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Determinants of nuclear power expansion in Indonesia

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ABSTRACT

As Indonesia is rich in natural resources, nuclear power remains a low priority among energy alternatives. However, Indonesia needs to introduce nuclear power to improve the atmospheric environment and to support sustainable economic growth. This study conducted a two-stage survey of logit-probit and analytic hierarchy process to analyze the perception of Indonesian energy policymakers regarding the introduction of nuclear power, the potential for change, and key decision factors. The analysis confirms that the perception of nuclear power is positive and that the willingness to expand nuclear power can improve if negative conditions, such as underdeveloped technology level, foreign aid and assistance, and safety issues are addressed. In addition, it is confirmed that the policy makers consider political/social and environmental factors to be more important for decision-making. The results of this study can give inplications and be used as a key reference for Indonesia's nuclear power policy

1. Introduction

Indonesia is a country rich in energy resources such as coal, natural gas, and oil, hydro and geothermal. In the past, Indonesia's abundant natural resources were used not only to meet domestic energy demand but also to secure finances through export [1]. However, as domestic energy demand increased due to rapid economic development, the government has made significant changes in energy policy. In the National Energy Policy statement issued in 2014 (Government Regulations No. 79/2014), Indonesia is implementing policy to preferentially use energy sources produced in its own country. This includes increasing the share of renewable energy and natural gas used, controlling the usage of coal and minimizing the use of oil. In particular, the Indonesian government regards nuclear power as an 'option of last resort' and has set the use of nuclear energy as a low priority option. Therefore, nuclear power is not currently being supplied to the Indonesian energy market [2].

Although nuclear power is not a main option of policy, Indonesia continues to show interest in it. That is because nuclear power has the characteristics of zero-carbon source of electricity [3–5]. Due to the energy mix in Indonesia, which is produced mainly by fossil fuel power generation. Indonesia's pollution of the atmospheric environment is serious. Indonesia's CO_2 greenhouse-gas emissions in 2015 were 946.8 million tonnes, an increase of more than 1.24 times from 760.5 million tonnes in 2010 (total world average increase - 1.05 times) [6], and according to Koplitz et al. [7], a significant number of Indonesians are exposed to 20 times more air pollution than recommended by the World Health Organization guidelines. Another reason is because nuclear power is considered as a cost-effective energy source [8,9]. Energy is the driving force for economic and social development, which requires constant energy input for the development of Indonesia. Considering the economic situation in Indonesia, which is not abundant, the introduction of nuclear power is required as a realistic alternative to solve the air pollution problem.

Indeed, the Indonesian government has continued to make efforts to introduce nuclear power in the past. Since the late 1970s, the government has conducted feasibility studies on the introduction and construction of nuclear power plants (NPPs) with the support of Italy, France and the United States, and the International Atomic Energy Agency, and also conducted a comprehensive survey on the selection of construction site [10]. International cooperation with various countries is ongoing, from technical cooperation such

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as reactor design [11] and floating NPP construction [12,13] to policy cooperation and training of human resources [14,15]. In particular, efforts to increase public perception of the introduction of nuclear power were made with a government-level program [16]. In addition, some academic research on the perception was conducted [17–19]. However, the academic approach is rather lacking compared to the recent active moves to introduce nuclear power, and there is no research on the perception of government officials in particular.

Therefore, this study aims to analyze determinants of nuclear power expansion in Indonesia, particularly focusing on the decision-making structure of policymakers. To this end, this study conducted a two-stage survey to analyze the perception and decision-making of Indonesian energy policymakers with respect to nuclear power expansion. The 1st survey (basic survey) was conducted to investigate the policymakers' awareness of nuclear power. In addition, this study used logit-probit analysis to examine whether their willingness to expand nuclear power within the country increases if negative conditions improve and what those conditions are. The 2nd survey (in-depth survey) focused on identifying what decision-making factors were important to the policymakers as related to expansion of nuclear power. This study is expected to offer an opportunity to examine the circumstances of the country objectively before introducing nuclear power.

