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The Problems of Renewable Power Plant Construction Affecting the Energy Security of Thailand

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ABSTRACT

The objectives of this research were to study the process of submitting an application for every license that affects the success of renewable power plant construction and the energy security of Thailand in accordance with the Energy Industry Act 2007, the engineering factors used in the selection of all types of renewable power plant construction, and the key performance indicators of all types of renewable power plant construction. The data analysis was divided into two sections. For the first section, the quantitative data was collected from the questionnaire conducted by purposive sampling that included participants related to renewable power plant projects, which asked the questions about the rules and regulations and power purchase agreements under the Energy Industry Act 2007. As for the factors influencing the success of projects, the private sector, combined in the sample group, included the design engineers, consulting and control engineers, and contractors. The 400 engineers were randomly selected from the registration of the Council of Engineers, including senior professional engineers, professional engineers, associate engineers, and adjunct engineers. In the second section, the qualitative data came from in-depth interviews with five specialists and experts in the renewable power plant industry and the legal knowledge about the rules and regulations and power purchase agreements according to the Energy Industry Act 2007, who work at the Electricity Generating Authority of Thailand (EGAT), a renewable power plant construction company, a renewable energy consulting company, in the field of renewable power plant investment, and as a renewable power plant specialist (Office of the Energy Regulatory Commission). The data was analyzed using the following statistics: percentage, frequency, mean, standard deviation, multiple regression and numerical method to find the acceptable equations for value prediction and results evaluation from the recorded data. Also, the mathematical methodology as demonstrated resulted in a coefficient of determination of 0.7 and a correlation coefficient of 0.84, respectively. According to the results, the overall success of using the engineering factors in selecting a renewable power plant establishment has the mean at a high level. With regard to the types of power plants, the solar power plant is ranked at the top, followed by the biomass power plant, the waste-to-energy power plant, the biogas power plant, and the wind power plant, respectively. The findings indicate the engineering factors related to the success of all types of renewable power plants. Moreover, regarding the problem of energy policy to decide which type of energy to use is highly complicated because there are many dimensional reasons and no form of energy is the best or the worst option. However, it is not exceedingly difficult for specialists to make a decision.

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1. INTRODUCTION

Electricity is in greater demand every year. In Thailand, a developing country, the Power Development Plan 2012-2030 (PDP2015) states that the electric generation capacity of Thailand as of December 2014 was 37,612 MW [1-3]. The forecast of electricity demand shows that, during 2015 - 2030, the demand for the generation capacity to the system will increase to 57,459 MW. Moreover, this PDP includes the 800-MW generation capacity of the coal power plant in Krabi where the project could not be achieved as planned because there are people who try to reduce the use of fossil energy, especially petroleum and coal, and are opposed to the construction of power plants. Thus, nowadays, the renewable power plant is a good option to increase the power generation in accordance with the PDP of Thailand. At the conclusion of January - July 2018, Thailand's final energy consumption during the 7th month of 2018 amounted to 49,822 thousand tons, which compared with crude oil, was an increase of 6.7% from the previous year, or amounted to THB 837,380 million. Energy consumption is still increasing due to economic growth. Petroleum accounts for the highest consumption, or 48.6% of the total energy consumption [4-5]. The others are electricity, renewable energy, coal/lignite, existing renewable energy, and natural gas, at 19.6%, 94%, 8.7%, 6.9%, and 6.8%, respectively.

In regard to Thailand's economic conditions in July 2018, according to the Bank of Thailand, the economic expansion grew more than the previous month as the imports unceasingly expanded, which affected the growth of the industrial sector, as well as the investment of the private sector and the expenditures of the state [6-8]. Meanwhile, tourism slowed down due to the impact of a sunken ship in Phuket. As for the economic stability, the inflation rate rose due to the domestic retail price of petroleum, but the core inflation was slightly reduced from the previous month, and the unemployment rate decreased as well. The current account declined according to the trade balance, while the capital and financial accounts recorded a net deficit [9].

On the other hand, the total energy consumption increased in every economic sector. It was found that the agricultural sector increased by 17.4%, the industrial sector by 11.5%, the housing sector by 6.6%, the trading business by 0.5%, and the transportation sector by 3.0%, compared with the previous year. Transportation was the sector that consumed higher amounts of energy than the others. The consumption proportion was 39.1% of the total energy consumption, followed by the industrial sector, the housing sector, trading, and agriculture, using 36.3%, 13.7%, 7.5%, and 3.4%, respectively.

This research includes data for Thailand from 1971 to 2014. The average increase for Thailand during that period was 41.73 percent with a minimum of 32.41 percent in 1987 and a maximum of 49.18 percent in 1980. The latest increase from 2014 was 41.57 percent [10-13]. For comparison, the world average in 2014 based on 133 countries was -15.39 percent (see Figure 1). The primary energy consumption data for Thailand from 2009 to 2019 is provided, as shown in Figure 2. In the 7th month of 2018, Thailand's imported energy amounted to THB 627,351 million. Crude oil was the first top import. Because the government adopted the policies to encourage the use of more renewable energy in the country (see Figure 3) and also to enhance the efficiency of energy consumption by reducing energy intensity per GDP, it was found that, in the 7th month of 2018, Thailand consumed renewable energy of 7,638 thousand tons, which when compared with crude oil, was an increase of 13.4% from the previous year. Also, the proportion of energy intensity per GDP continued decreasing compared with 2010, which was the beginning of the 20-year Energy Efficiency Plan (2011-2030), which was revised to the 20-year Energy Efficiency Plan (2015-2036).

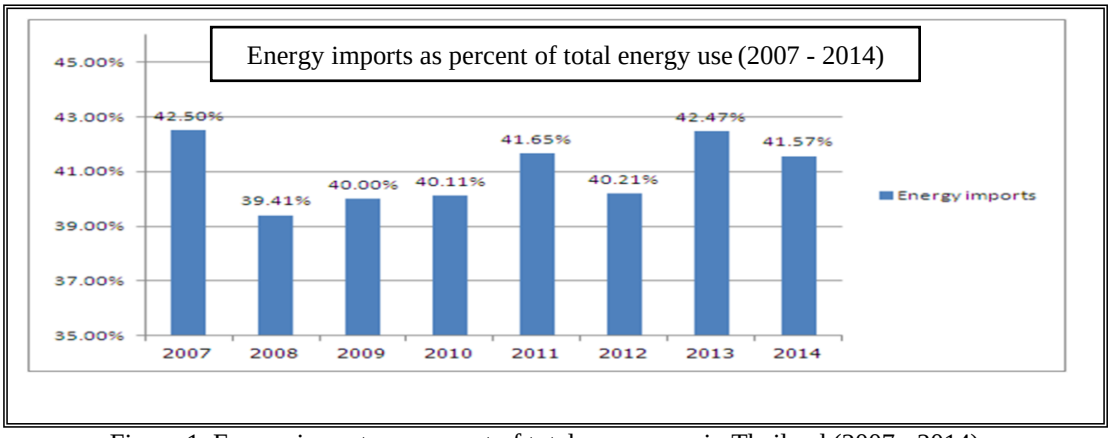

Figure 1. Energy imports as percent of total energy use in Thailand (2007 - 2014)

