selection of respondents generally resolves through the use of the nomination process.

3. Selecting sample sizes. The respondent panel size varies with homogeneous groups with 10-15 participants may be sufficient. But in a case where varied references are needed larger participants are needed.

4. Develop first questionnaires and first survey. The first questionnaire in Delphi followed the participants to write responses to the problem outline. The letter cover includes the purpose, for the results, orders and the deadline for the response.

5. Questionnaire analysis 1. Questionnaire analysis must be produced in a summary with side parts - identified parts and comments are made clearly and can be understood by respondents to the questionnaire 2. Working group members document each response on the index card, choose the card into the general category, develop a consensus on the label for each category and prepare a summary of the shadow that contains the categories.

6. Development of second questionnaires and second survey. A second questionnaire was developed using a summary of respondents from the questionnaire 1. The focus of this questionnaire was to identify the agreed areas and those who did not, discuss and identify the desired parts and help participants know each position and move towards accurate opinions, respondents were asked to vote on the summary part of questionnaire 1.

7. Questionnaire analysis 2. The task of the working group is to count the number of votes for each section which summarizes comments made about each section. The purpose of this stage is to determine if complete information will help to solve the problem or at least prove to be used in various ways.

8. Developing third questionnaires and test 3. Questionnaire 3 was designed to encourage input into the Delphi process.

9. Questionnaire analysis 3. Analysis of this stage follows the same procedure in questionnaire analysis 2.

10. Prepare the final report

In this study, the Delphi Method is a verification tool for the results of the analysis carried out by the researcher, with the aim of knowing the opinions of experts, in this case people who know the issues and problems and conditions on the actual field.

4. Results and discussion

Determination of Criteria and Sub-criteria Data collection on respondents' answers in choosing subcriteria from selected criteria can be seen in Table 2.
Table 2. Recapitulation of sub-criteria determination questionnaire data.

| No | Criteria                | Sub-criteria                  | Respondent's answer |
|----|-------------------------|-------------------------------|---------------------|
|    |                         |                               | R-1 | R-2 | R-3 |
| 1  | Technology Aspects      | Energy Efficiency             | 4   | 4   | 5   |
|    |                         | Security risk                 | 4   | 5   | 4   |
|    |                         | Energy Production Capacity    | 5   | 4   | 5   |
| 2  | Economic aspects        | Investment Costs              | 4   | 5   | 5   |
|    |                         | Operation and Maintenance Costs| 4  | 5   | 5   |
|    |                         | Financial risk                | 4   | 5   | 5   |
|    |                         | Payback Period                | 4   | 4   | 4   |
| 3  | Environmental aspects   | Methane Emissions             | 5   | 5   | 5   |
|    |                         | CO2 emissions                 | 5   | 5   | 5   |
|    |                         | CO emissions                  | 5   | 5   | 5   |
|    |                         | Land Use                      | 4   | 4   | 5   |
|    |                         | Ecosystem Impact              | 5   | 4   | 5   |
| 4  | Social and Political Aspects | Labor                      | 5   | 4   | 5   |
|    |                         | Political Support / Policy    | 4   | 4   | 4   |
|    |                         | Human Health Impacts          | 5   | 4   | 5   |
|    |                         | Social benefits               | 4   | 4   | 5   |

Information:
1 = Very Influential, 2 = No effect, 3 = Normal, 4 = influential, 5 = Very influential

Based on the results of data collection from the subcriteria determination questionnaire, all predetermined subcriteria are in accordance with the new renewable energy assessment because all sub-criteria can be seen as influential and very influential.

Determination of new renewable energy assessment criteria at a power plant in North Sumatra Province uses the delphi method of collecting techniques. The sampling technique used in the delphi method is purposive sampling where respondents are experienced people or experts in their fields. The criteria taken are new renewable energy assessment criteria based on previous research that has been selected by the researcher.

With this method, a semi-open questionnaire was distributed (Phase I questionnaire) to 3 experts in the energy sector, especially new renewable energy at the power plant, so that criteria and subcriteria were obtained in the new renewable energy assessment at the power plant. Of the 4 criteria offered, namely economic aspects, environmental aspects, technological aspects and social and political aspects, the four have their respective averages 5. This figure on the delphi scale means very important, so the four criteria are accepted by experts as assessment criteria new renewable energy at power plants in North Sumatra Province.

Furthermore, experts received 16 subcategories offered, namely energy efficiency, security risk, energy production capacity, investment costs, operating and maintenance costs, financial risk, payback period, methane gas emissions, CO2 emissions, CO emissions, land use, ecosystem impacts, labor, support / political policy, human health impacts and social benefits.

An explanation of the criteria and subcriteria for new renewable energy assessment at a power plant in North Sumatra Province can be seen in Table 3.
### Table 3. New renewable energy assessment criteria.

| No | Criteria                  | Sub-criteria               | Information                                                                 |
|----|---------------------------|----------------------------|-----------------------------------------------------------------------------|
|    |                           | Energy Efficiency          | Efficiency refers to how much useful energy we can get from an energy       |
|    |                           | Security risk              | risks that can occur if something happens that can cause damage to the surrounding environment |
|    |                           | Energy Production Capacity | Is a capacity that can be produced when building a power plant in the new renewable energy source |
|    |                           | Investment Costs           | Investment costs consist of all costs related to: the purchase of mechanical equipment, technology installations, road construction and others |
| 1  | Technology Aspects        | Operation and Maintenance Costs | Operation and maintenance costs consist of two parts, including employee wages, and funds are spent on energy, products and services for the operating energy system |
|    |                           | Financial risk             | Financial risk is the risk that will occur if a power plant in a new renewable energy source is built |
|    |                           | *Payback Period*           | The period of return of an energy project refers to the period of time required for the return of an investment to the amount of the initial investment |
|    | Economic aspects          | Methane Emissions          | Emissions or expenditure of methane directly into nature from the proceeds of disposal at the power plant |
|    |                           | CO\(_2\) emissions         | Emissions or the release of CO\(_2\) directly into nature from the proceeds of disposal at the power plant |
|    |                           | CO emissions               | Emission or release of CO directly to nature from the results of disposal at the power plant |
|    |                           | Land Use                   | The energy system occupies several fields. Environment and landscape are directly affected by the land occupied by system energy |
|    |                           | Ecosystem Impact           | Ecosystem impacts are impacts that occur on the environment when a power plant is built in the area |
| 2  | Environmental aspects     | Labor                      | This criterion is considered as the potential for employment in the energy supply system |
|    |                           | Political Support / Policy | a support and policy provided directly by the government so that the utilization of new renewable energy runs smoothly |
|    |                           | Human Health Impacts       | It is a condition where people do not experience poor health conditions around the power plant |
|    |                           | Social benefits            | Namely the benefits that will occur if the power plant is operated like a tourist attraction, jobs and others |

*Source: Data Processing*

### 5. Conclusion
Criteria for evaluating new renewable energy used in this study consisted of four criteria, namely the technological aspects, economic aspects, environmental aspects, and social and political aspects.
which were developed into 16 subcriteria namely energy efficiency, security risk, energy production capacity, investment costs, operating and maintenance costs, financial risk, payback period, methane gas emissions, CO₂ emissions, CO emissions, land use, ecosystem impacts, labor, political support / policy, human health impacts, social benefits.

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