2. Expansion of new energy sources

2.1. Previous studies on the expansion of new energy sources

There are conflicts and difficulties in attracting new energy resource facilities, from nuclear energy to renewable energy [20]. These problems stem from various causes, such as technical issues and economic and environmental factors, and vary greatly depending on the country's circumstances. As each country has a variety of constraints regarding the introduction or expansion of nuclear power, such as land environment, economic conditions, government policy, and institutional differences, an evaluation of the energy characteristics and constraints for each country is needed. Failure to do so could result in adverse effects such as delays, unexpected costs, or failure to implement plans entirely [21].

Previous studies on the introduction and expansion of new energy sources can be categorized as those that analyze obstacles to the introduction of equipment, those that examine public perception and acceptance of expansion of new energy sources, and those that evaluate and select optimal energy sources. Many researchers have conducted research on obstacles to the introduction new energy source. As mentioned above, each country has a variety of technical level, economic conditions, and geographical characteristics, therefore, it has a different degree of problems. This issue needs to be considered the differences between the types of energy sources-renewable energy and nuclear power. Nguyen et al. [22], Reddy and Painuly [23], Painuly [24], and Richards et al. [25] analyzed obstacles to the introduction of renewable energy facilities and then prioritized them. Painuly [24] emphasized the importance of identifying barriers to the introduction of renewable energy prior to studying them. In particular, the author suggests that complimentary methods such as literature reviews, site visits, and interactions with stakeholders need to be utilized comprehensively to identify barriers. The author identified key barriers including market failures, market distortions, economic and financial factors, institutional factors, technical factors, social, and cultural and behavioral factors. Reddy and Painuly [23] distinguished the obstacles to the diffusion of renewable technologies from economic, technological, market, and institutional perspectives, and prioritized the obstacles based on the awareness of various stakeholders (household, industry, and commercial establishments) in India. Nguyen et al. [22] analyzed obstacles to the deployment of geothermal, small hydro and advanced coal power generation technologies in Vietnam. In particular, the authors identified barriers for each energy source through a questionnaire administered to energy experts and stakeholders. They suggested that the best alternatives are to improve research and development (R&D) capabilities by increasing R&D investment and reform investment policy related to the electric power industry. Richards et al. [25] identified barriers to the construction of a large-scale wind energy plant in Saskatchewan, Canada. As a result of the survey, technological and political barriers were identified as the biggest obstacles.

Pingkuo et al. [26], Greenhalgh and Azapagic [27], and Adamantiades and Kessides [28] analyzed the obstacles for the introduction of nuclear power. Each country recognizes the necessity of nuclear power because of common environmental and energy security issues; however, there are slight differences among the different studies regarding the factors that are recognized as obstacles. Pingkuo et al. [26] analyzed the macro-environment to diagnose the difficulties of four aspects - political, economic, technical, and social - of expanding nuclear power in China and to suggest countermeasures in the areas of technology support and policy framework. Greenhalgh and Azapagic [27] chose energy security, the decrease in energy generation capacity, and climate change as drivers that prompted the British government - once neutral about nuclear power - to encourage the private sector to build an NPP. In addition to the aforementioned drivers, the perception change of the public on the nuclear power has emerged as one of the major factors in changing the government's position. Nevertheless, Greenhalgh and Azapagic [27] maintained that in addition to the national planning system, perception remains a major obstacle for nuclear power generation. Adamantiades and Kessides [28] argued that the nuclear renaissance arrived on the basis of energy security, the ability to respond to fossil fuel price volatility, the ability to respond to climate change, and the changes in public perception. However, the authors noted that safety, major reactor accidents, safety risks and perception, disposal of nuclear waste, and risk of nuclear weapons proliferation remain unresolved issues.

Some researchers focused on public perception and acceptance of the aforementioned obstacles. Studies on public perception and acceptance can be divided into two categories, one that compares the difference in the perception of multiple energy sources, and another that compares the change in perceptions of a single energy source, with the latter primarily focusing on nuclear power. Poortinga et al. [29] examined public opinion on the UK's future energy options - nuclear power, renewable energy (wind), and coal. In particular, the authors conducted interviews focusing on public attitudes toward nuclear energy, in terms of it being a way to respond to climate change. Although nuclear power is believed to contribute to the mitigation of climate change and is actually ready to accept it, it was analyzed that respondents did not actively prefer it over renewable energy. Hämäläinen [30] compared the perception of government officials and industrial executives on three alternatives - no big power plant, coal fired power plant, and NPP. Given the national economy, health and safety, and political factors, government officials preferred in order of no big power plant, coal fired power plant, and NPP, while industrial executives showed the opposite preference. Bird et al. [31] examined how the Fukushima nuclear accident affected the perception of Australians on nuclear power. After the accident, citizens were found to be unwilling to accept nuclear power even if it could help address climate change. Goodfellow et al. [32] compared the calculated and perceived risk