Presently, the state sector provides significant support for renewable energy investment in the state agencies and the private sector in compliance with the Power Development Plan 2012-2030 (PDP2015) and the Alternative Energy Development Plan 2015-2036 (AEDP2015). The state's policy is to encourage

electricity generation from renewable energy, and the goal of increasing the electricity generation from renewable energy from 9.9% in 2014 to 20.1% in 2036 has been set. For the private sector, the energy businesses are conducted in accordance with the Energy Industry Act 2007 [14]. The governance and energy policy administration is under the responsibility of the Energy Regulatory Commission (ERC) for better efficiency in energy consumption. His Majesty the King graciously appointed this agency to manage the domestic energy industry based on the Energy Industry Act 2007.

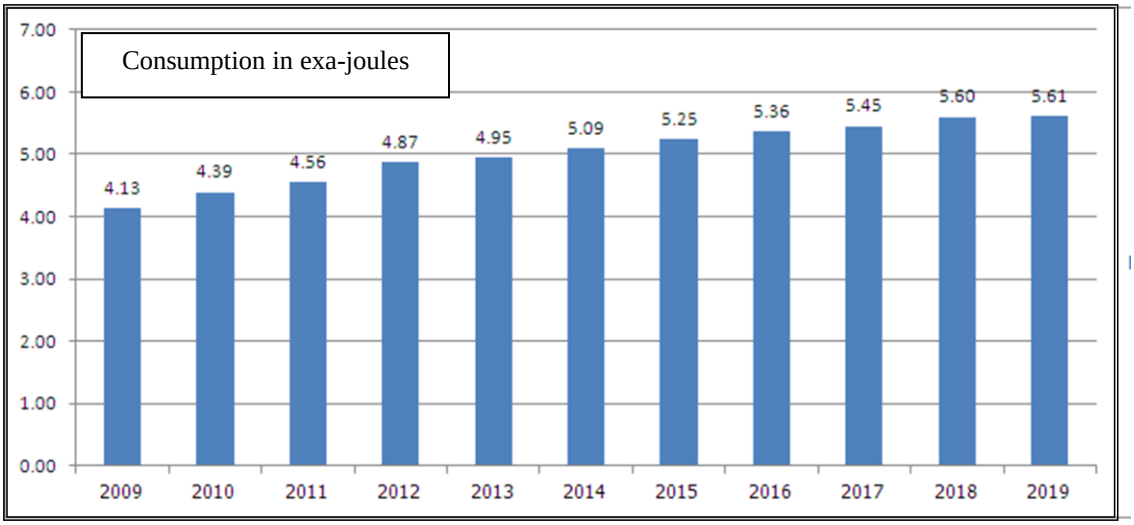

Figure 2. Primary energy consumption in Thailand

The Energy Regulatory Commission gained the authority to introduce the rules, regulations, and declarations, as well as the criteria, methods, and conditions to govern energy businesses according to the laws and to use energy efficiently. The agency supports the state policy that encourages the energy security of Thailand by operating the renewable power plant businesses [15].

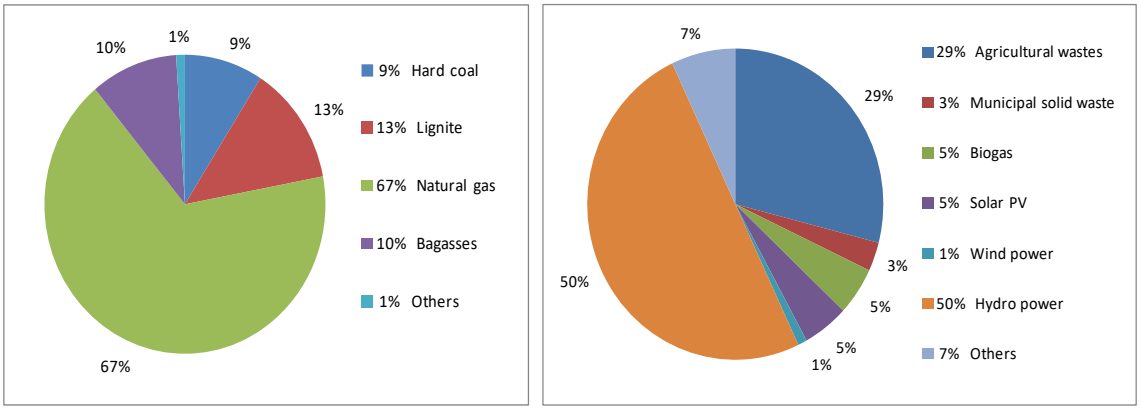

Figure 3. Proportion of Thailand's renewable energy consumption based on data from the Electricity Generating Authority of Thailand (EGAT)

Furthermore, the granting of licenses is also under the responsibility of the ERC. Regarding the licensing in compliance with the Energy Industry Act 2007, the private companies that operate the renewable power plant businesses must follow Section 47 - License for Energy Business, Section 48 - License for Power Generation Control (PorKor.2), Section 48 - License for Power Plant Operation (RorNgor.4), Section 48 - License for Construction (Aor.1), and the License for Building Construction (Aor.6). In the main content of Section 47, the issuance of the license for power business operation by the ERC, the agency indicates the type and duration of the permission license along with the concerns regarding the impacts. In Section 48 - Building Construction or Factory Establishment for Power Business Operation, it is required that the Factory Act, the Building Control Act, the Town Planning Act, and the Energy Development and Promotion Act must be followed. The ERC needs to be asked for approval from the authorized agency, and the entrepreneurs must receive the Power Purchase Agreement (PPA) from the Electricity Generating Authority of Thailand or the Provincial Electricity Authority, and the Metropolitant Electricity Authority of Thailand needs to accept the

method and/or rights to purchase electricity [16]. The contract allows investors from the state or private agencies to initiate the project. In addition, the ERC provides public consultation to these projects for public relations and providing information about the analysis report of environmental impacts. In consequence, the stakeholders will become familiar with the information of the project, including the impacts from it, prevention measures, solutions, and the monitoring of the environmental, social, and health effects [17-18]. This provides the opportunity for the stakeholders to share ideas and suggestions that will benefit the study of environmental impacts, the planning of development, prevention and solution measures, and follow-up of the social, environmental and health effects.