of nuclear plant construction. The authors argue that public perception for nuclear power is an important factor for the construction of new nuclear plants, particularly, social consensus for nuclear plants can be built through public participation from early stages. Park [33] investigated the difference between public and academic perceptions towards nuclear power after the Fukushima nuclear accident. Nuclear workers have a more positive outlook on nuclear energy compared to the public, and the perception of nuclear workers has not changed, even after the Fukushima nuclear accident.

Based on these studies, further studies on selecting the optimum energy source were also conducted. These studies conducted a survey to select the most suitable energy source considering the conditions in the country among various energy sources. Akash et al. [34] researched the most appropriate energy alternatives among fossil fuel power plants, nuclear, solar, wind, and hydro power in Jordan. Solar, wind, and hydro power were suggested as the best power alternatives in terms of cost and benefits. Chatzimouratidis and Pilavachi [35] assessed ten types of power plants according to technological, economic, and sustainability aspects, and renewable energy plants were comprehensively shown to be as competitive as fossil fuel plants. Erol and Kılkış [36] determined the optimal energy sources as perceived by various stakeholders, such as environmentalists, industry, local community, and local authorities. Kaya and Kahraman [37] proposed the VIKOR-AHP methodology to determine suitable energy alternatives for Istanbul and found that wind energy is the most suitable option.

2.2. Studies on public perception of nuclear power expansion in Indonesia

Indonesia government has implemented a program to reduce public disapproval of nuclear power and increase its acceptability [16]. At the end of 1985, the National Atomic Energy Agency of Indonesia, which is responsible for research and development of nuclear energy, established the 'Team on Public Acceptance of NPP' and conducted activities to raise awareness of NPP for leaders and the public in local communities, particularly in Muria peninsular, from 1990 to 1994. The purpose of this program was to provide people with information about nuclear power and to educate them to recognize nuclear power is necessary for industrial and economic development and not to be afraid. The program included an evaluation of the effectiveness of the education, i.e. how public's perceptions of nuclear power changed.

Academic research on public perception have been done in various ways. Suhaemi and Syaukat [38] studied the acceptance strategy for NPP. They argued that Indonesia's NPP adoption process included infrastructure development, however, it needed an advanced implementation and adoption strategy at a government-level. Kim et al. [17] compared the public perception of nuclear power in 19 countries, including Indonesia. They conducted face-to-face interviews with 1000 people in each country. They confirmed that Indonesians recognized nuclear power as risky but conductive to power supply and were willing to accept it. Sugiawan and Shunsuke [18] also analyzed Indonesia's public acceptance of nuclear power and conducted face-to-face interviews with 5372 people over the age of 15. This study confirmed that trust in each government - central government, nuclear energy authorities, local government - has a positive effect on nuclear acceptance in Indonesia, a multilevel managing authority system. Meanwhile, the National Atomic Energy Agency analyzed public acceptance of nuclear science and technology in 2016, and more than 77% of the Indonesia's population supported on NPP construction [19].

Taken together, these studies have focused on the public perception of nuclear power in Indonesia, and the public is somewhat acceptable to nuclear power. However, no analysis has been made on the position of public officials who are decision-makers on major energy policies. Considering that there is substantial movement for nuclear power generation in Indonesia, it is necessary to examine the inclination of government decision-makers to expand and introduce nuclear power generation, and to examine conditions that support or hinder the introduction of nuclear power in Indonesia.

3. Research design and analytical methods

3.1. Research design

This study conducted a two-stage survey to analyze the perception and decision-making of Indonesian energy policy-makers with respect to nuclear power expansion. The 1st survey (basic survey) was focused on investigating the policymakers' awareness of nuclear power. In addition, this survey included questions on how much the respondents agreed with nuclear power expansion. The 2nd survey (in-depth survey) focused on identifying what decision-making factors were important to the policymakers as related to expansion of nuclear power.