All large-scale projects must pass the hearing of public opinions using the Official Regulations of the Prime Minister as a guideline. The opinions and concerns of the stakeholders will be reviewed before concluding the prevention and solutions to reduce the concerns regarding the impacts and conflicts that might occur during the project operations. Furthermore, a questionnaire will be used to review the understanding and the attitudes of the community towards the projects before planning the procedures later. Arrangement of the participation process for the hearing of public opinions includes 1) distribution and presentation of the basic information about the project, 2) review of the information of the project, 3) listening to the opinions of the stakeholders, for example, the people living in the project area, the local administrative units, and any related private agencies, 4) presentation and conclusions regarding the best options after listening to the public opinions of the stakeholders, the basic construction process and the basic impact reduction measures, 5) clarification of the construction process of every project in order to explain the impact reduction measures, listen to the public opinions of the stakeholders, and solve and reduce the primary conflicts resulting from the project operations that might affect the community's way of life, and 6) the review and follow-up of claims due to the impacts of the construction. For the national development to be conducted as planned, energy security is indispensable. In consequence, the private sector's success in operating renewable energy businesses is greatly required for the nation. In the present day, the businesspersons of many projects have been granted licenses to operate renewable power plants, but they were unable to achieve success. In other words, they could not sell the electricity as scheduled, resulting in them being charged by the state, and the severest punishment is having their business seized according to the laws, rules, and regulations of the licensing and the power purchase agreement in compliance with the Energy Industry Act 2007.

For example, **the lawsuit in the case of the power plant of Thep Sathit Wind Farm in Chaiyaphum** involved a land rental contract for the farmers to operate the energy business by building a wind power plant. On the contrary, the land had been legalized by the government to allow only citizens who are farmers to manage it for agricultural purposes, but the electricity generated by Thep Sathit Company was purchased by EGAT and sent to the Bannarong high voltage station for distribution; therefore, it was not as beneficial to the local citizens as expected. Consequently, the Supreme Administrative Court ordered that the lease agreement for the instalment of the wind turbines of the Thep Sathit Wind Farm Company Limited be cancelled due to the unlawful operation.

Furthermore, the wind turbine installation business is located in a Grade 1B area, which is under the report of the environmental impact analysis and thus, must be approved by the Office of Natural Resources Policy and Planning, the National Environment Board, and the Council of Ministers before granting permission to continue the project. However, the mentioned project did not prepare the environmental impact analysis report and did not receive permission to use the land as they desired. In consequence, the Chaiyaphum Land Reform Commission and the permission orders of the Office of the Secretary-General of the Ministry of Education resolved the case as unlawful.

This research, therefore, focused on studying the problems of renewable power plant construction that affect the energy security of the nation in accordance with the Energy Industry Act 2007. The study includes the engineering factors used in the selection of each type of renewable power plant construction for obtaining the licenses to establish a power plant. The main obstacles to constructing a power plant are the licensing and the engineering factors. This is for the highest benefit of the private sector who would like to operate the renewable power plants, and they can proceed with the action by following the laws, rules and regulations of the licenses and the power purchase agreements in compliance with the Energy Industry Act 2007. Accordingly, the research created the key performance indicators of the renewable power plant establishment.

2. RESEARCH METHODOLOGY

This study was a combination of quantitative and qualitative research. The methodology used in this research was conducted as follows:

2.1. Documentary study

The documentary study involved assessing a set of research documents from academic textbooks and articles published both domestically and internationally and the literature, laws, rules, and regulations related

to renewable power plant construction, including disputes affecting quality, duration, and investment in the renewable power plant projects, in order to identify the relationships and the causality of the independent and dependent variables as the guidelines to create the survey tools.

2.2. Field study

The field study defined the creation of the research tools. In this study, the authors used a questionnaire as one tool for data collection, which asked about the general information of the respondents, namely their position, workplace, education, work experience, and involvement with and relationship to the requests for the licenses to establish a renewable power plant. Moreover, the questionnaire asked if they had encountered any obstacles in the licensing process or not. For the engineering factors in selecting the type of renewable power plant, they can be divided into project quality, duration of operation, and project investment. The following section explains the details.

The procedures of creating the research tools, the questionnaire and the interviews for the data collection are as follows:

Creation of Tools:

Step 1 - The authors researched through the journal sources for papers that are related to the selected variables in order to understand the content that conformed to this research.

Step 2 - The authors interviewed five specialists and experts who have direct knowledge and experience of the renewable power plant industry in terms of the laws, rules, regulations, and power purchase agreements according to the Energy Industry Act 2007. Interviewees work for the following:

1) Electricity Generating Authority of Thailand
2) Contractor Company for Renewable Power Plant Installation
3) Consulting Company for Renewable Energy
4) Investors in Renewable Power Plants
5) Specialists in Renewable Power Plants (Office of Energy Regulatory Commission)

To create the questionnaire, it was necessary to comprehend and examine the theoretical background related to the variables used in this study.

Step 3 - The authors designed the framework of questions and the scope of the study to create the questionnaire. After receiving the opinions of the advisors regarding the consideration of the content accuracy and revision, the suggestions were implemented for the improvement of the survey.

Step 4 - The authors created the questionnaire as planned before presenting it to the advisors for the consideration of the content accuracy and revision, and the suggestions were implemented for the completion of the survey.

The creation of an interview to confirm the results:

This was the tool used for collecting the qualitative data by interviewing the specialists and experts who have direct knowledge and experience in the renewable power plant industry in order to obtain more profound data than the questionnaire and to confirm the analytical results from the quantitative data.

2.3. Key Informants

Quantitative Data: The population in the study included those who are involved with the renewable power plant projects and are familiar with the laws, rules, regulations, and power purchase agreements under the Energy Industry Act 2007. For the topic of the influence on the project success, the population included 400 persons from the private sector who are designing engineers, consulting and control engineers, and project contractors.

Based on the study to find the problem-solving instrument and patterns, the authors found that the numeric method could be useful and effectively responsive to engineering works. In addition, the authors created the mathematical program with the numeric method as it could display the results of the tested data in the form of 2D and 3D graphs. Next, the said program was used to create the correct mathematical functions from the raw data as recorded. The accuracy of the interpolation and approximation functions depends on the numerical and sampling data. Moreover, this aforementioned method can find the correct coefficient of determination (r^2) and correlation coefficient (r). Additionally, regarding the test of the created program with polynomial functions, the results can represent the data set at more than 90%.

Qualitative Data: The authors performed the in-depth interviews with five key informants who are specialists and experts in the renewable power plant industry and have legal knowledge about the rules and regulations as well as the power purchase agreements based on the Energy Industry Act 2007 and work in 1) the Electricity Generating Authority of Thailand, 2) a renewable power plant contracting company, 3) a renewable energy consulting company, 4) a renewable power plant investment company, and 5) the Office of the Energy Regulatory Commission, as a renewable power plant specialist.

2.4. Tools

The first tool in this study was the questionnaire, which asked for the general information of the respondents, namely their position, workplace, education, work experience, and involvement and relation to the request for the licenses to establish a renewable power plant. Moreover, the questionnaire asked if they had encountered any obstacles in the licensing process or not. For the engineering factors in selecting the type of renewable power plant, they were divided into project quality, duration of operation, and project investment. In addition, the interviews asked for general information and about the process to obtain each license that influenced the success of the renewable power plant establishment and the factors in selecting the power plant that affect the project success, including the impacts of energy security. Next, both tools were evaluated for validity by the advisors.

2.5. Data Collection

The authors gathered the various data for the results that corresponded to the objectives of this study. The data collection approaches were as follows:

For the quantitative data, the steps were as follows:

1) The authors gathered the quantitative data using the questionnaire, and then studied and gained a profound comprehension of the content of the questionnaire. The types of questions included multiple-choice questions, multiple responses, and open-ended questions for the freedom of ideas and suggestions.
2) The authors studied the data in advance as a means to correctly collect data by interviews with the questionnaire.
3) After collecting the completed questionnaires, the data was examined.
4) Categorical frequency distribution and percentag were applied to the data for the subsequent analysis.

For the qualitative data, the authors arranged the in-depth interviews with five key informants who are specialists and experts in the renewable power plant industry who have legal knowledge about the rules and regulations and power purchase agreements according to the Energy Industry Act 2007. The questions were opened-ended, and the results supported and confirmed the results of the data analysis.

2.6. Data Analysis

For the analysis of the qualitative data following the in-depth interviews with the specialists and experts in the renewable power plant industry that have legal knowledge about the rules and regulations and power purchase agreements according to the Energy Industry Act 2007, the authors conducted the content analysis. In other words, the patterns received from the quantitative research were processed in order to conclude the results, which became the suggestions that can potentially be useful to the state sector and the business sector as shown in the research. The analysis of the quantitative research processed the data of the questionnaire. The authors checked the accuracy and analyzed the data with a computer program (quantitative) using these following statistics.

1) Percentage and frequency were applied for the general characteristics of the Certified Accounting Practice in Thailand.
2) Mean and standard deviation were applied to analyze the quality of the services of the Certified Accounting Practice in Thailand.
3) Mean and standard deviation was applied to analyze the components of the service providing process of the Certified Accounting Practice in Thailand.
4) Hypothesis testing to analyze the predictive relationship of the engineering factors in selecting the power plant for each renewable power plant was conducted by the Enter method of multiple regression.

2.7. Numerical Analysis

After receiving the recorded data, the program performed the numerical analysis by searching for interpolation and approximation functions. The values from the experiment are probably located at one specific point or multi-points, which might be unacceptable for the calculation. Therefore, there must be a mathematical method to change the group data to a continuous function, which could be performed with the major keys to find interpolation and approximation functions, as follows. The difference between the two methods is that, for interpolation, the function passes every data point, but the approximation function does not need to be done the same way. In other words, the first function could pass or exceed, but the function must be continuous and have a value close to every point, or the most appropriate graph that matches the data group [19-20]. The

numerical analysis of the two cases contains various methods, but this research article considers two cases as follows:

1) Interpolation applied in this research is a polynomial interpolation linking the data set from two points with the curved line or the straight light. With the straight line, it is referred to as Linear interpolation. In addition, Cubit-spline interpolation is a straight line from two multi-points linking to a third point nearby. Furthermore, the slope of the curve ends at the equal value point. In other words, the curved line will slope at the two connected points.
2) Curve-fitting by Least-square curve fitting was adapted as an option in which the user wants the polynomial curve to pass the data group while the sum of the distance from each data point is the closest to the curved line.

2.7.1. Mathematics Algorithm Test

The interpolation and approximation functions

For this case, polynomial regression was applied to estimate the appropriate order and the m^{th} order polynomial. The equation is as follows:

Equation: m^{th} degree polynomial

$$y = a_0 + a_1 x + a_2 x^2 + \ldots + a_m x^m + e \quad (1)$$

The general pattern

$$y = a_0 z_0 + a_1 z_1 + a_2 z_2 + \ldots + a_m z_m + e \quad (2)$$

whereas $z_0, z_1, \ldots, z_m$ is the estimated function.

Formulate the new equation as follows:

$$y(x) = a_0 z_0(x) + a_1 z_1(x) + a_2 z_2(x) + \cdots + a_m z_m(x) + e \quad (3)$$
$$= \sum_{j=0}^{m} a_j z_j(x) + e$$

- **Criteria to find the most appropriate line**

One method to find the most appropriate line is the minimize the sum of the squares of the residuals S_r and consider the condition as follows:

$$S_r = \sum_{i=1}^{n} e_i^2 = \sum_{i=1}^{n} \left[y_i - \sum_{j=0}^{m} a_j z_j (x_i) \right] \quad (4)$$

Set $z_{ji} = z_j(x_i)$, which results in:

$$S_r = \sum_{i=1}^{n} \left[y_i - \sum_{j=o}^{m} a_j z_{ji} \right] \quad (5)$$

To find the minimum:

$$\frac{\partial S_r}{\partial a_j} = 0 \qquad (j = 0,1,2...,m)$$

$$\sum_{i=1}^{n}\left\{\left[y_i-\sum_{k=0}^{m}a_k z_{ki}\right]z_{ji}\right\} = 0 \quad (6)$$

Resulting in:

$$\sum_{i=1}^{n}\sum_{k=0}^{m}a_k z_{ki} z_{ji} = \sum_{i=1}^{n} y_i z_{ji} \quad (7)$$

$(j = 0,\ldots,\mathrm{m})$

This results in the "Normal Equation" for regression coefficients $a_0 \ldots a_m$, whereas the normal equation is $(z^T z)A = z^T y$. The normal equation can be written in metrics as follows:

$$y=\begin{bmatrix} y_1 \\ y_2 \\ \cdot \\ \cdot \\ \cdot \\ y_n \end{bmatrix} \quad A=\begin{bmatrix} a_0 \\ a_1 \\ \cdot \\ \cdot \\ \cdot \\ a_m \end{bmatrix} \text{ and } z=\begin{bmatrix} z_{01} & \cdots & z_{j1} & \cdots & z_{m1} \\ z_{02} & & z_{j2} & & z_{m2} \\ \cdot & & \cdot & & \cdot \\ \cdot & & \cdot & & \cdot \\ \cdot & & \cdot & & \cdot \\ z_{0n} & & z_{jn} & & z_{mn} \end{bmatrix} \quad (8)$$

The standard error of the estimate ($S_{y/x}$) is

$$S_{y/x} = \sqrt{\frac{S_r}{n-(m+1)}} \quad (9)$$

Where m is the order of polynomial function.
Sum of squares of residuals related to the mean $\bar{y}$ (S_t)

$$S_t = \sum(y_i - \bar{y})^2 \quad (10)$$

Coefficient of determination (r^2)

$$r^2 = \frac{S_t - S_r}{S_t} \quad (11)$$

Correlation coefficient (r)

$$r = \sqrt{\frac{S_t - S_r}{S_t}} \quad (12)$$

The condition to decide which value is the most appropriate is $S_r = 0$, $r^2 = 1$ and $r = 1$. If the result is in accordance with the aforementioned, it shows that the line provides continuity, and it could represent of the data %100.