Fig. 1 shows the flow of the whole study. This study attempts to present the results of basic and in-depth survey responses in three forms. The first is the negative response rates to various conditions related to the nuclear power generation; that is, the negative response rates. Based on the results of the basic survey responses, whether positive or negative perception of nuclear power is dominant can be determined. The second is the results of an ordered logit-probit analysis. This is an analysis of the relationship between the introduction and expansion of nuclear power and awareness of the respondents and shows the willingness to introduce and expand nuclear power grows if outlook on it is improved. The third is the Analytic Hierarchy Process (AHP) weights calculated from the in-depth survey. This indicates which of the given factors is important to consider when introducing and expanding nuclear energy; that is, whether it is a decision-making factor for the expansion of nuclear power. By synthesizing the results, the decision-making structure of the Indonesian nuclear power expansion from a variety of perspectives can be identified. In other words, it shows the main decision-making factor with regard to the expansion of nuclear power in Indonesia, why that specific factor is important due to a certain perception (positive/negative), and whether the inclination towards nuclear power expansion increases if the perception improves.

A basic survey was prepared based on previous studies [24,30,34,36,39–45,47,48] and consisted of 25 questions regarding the views on and perceptions of nuclear power expansion under eight categories: technical conditions, inherent risks of nuclear power, economic conditions, conditions of international relations, geographical conditions, environmental conditions, social conditions, and institutional conditions. A short description of each category is given below.

- *Technical conditions* include the underdevelopment of domestic energy technology, and thus the need for foreign technology to increase production energy.
- *Inherent risks of nuclear power* are the risks inherent in the energy source. An energy source vulnerable to natural disasters and harmful to human health may be subordinated to other alternatives.
- *Economic conditions* include high costs relative to benefits, and underdevelopment of the industry, labor, and infrastructure to support the supply of the energy source. Poor perception of its

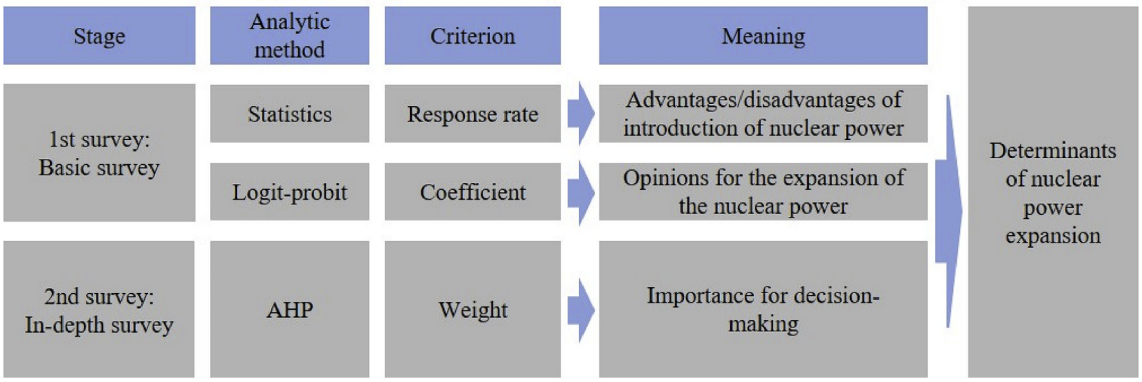

Fig. 1. Research flow.

ability to contribute to developing industry and creating jobs also discourages expansion of the energy source.

- *Conditions of international relations* can greatly affect the expansion of energy sources, especially in terms of foreign aid and assistance.
- *Geographic conditions* restrict the expansion of energy sources, in terms of unfavorable natural conditions, such as scarce resource endowment and site selection.
- *Environmental conditions* have become a major consideration in expanding energy, as climate change mitigation and greenhouse gas reduction have emerged as global tasks. The amount of water, soil, and air pollution can also be critical factors in energy selection.
- *Social conditions* can contribute to the stabilizing/destabilizing of a society and the economy of the country. Dependability of the electricity supply from the energy source also affects societal stability. A country's status as an exporter or importer of the energy source is also associated with social issues.
- *Institutional conditions* are directly linked to energy selection decisions and expansion. An increase in an energy source can be better facilitated if the current government has the will to do so and will encourage it with energy policies and laws.