2.8. Research Presentation

The descriptive presentation was applied, which is associated with the photos and descriptions related to the quality in providing the services of the Certified Accounting Practice for the adoption at the policy and organizational levels.

In this section, how the research was conducted should be explained, including the research design, research procedure (in the form of algorithms, Pseudocode, etc.), how to acquire the data, and how to perform any tests. The description of the process of the research should be supported by references, so that the explanation can be accepted scientifically.

3. QUANTITATIVE ANALYSIS

The quantitative analysis was conducted on the data collected by the questionnaire from a specific sample that comprised people related to renewable energy power plant projects, which consists of qualified engineers with 400 samples, who have involvement in obtaining a license to establish a renewable energy power plant and the obstacles in applying for a license to establish a renewable energy power plant. The tools in this research were used to determine the accuracy of the content by the group of three advisors, including testing the reliability of the population with 30 examples in order to analyze the reliability with Cronbach's method.

3.1. General Data Analysis presented with Percentage and Frequency

The data analysis for the general information of the percentage and frequency of respondents, from Table 1, the initial results of the analysis of the 400 sample respondents in this study of the variables are as follows.

1) Position: It was found that the position of electrical engineer accounted for 48.00 percent, the position of manager accounted for 38.00 percent, management positions accounted for 11.00 percent, and the position of full-time lecturer accounted for 3.00 percent.
2) Agency: It was found that private agencies accounted for 84.75 percent, government agencies accounted for 9.25 percent, and state enterprises accounted for 6.00 percent.
3) Highest level of education: It was found that for the highest educational level, Bachelor's degree accounted for 55.25 percent, Master's degree accounted for 5.50 percent, and Doctoral degree accounted for 9.25 percent.
4) Work experience: It was found that 10 - 20 years of work experience accounted for 52.00 percent, more than 20 years accounted for 38.75 percent, and less than 10 years accounted for 9.25 percent.
5) Involvement in applying for a license to establish a renewable energy power plant, customers who purchase electricity that were involved in applying for a license to establish a renewable energy power plant: It was found that the customers who are electricity purchasers accounted for 47.50 percent, electricity producers accounted for 41.25 percent, electricity suppliers accounted for 9.75 percent, and owners of the power transmission system and system operators accounted for 1.50 percent.
6) In connection with applying for a renewable energy power plant license, it was found that 53.50 percent had never been involved with a renewable energy power plant license application, and those who were previously involved with a renewable energy power plant license application accounted for 46.50 percent.
7) There were no obstacles in applying for a renewable energy power plant license accounted for 65.50 percent, and there were obstacles in applying for a license to establish a renewable energy power plant accounted for 34.50 percent.

Table 1. Number and percentage of general data of the sample of 400 people

General information	Quantity	Percentage
1) Involvement in obtaining a license to establish a renewable energy power plant		
- Independent Power Producers	165	41.25
- Owner of the power transmission system and system operator	6	1.50
- Electricity supplier	39	9.75
- Electricity purchasers	190	47.50
2) Involvement in obtaining a permit to establish a renewable energy power plant		
- ever	186	46.50
- never	214	53.50
3) Obstacles to obtaining a license to establish a renewable energy power plant		
- obstacles were encountered	138	34.50
- no obstacles	262	65.50
Total	400	100.00

3.2. Levels of success of engineering factors used in the selection of renewable energy power plants

The data analysis of the engineering factors used to select the power plant of renewable energy in each category included average (mean) and standard deviation (SD). An analysis of the success level of the engineering factors used in the selection of each type of renewable energy power plant, where the average of 1.00 - 1.49 indicates that the opinion level is the lowest, the average of 2.50 - 3.49 indicates that the opinion level is moderate, and the average of 3.50 - 5.00 indicates that the opinion level is the highest.

In Table 2, the success levels of the engineering factors used in the selection of renewable energy power plants overall are shown. It was found that the success of the engineering factors used in the selection of renewable energy power plants have a high average of achievement scores with an average value of 3.55. Considering by type of power plant, it was found that solar power plants have a mean value of 3.66, followed by biomass power plants with a mean value of 3.59, the waste power plants with a mean value equal to 3.57, the biogas power plants with a mean value equal to 3.56, the wind power plants with a mean value equal to 3.53, and the hydroelectric power plant success score was moderate with an average of 3.36, respectively.

Table 2. Levels of success of the engineering factors used in the selection of renewable energy power plants

Engineering factors used in the selection of renewable energy power plants	Skewness	Mean	Standard Deviation	Translate
1) Biogas power plant	-0.07	3.56	0.67	high
2) Biomass power plant	-0.12	3.59	0.68	high
3) Waste power plant	-0.01	3.57	0.74	high
4) Hydroelectric power plant	0.45	3.36	0.77	moderate
5) Wind power plant	0.17	3.53	0.75	high
6) Solar power plant	0.14	3.66	0.75	high
Total	0.44	3.55	0.60	high

3.3. Predictive correlation among engineering factors used in the selection of renewable energy power plants

The numerical methodology for the estimation of the polynomial functions and estimation analysis uses the key that the graph from the estimation probably does not pass every data point, and the graph that causes the least error is regarded as the appropriate graph to represent the data group and to be applied in other system analyses.

Table 3. Computed and comparative examples of definite integrals of value functions

Orders of Polynomial Functions used in the estimation	Standard error of the estimate ($S_{y/x}$)	Coefficient of determination (r^2)	Correlation coefficient (r)
1st (Straight-lined Equation)	5.7549	0.4331	0.6581
2nd (Parabola Equation)	2.7158	0.5842	0.7643
The mth order	2.8284	0.9974	0.9987

According to Table 3, for the computed and comparative examples of the definite integrals of value functions, it was found that adding an order of polynomial functions used in the estimation causes the decrease of error estimation. In other words, the result is very similar to reality. Nevertheless, the errors in other sections must be considered, including round-off errors and truncation errors. After applying the appropriate algorithm and methodology, the next step is to test the algorithm and the said method for accuracy. The test was performed with the definite integrals of value functions and the algorithm applied with the real system. Considering the value of estimation to find the appropriate line using the order of polynomial functions, it resulted in the difference of the coefficient of determination (r^2). If selected in the appropriate order, the sum of error will be low, and the appropriate graph can be applied in the subsequent data analysis.

As for the computation by polynomial functions and real data testing, it resulted in the maximum coefficients of determination (r^2) at the 10th order, as r^2 equals 0.7. Meanwhile, the exponential function resulted in a coefficient of determination (r^2) of 0.5, which is regarded as inappropriate, due to the error being higher than the estimation by a polynomial function. According to the experiment and the comparison using a polynomial function and exponential function as aforementioned, the appropriate function for the application in data analysis is the polynomial function due to the lower error than the value of the exponential function.

The predictive correlation among engineering factors used in the selection of renewable energy power affected the success of the renewable energy power plant establishment (solar power plants), as shown in Table 4.

Table 4. Predictive correlation between the engineering factors used in the power plant installation selection affecting the success of the renewable energy power plant establishment (solar power plants)

Forecast variable or independent variables	Unstandardized Coefficients		Standardized Coefficients	*t*	P-value
	B	**Std. Error**	**Beta**		
(Constant)	1.248	.094		13.295	.000
1) Power plant design (X_1)	.154	.064	.198	2.431	.016
2) Power plant installation (X_2)	-.055	.069	-.074	-.798	.425
3) Test system of power plant (X_3)	.385	.053	.501	7.206	.000
4) Size of the installation area of the power plant (X_4)	.234	.052	.340	4.516	.000
5) Raw materials used to produce electricity (X_5)	-.079	.034	-.117	-2.326	.021
6) Location for installation of power plant (X_6)	-.007	.049	-.010	-.142	.888
r^2 = 0.677, Std. Error = 0.344, F = 119.099, df = 6.393, $Sig.$ = 0.00*					

* Statistically significant at the 0.05 level

In Table 4, based on the analysis of the engineering factors used in the selection of power plants that affect the success of the establishment of renewable energy power plants, the solar power plants can be predicted for the success of the establishment of an energy power plant. Regarding the solar power plants as a whole, it can be written in the form of an equation as follows:

- Raw score formula

$$Y = 1.248 + 0.154\ (X_1) - 0.055\ (X_2) + 0.385\ (X_3) + 0.234\ (X_4) - 0.079\ (X_5) - 0.007\ (X_6) \quad (13)$$

- Standard score formula

$$Z = 0.198\ (Z_1) - 0.074\ (Z_2) + 0.501\ (Z_3) + 0.340\ (Z_4) - 0.117\ (Z_5) - 0.010\ (Z_6). \quad (14)$$

Considering the adjusted predictive success, Adj. r^2 is 0.677. It can thus be said that the probability of assuming that the engineering factors used in the power plant selection correlated with the success of the establishment of renewable energy power plants, the solar power plant accuracy in forecasting is up to 67.7 percent influence, with the remaining 32.3 percent being due to the influence of other variables, so the engineering factors used in the power plant selection affect the success of the establishment of renewable energy power plants. The solar power plant is significant at the 0.00 level, and the standard error value (SE = 0.344) can be arranged in order of importance as follows. The power plant system testing (X_3) with the standard coefficient (β) is equal to 0.501, the size of the power plant installation area (X_4) with the standard coefficient (β) is equal to 0.340, the power plant design (X_1) with the standard coefficient (β) is equal to 0.198, the raw material used to produce electricity (X_5) with the standard coefficient (β) is equal to -0.117, the installation of the power plant (X_2) with the standard coefficient (β) is equal to -0.074 and the site for plant installation (X_6) with the standard coefficient (β) is equal to - 0.010.

4. QUALITATIVE DATA ANALYSIS

The tools of this research included the in-depth interviews with five key informants who are specialists and experts in the renewable power plant industry and have legal knowledge about the rules and regulations as well as the power purchase agreements based on the Energy Industry Act 2007 and work in the Electricity Generating Authority of Thailand, a renewable power plant contracting company, a renewable energy consulting company, a renewable power plant investment company, and the Office of the Energy Regulatory Commission as a renewable power plant specialist. The data analysis was divided into three sections as follows:

Section 1 General information of the key informants

Section 2 Types of license granting affecting the success of renewable energy power plant establishment

Section 2 Engineering factors used in the selection of renewable energy power plants affecting the success of renewable energy power plant establishment, including the impacts of energy security

4.1. General information of the key informants

According to the interviews with the five key informants, they are specialists and experts with direct knowledge and experience relating to the rules and regulations as well as the power purchase agreements based on the Energy Industry Act 2007 and work in the Electricity Generating Authority of Thailand, a renewable

power plant contracting company, a renewable energy consulting company, a renewable power plant investment company, and the Office of the Energy Regulatory Commission as a renewable power plant specialist, who are involved with the license granting for the renewable energy power plant establishment as the project planner, the project consultant, the technical engineering consultant, and the project operator to construct and operate the power generating business.

4.2. Types of license granting affecting the success of renewable energy power plant establishment

1) Electricity Production License

According to the interviews, the Electricity Production License is intended to govern a power plant's policy/performance to follow the rules of the Office of the Energy Regulatory Commission (OERC). It is the first license before being granted the others, and it greatly affects the power plant establishment. The Electricity Production License affects the possibility of the success of the renewable energy power plant establishment by 25%. Furthermore, it is important to the community because the licensed power plant will transfer money to the Power Development Fund, resulting in renewable support in the related community. The power generation requires permission from the OERC in compliance with the Energy Industry Act 2007. Consequently, power generation, distribution, and power distribution industries are required to be approved in accordance with the said act.

2) License for Power Generation Control (PorKor.2)

According to the interviews, the License for Power Generation Control (PorKor.2) is intended to examine the safety of power instruments in accordance with the Department of Energy Development and Promotion. It is the last license and normally will be granted before the operation or before the power distribution. It can be regarded that the renewable energy power plant that receives the PorKor.2 succeeds in the power plant establishment and the safety of power instrument installations, and that the power plant is ready to generate power or distribute it safely. The production or the power capacity must be controlled and approved by the department in accordance with the Factory Act 1992. Therefore, the renewable energy power plant must be granted the License for Power Generation Control.

3) License for Power Plant Operation (RorNgor.4)

According to the interviews, the License for Power Plant Operation (RorNgor.4) is intended to examine the community and the environment safety. This license plays a major role in the success before the renewable energy power plant establishment due to the fact that if this license is denied, the construction cannot proceed. In addition, if the power plant obtains this RorNgor.4, it increases the possibility of the success of the renewable energy power plant establishment by 50%. Furthermore, this license is important to the community around the power plant as the people will acknowledge and understand the construction. It reduces the risk of protests or community conflict. The renewable energy power plant is regarded as one of the main types of power plants in compliance with the Factory Act 1992 for the factory ype 88, Therefore, it is required to obtain the Factory Operation Permit.

4. License for Construction (Aor.1)

According to the interviews, the License for Building Construction (Aor.6) is intended to examine the safety of the building in accordance with the local laws and the Department of Public Works and Town & Country Planning. This license is important to the success before the renewable energy power plant establishment because the rejection of this license will obstruct the building construction. In addition, if the renewable energy power plant also obtains the License for Construction (Aor.1), it increases the possibility of the success of the renewable energy power plant establishment by 75%. Furthermore, the permission of the Aor.1 is important to the safety of building construction sustainability as the operation will be legally inspected by the local officers. In compliance with the Building Control Act 1979 and the Town Planning Act, the building of power plants is under the responsibility of building and construction control, which requires permission and construction certification before the operations.