For all the questions, the respondents were asked to respond on a 5-point scale. For the question on the willingness to introduce nuclear power, they were asked to assign 5 points for being most agreeable item and 1 point for being least agreeable; while for the question on the recognition of nuclear power, they were asked to assign 1 point when it is considered as the most disadvantageous and 5 points when it is considered as the most advantageous.

The in-depth survey was constructed based on the contents of the basic survey. Through expert consultation, eight categories in the basic survey were recategorized into four determinants: technical, economic, environmental, and political/social factors. This process of simplifying the questionnaire category was taken to facilitate the in-depth AHP analysis, considering the characteristics of AHP analysis that puts importance on the consistency of the responses. Fig. 2 shows the linkage between the contents of the two surveys.

The in-depth survey consists of pair-wise comparison. The respondents were asked to respond using a 5-point scale on which of the two factors in the pairs was more important. For example, in the pairs of technical and economic factors, 1 must be selected if the technical factors are considered relatively important, and 5 if the economic factors are considered more important.

Since the introduction and expansion of nuclear power in Indonesia is primarily a matter of the government policy, the respondents surveyed were limited to government officials in the Ministry of Energy and Mineral Resources in Indonesia, who are directly involved in energy policy decision-making. The survey respondents were 22 in total. The surveys were conducted from June 2017 to April 2018, via Google Survey and e-mail.

3.2. Ordered logit-probit analysis

The ordered logit-probit model was used to determine the correlation between the acceptance and the constraints on nuclear power. Five choice options in a sequential order were given to the respondents in the basic survey, and since the respondents could choose one of them, the variable had an ordinal form. In this case, the problem is that the assumptions of homoscedasticity and normality of the error terms are in violation when a regression analysis of ordinary least squares (OLS) is performed. Thus, it is necessary to use a method suitable for ordinal variable analysis instead of the OLS method, and the ordered logit-probit model is advantageous in that it is one of a sequential regression model to analyze ordinal variables.

The ordered logit-probit model assumes that the error terms follow the logistic distribution. The ordered logit-probit model is derived according to the following procedures.

$$y_i^* = x_i\beta + \varepsilon_i \tag{1}$$

where it is assumed that y_i^* is a respondent's unobservable response variable and five selectable options (y_i) are given to the respondents, as in this study. Similar to the dependency variables of this study, when asked whether they agree with the expansion of the proportion of future energy sources, the selectable answers are divided into 'highly agree,' 'agree,' 'neutral,' 'do not agree,' and 'do not agree very much'. Suppose that the responses of the respondents are observable by the choice of y_i , and that the relation between y_i^* and y_i at this time follows the next inequalities (2).

$$\begin{aligned}
&y_i = 1, \text{ if } \tau_0 = -\infty \le y_i^* \le \tau_1 \quad \text{(Do not agree very much)}\\
&y_i = 2, \text{ if } \tau_1 \le y_i^* \le \tau_2 \quad \text{(Do not agree)}\\
&y_3 = 3, \text{ if } \tau_2 \le y_i^* \le \tau_3 \quad \text{(Neutral)}\\
&y_4 = 4, \text{ if } \tau_3 \le y_i^* \le \tau_4 \quad \text{(Agree)}\\
&y_5 = 5, \text{ if } \tau_4 \le y_i^* \le \tau_5 = \infty \quad \text{(Highly agree)}
\end{aligned} \tag{2}$$

Where τ_1, τ_2, τ_3, τ_4 and τ_5 are the cutoffs and the parameter to be estimated in the model. The probability of observing $y_i = m$ for a