5. Power Purchase Agreement (PPA)

According to the interviews, the Power Purchase Agreement (PPA) is important for commercial use of the renewable energy power plant that aims at distributing electricity to PEA. If the PPA is obtained, the power plant will have financial achievement and income security throughout the project, under the 20-year FIT contract. As the power plant should have sustainability for the business operations, the power purchase agreement is one factor to review the investment plan and the feasibility of the business project. Therefore, the Power Purchase Agreement is required for the project.

4.3. The engineering factors used in the power plant installation selection affecting the success of the renewable energy power plant establishment

How do the factors used in every type of renewable energy power plant affect the success of the renewable energy power plant establishment?

1) Licenses

According to the interviews, the licenses are a major factor of the power plant establishment, which requires permission to operate. Licenses are critically important to start every renewable energy power plant project because if the license is denied, the project will not be able to proceed. The probability of related licenses being granted is directly connected to the criteria regulated by the laws, rules, and regulations relating to the act, including the construction, city planning, building control, natural and environmental conservation, community impact, and energy production control.

2) Energy Source Capacity

In regard to the interviews, apart from the licenses, the energy sources or fuel sources also play a major role because they determine the type and the size of the power plant, including the distance of the fuel source/quantity affecting the size and the stability of the power plant as well as the cost per unit. It is a part of the technique to select the type of the renewable energy power plant, to determine which raw material is used in the energy production, and the project location. Without the raw material capacity, the project cannot proceed in the long run because the power plant might not be able to generate electricity as regulated by the contract, and this will result in loss. Most of the fuel of the renewable energy power plants is derived from agricultural products, which can be produced, for example, plant energy or gas from wastewater in the agricultural product production system. Therefore, the factor that affects the success of the renewable energy power plants in terms of fuel does not depend on the quantity of fuel production only but also on the quality of fuels due to the plant location. In consequence, consideration of the capacity of fuel sources for the case of the renewable energy power plant establishment is required in terms of the appropriateness of the fuel quality and the power generating technology.

3) Environment

Based on the interviews, the power plant design must be concerned with the environmental impacts. Apart from the design following the relevant standards, it is also required that the impacts that might affect the nearby community be understood. The environment is a major part of sustainability regarding the issue of the environmental damage of a project and the polluting power plant. It might result in protests from the local people, and the project could possibly be terminated. All current power generation technologies still affect the environment. Thus, the establishment of the renewable energy power plant must focus on controlling the environmental impacts by avoiding the impacts on the environment and the community. Therefore, selection of the location of the establishment that affects the community the least will receive more acceptance from the community.

4) Fuel Use

In respect to the interviews, fuel management is one of the main factors in designing the power plant and it directly influences the performance, the environment, transportation, and production costs. The use of fuel, including the quantity used, is needed by all building-completed power plants to generate electricity and distribute it to the government as in the contract, fully. Therefore, the fuel that is used must be sufficient for power generation as the project will be operated according to the contract. The rate of fuel use affects the power generation process. However, if the renewable energy power plant requires fuel from agricultural products, it must be concerned with the benefits for the farmers. If the power plant has significant fuel use or abundant fuel returns, the participation of the agricultural community will also increase. On the contrary, if the power plant has a low rate of fuel use or is unable to produce sufficient fuel returns for the community, it will affect their support for establishing the power plant.

5) Production Costs

Based on the interviews, the production costs directly affect the request for licenses because they determine the electricity price per unit. Most of the production costs mainly include the fuel price, building and construction design price, product management costs and power plant maintenance costs, and funds. The production costs are concerned with management because it is required that the cost of the power generation to distribute to the state sector be limited. However, the performance of electricity production must be according to plan because the income from electricity distribution must be allocated to manage the fuel, repairs

and maintenance, and employment. As previously mentioned, the success of the power plant establishment needs significant support from the fuel production sector. Therefore, reducing the production costs must be mainly focused on having the least impact on the fuel production sector.

6) Life Quality and Family Balance

According to the interviews, a project needs to consider the life quality of the nearby community, which includes the environment and the economy. The projects, specifically the large-scale projects, may affect transportation and/or the environment, for instance, but the balance adjustment will increase the benefits of the community, such as employment, fuel production and sales; for example, energy plants sold to the power plant. Some projects become the knowledge promotion centers and tourism destinations for knowledge promotion, education, religion, and community development; therefore, the power plant can be successful. The renewable energy power plant business is regarded as one of the industrial fields that can blend into the agricultural community way of life. Consequently, the electricity production from renewable energy could be managed with community participation and also promote the life quality and family balance of the communities nearby more than the other industries. In the conclusion of the interview, the energy policy problem, which type of energy is to be used, is highly complicated because it requires an examination of several dimensions. None of the energy sources is perfectly acceptable and none of the energies is entirely unacceptable, but the energy policy is not a very difficult topic and only requires the specialists to make a decision.

Generally speaking, the new energy has major topics to be considered as follows:

a. The security of energy resources: It is true that to collect the energy, the sources must be varied and not specifically focused on one type. To be precise, deciding the energy to be used must consider if it is the primary domestic energy or imported energy, for example, the coal produced in the country provides more security than imported coal. However, this topic is complex and difficult to answer regarding which way is more secure compared between imported coal and domestic bio-energy.

b. Price (The electricity generated is available at an affordability level): The word “cheap” is inappropriate because the produced electricity price may seem cheap, but it is truly not. This is because it does not include the environmental damage price (externality) as it has no market value. Although the price is not paid today, the damage must be compensated for in the future, no matter what. An example of this is the greenhouse effect towards global warming. Contradictorily, if the cleanest energy is selected, the cost of power generation is very high, and the economy cannot bear it. Another example is when the oil price is high, it results in all types of electric usage increasing in cost, and the economy starts to slow down. Therefore, the policy planning must identify the most appropriate point at which the price is the most appropriate.

C. Environment: The environmental issues have recently become an alarming topic in Thai society compared to the past (considering the cost of energy and environment in this case). In general, dirty energy affects the environment, but the price is low, for example, nuclear energy and coal energy. Meanwhile, the cleaner energy tends to be more expensive, for example, solar and wind energies.

d. Social Justice: The social problems are directly related to the environment, especially those who are affected resulting in worse living and long-term social-political problems. Therefore, these people must receive compensation until their lives become stable or are improved. This will decrease the protests and strengthen justice for the people who have suffered loss due to the projects. The compensation will be added to the electricity price, and it will be returned to the people who need the compensation.