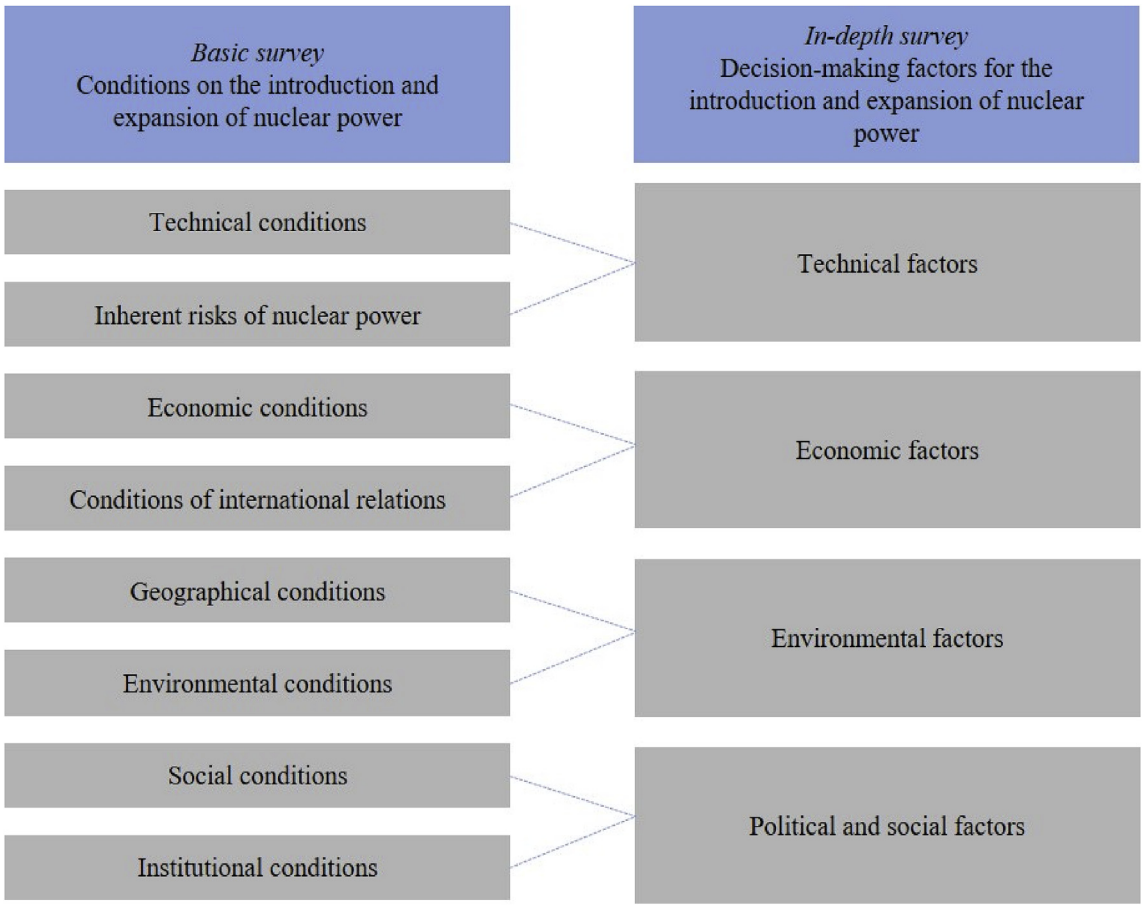

Fig. 2. Linkage between the basic and in-depth survey.

given explanatory variable (x) is as follows.

$$\Pr[y = m|X] = \Pr[\tau_{m-1} \le y_i^* < \tau_m|X]$$
$$\Pr[y = m|X] = F[\tau_m - x\beta] - F[\tau_{m-1} - x\beta] \quad (3)$$

Where $F[\cdot]$ is the cumulative distribution function of the error term ε_i and it is recognized as an ordered logit model assuming a logistic distribution.

When the ordered logit model is presented as a nonlinear probability model, it is equivalent to equation (4). For a given X, the odds for which a certain result is less than or equal to m is defined as follows.

$$\Omega_{\le m|>m}(x) \equiv \frac{\Pr[y \le m|X]}{\Pr[y > m|X]}, \quad \text{for } m = 1,\ 2,\ 3,\ 4,\ 5 \quad (4)$$

The logarithm of the odds is calculated as a linear function of the explanatory variable (X), and the odds ratio is obtained as equation (5), where multiplication occurs if X increases by 1 unit.

$$\frac{\Omega_{\le m|>m}\left(X,\ x_k + 1\right)}{\Omega_{\le m|>m}\left(X,\ x_k\right)} = e^{-\beta_k} \quad (5)$$

3.3. Analytic hierarchy process analysis

The AHP was used to analyze the decision factors of government officials on expanding nuclear power in Indonesia. The AHP was used to analyze the factors considered to be important in the decision-making process regarding the introduction and expansion of nuclear power. The AHP was proposed by Tomas Saaty in the late 1960s as a multidisciplinary evaluation criterion for numbers of alternatives and the decision-making method designed for decision-making by multiple entities [46]. AHP is characterized primarily by deriving the importance through the pairwise comparison of sequential factors by layering the complex evaluation criteria. Also, AHP has the advantage of using consistency index to identify how consistently the respondents are thinking and to increase the rationality and logicality of the responses.