In the high-growth economic countries such as those in Western Europe, as well as Japan and even China, priority is given to this topic because it is connected to the security of human resources and the long-term political stability. At the same time, Thailand has not paid as much interest as it should because the country has the value of thinking that when the state decides to do something, the affected people must sacrifice for the loss without any conditions, and the compensation is not worthy of the damages that occur. Concurrently, the other electricity users receive less benefit from the price than they should. The conception of ‘the winners take all’ is a genuinely ancient form of economic development. Until 1970, the compensation indeed affected the higher price of electricity but when the state neglects this issue, it will cause more protesting and finally, every aspect of economic development will cease, which might lead to social and political chaos. Western Europe and Japan encountered this problem before; therefore, they ameliorate the energy policy due to the selection of any energy type causing damage anyway. The selection of mixed fuel energies has become the present practice of every country, but the most difficult issue in planning the energy policy is to weigh which dimension is more important since the groups that receive different benefits will have different points of view. For example, the

electricity users who do not receive direct effects tend to give more priority to the low price, while local people who are directly affected tend to pay more attention to the environment and the social justice.

The solution in the developed countries is that the state is not the judge to select which type of power plant should be developed but options are offered to the public and their opinions are heard. Moreover, they offer the opportunity to every group that presents other options and compare the pros and cons and who will lose the benefits, before asking for a consensus from the people. The power plant development plan of the country will follow the public opinion, for example, most Germans selected renewable energy as their long-term major goal, while the French selected nuclear energy as the primary energy, even though the two countries border each other. Recently, the Thai state has preferred to manage the energy following the pattern of DAD, which means to Decide by the state technocrats before Announcing the regulatory enforcement and the state policy when facing the protests. The Defense of the system might have been useful in the past because the people at that time rarely understood, but when there is economic growth, people become more aware; thus, the state should reform the practice by allowing the people to participate from the beginning to the end similar to the developed countries because they regard the people as partners. PAL means to present the information including the pros and cons to the people and let them participate. Participate means giving Advice for feasible options and dividing the responsibilities among the related sectors. Then, there is Liberate when Thailand steps into the mode of new energy reformation. There is no correct or wrong in the energy policy; instead, it depends on which design is preferable, and some solutions may seem good, although in the short term, they are not sustainable, while some others seem to have obstacles but have longer sustainability.

5. CONCLUSIONS

Nowadays, Thailand has the demand for electricity that increases 1,200 MW every year. As a result, the country needs to develop new power plants. With the power generation using natural gas accounting for 70% and lignite and coal for 20%, the other sources are renewable energy and the purchase of the neighboring countries' electricity. To reduce the risk of over-dependence on natural gas, in the current PDP, the development is mainly focused on the power plants that use the imported coal and nuclear energy; however, after the Fukushima Daiichi nuclear accident in Japan, the Thai government has postponed the nuclear power plant development plan. The main topic that people should understand is that the response to the increasing demand for electricity can be implemented by four pathways, which are to conserve electricity and use it wisely, to develop the primary fuel power plants, to develop the renewable power plants, and to purchase the electricity from the neighboring countries. In the present day, the related agencies of the state follow these pathways with integration. The development of the primary fuel power plants and renewable power plants must be coordinated, instead of selecting one specific way. The obstacle to Thailand's new power plant development is the protest and the resistance of the local communities and some members of civil society in the target areas. The main reasons for their protest are the pollution (and radioactivity for the nuclear projects). In the recent period, no matter which group or which region, they share this one same reason to oppose the projects as they demand that the state develop renewable power plants only. As a result, some communities and societies might have an incomplete understanding of renewable energy. Most of our renewable energies for power generation are biomass, hydroelectricity, solar power, and wind. The main concern of renewable energy is the uncertainty of the energy source; for example, whether water, solar, or wind is sufficient to generate power all of the time or not. Moreover, the cost of renewable energy remains high, for example, the power price from wind energy is THB 6 and from solar energy it is approximately THB 8 - 10, but now we pay only THB 3.5 for the general power price. If clean energy is used, many people will not be able to afford the electricity price rate or if there is excessive generation of power in the system, the overall price structure will be higher, and this will affect the cost of industry and the economic situation. The most important topic of renewable power generation is the security problem of the power system owing to the instability of the energy source; for example, even if the solar power generation and the wind power generation have 10 MW of generation capacity each, when the wind does not blow or the intensity is insufficient, or when the sun sets, the power generation will cease. Therefore, these factors affect the security of the power system. Finally, people must still pay for the electricity of the primary fuel. The major problems of some communities and civil society with regard to renewable power development nowadays involves three issues. Firstly, the local capacity to generate electricity in the community is not sufficient or ready in all areas or for every household. Secondly, the development of new national power plants that only need renewable energy cannot support the entire demand for electricity in the country, which increases by 1,200 MW every year. Thirdly, when the development of renewable power plants increases in the domestic power system, it is required that the primary fuel power plants be developed side by side as a means to support the instability of the renewable power plants, which results in repetitive investment. In consequence, the development of primary fuel power plants is still necessary as they are the main source of electricity in the domestic power system.

In conclusion, for Thailand's renewable power plant development, the situation is similar to a dead-end due to the opposition against the projects for many decades as usual with no solution or action until the situation reaches a crisis point. Currently, the natural gas for power generation accounts for 70% and most of it is from the Gulf of Thailand. It is expected that the reserved quantity shall be depleted within approximately 20 years. Therefore, it is necessary to search for other fuel sources as rapidly as possible as the development of large renewable power plants takes more than 6 to 7 years. The communication for a better understanding of and acceptance towards the projects operated by the related agencies has failed. On the contrary, the resistance to the current and future power plants has increased. The correct solution remains one in which the issue is elevated to the national agenda and to search for 'the mediators that every sector accepts to be the head of the commission'. The qualifications of the mediators are, for example, relation to a state agency, an industrial unit, a commercial entity, academic society, civil society, a people's representative, or the media. They can share and exchange opinions and discuss the options based on the facts and possibilities as a means to find the best solution for the highest benefit of the country. The results must be acceptable to all and the clear communication of information to the public must occur regularly. According to this study, the overall success of using the engineering factors when selecting a renewable power plant establishment has the mean at a high level. With regard to the types of power plants, the solar power plant is ranked at the top, followed by the second, the biomass power plant; then, the waste-to-energy power plant, biogas power plant, and wind power plant, respectively. Also, the power plant with a moderately high mean of success is the hydroelectric power plant.

These findings show that the engineering factors are related to the success of all types of renewable power plants. Moreover, regarding the problem of energy policy, deciding which type of energy to use is highly complicated because there are a large number of dimensional reasons and no energy source is the best option or the worst. However, it is not especially difficult for specialists to make a decision. In the countries where the economic growth is high, such as Western European nations, Japan, or even China, priority is given to this topic because it is associated with the security of human resources and the long-term political stability. This is in contrast to the Thai government, which mostly neglects this issue, as the Thai population shares the value that when the state makes a decision, the affected people must be sacrificed without any conditions, as the compensation cannot cover the actual damages.

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