Table 1
Main criteria and sub-criteria of the in-depth survey.

Main criteria	Sub-criteria
Technical factors	Expansion of the power supply
	Energy technology development
	Technical stability
Economic factors	Nuclear expansion costs
	Economic and industrial development
	Influx of foreign capital
Environmental factors	Mitigation of climate change
	Resources and uranium reserve
	Securing nuclear power sites
	Durability during natural disasters
Political/social factors	Social acceptance
	International interests
	Policy, law, institutional foundation
	Stability over social risks

Table 2
Policymakers' position on the introduction and expansion of nuclear power.

	Approval	Neutral	Opposition
Response rate (%)	55	18	27

This study derived four main criteria and 14 sub-criteria that were considered important in expanding nuclear power as shown Table 1. The sub-criteria of each factor were derived from the basic survey. As the criteria that evaluate relative importance should be independent of each other in terms of characteristics or content. For example, 'economic conditions' and 'conditions of international relations' in basic survey, although not completely identical, contain information about 'finance' in common. Therefore, eight categories of the basic survey were recategorized into four main determinants.

The in-depth survey was distributed to 22 of the people who answered the basic survey. A consistency ratio was used to determine the consistency of the responses to the collected questionnaires, and the results were analyzed using 11 responses meeting the consistency ratio of 10% or less.

4. Results and discussion

4.1. Results of the basic survey

The basic survey examined the policymakers' stances on nuclear power expansion and presents the results of an ordered logit-probit analysis to determine the negative response rates indicating their perception according to perspectives, and whether the inclination towards nuclear power expansion increases when such perception improves.

First, Table 2 shows the responses (approval, opposition, and neutral) to nuclear power expansion. Of the officials surveyed, 55% supported the introduction and expansion of nuclear power, while 18% and 22% were neutral or opposed it, respectively. Indonesia is a country that does not officially generate nuclear power; however, more than half of the respondents supported the introduction of nuclear power. In other words, key decision-makers are favorable to nuclear power expansion.

Table 3 shows the negative response rates and the logit-probit analysis results. As for the negative response rate, the respondents cited conditions of international relations as a significant challenge to nuclear power expansion. This includes the necessity for overseas aid and financial support to expand nuclear power. Technical conditions also displayed a high negative response rate, indicating that the technology levels of nuclear power in their own country is low while the introduction of overseas' technology is necessary for the expansion of nuclear power. The negative response rate for the inherent risks of nuclear power reflects the safety concerns of the Indonesian government; in particular, the possibility of accidents due to natural disasters reduces confidence in nuclear power.

From the results of the ordered logit-probit analysis, it can be seen that the conditions contributing to nuclear power expansion are geographical, environmental, and social. They are conditions under which the current level of nuclear power is perceived favorably or the more the conditions are expected to be improved by future nuclear power generation, the more willing they are to expand nuclear power. In the case of geographical conditions where the negative response rate is 67%, if the geographical constraints arising from the archipelagic territories are resolved, it may contribute to the expansion of nuclear power. Environmental conditions involve the eco-friendly nature of nuclear power, such as improvement of air pollution, mitigation of climate change and reducing greenhouse gas emissions. Such a positive perception regarding the environment is a factor in increasing the approval of nuclear power expansion. In addition, the stable power supply function of nuclear power and its social and economic stability promote the inclination to expand nuclear power, which is a social condition.

4.2. Results of the in-depth basic survey

The AHP analysis provides the results of a pairwise comparison of the factors of the main criteria and sub-criteria, respectively. Table 4 shows the weights of the decision-making factors of the main criteria. The Indonesian government puts the most importance on political/social factors in its decision to introduce and expand nuclear power. The importance of decision-making factors is in the following order: political/social factors > environmental factors > technical factors > economic factors.

Table 5 shows the weights of the decision-making factors of the sub-criteria. From the decision-making factors of the sub-criteria, the importance of political/social factors is related to the issue of social acceptance of nuclear power expansion. In addition, it is confirmed that the durability during natural disasters is significant among the environmental factors which is the second highest of the main criteria.

4.3. Comprehensive analysis and discussion

Given the overall analyses, it can be seen that the political/social factors are of great importance in Indonesia's decision to expand nuclear power. In particular, they appreciate the social functions of nuclear power such as a stable power supply, because more than 100 million people have suffered damage due to a massive power outage in August 2005, and the country is still experiencing power outages. Considering that a large amount of chaos is caused by power outages, the result that Indonesia emphasizes 'the stability of nuclear power in regard to social risks' is also interpreted in the same context. In particular, as the perception of the social function of nuclear power increases, the willingness of decision-makers to introduce nuclear power also increases. From the point of view of the Indonesian government, it is necessary to emphasize the stable power supply capability of nuclear power that can take charge of the base load when nuclear power is supplied in Indonesia.

Environmental factors are also important issues regarding the nuclear power expansion in Indonesia. What is particularly emphasized is the stability of nuclear power against natural disasters. Indonesia is a country belonging to the Circum-Pacific belt and suffered damage from an earthquake in July 2018. Indonesia has geographical problems such as frequent blackouts due to frequent earthquakes and regular interruption of local power facilities. Therefore, the issue of radiation exposure from nuclear power is seriously taken into consideration, and the high negative response rate to the inherent risks of nuclear power reflects these concerns due to such environmental conditions. On the other hand, another factor that the Indonesian government considers a major decision in nuclear power is the eco-friendly nature of nuclear power. The Indonesian government responded positively to the function of nuclear power for improving air pollution and mitigating climate change. Taking all of these environmental perceptions into consideration, in order to advance nuclear power in Indonesia, it is necessary to establish a strategy to reinforce stability and emphasize the eco-friendly functions of nuclear power.

In addition, Indonesia comprises many small islands which makes securing sites difficult. However, if geographical limits can be overcome, or improved, policymakers would be more willing to expand nuclear power. Therefore, it is necessary to consider various

Table 3
Results of basic survey: negative response rates and ordered logit–probit.

Category	Negative response ratio (%)	Ordered logit-probit	
		Correlation between the will to introduce and the perception *	The degree of willingness to introduce according to the improvement in perception (X)[a]
Technical conditions	*88*	0.168 (0.414)	0.847
Inherent risks of Nuclear power	*83*	−0.244 (0.496)	1.276
Economic conditions	57	−0.128 (0.123)	1.137
Conditions of International relations	*92*	−0.562 (0.756)	1.754
Geographical conditions	67	*−0.659 (0.376)**	*1.933*
Environmental conditions	17	*−0.407 (0.216)**	*1.502*
Social conditions	44	*−0.320 (0.176)**	*1.377*
Institutional conditions	77	−0.273 (0.272)	1.314

Note: * indicates coefficients, significance rates (* * * 1%. * * 5%, * 10%), and standard errors (in parentheses) which were derived by analyzing the inclination to expand nuclear power as a dependent variable and the conditions of introducing nuclear power as explanatory variables.
[a] Is an odds ratio of the ordered logit-probit analysis, which indicates how many times the willingness to introduce increases when the negative response is decreased by 1.

Table 4
Results of the in-depth survey: weights of the decision-making factors of the main criteria.

Main criteria	Weights
Technical factors	0.2188
Economic factors	0.1712
Environmental factors	0.2765
Political/social factors	0.3335

Table 5
Results of the in-depth survey: weights of the decision-making factors of the sub-criteria.

Main criteria	Sub-criteria	Weight
Technical factors	Expansion of the power supply	0.2750
	Energy technology development	0.2539
	Technical stability	0.4711
Economic factors	Nuclear expansion costs	0.3303
	Economic and industrial development	0.3894
	Influx of foreign capital	0.2803
Environmental factors	Mitigation of climate change	0.2051
	Resources and uranium reserve	0.1889
	Securing nuclear power sites	0.2441
	Durability during natural disasters	0.3619
Political/social factors	Social acceptance	0.3204
	International Interests	0.1288
	Policy, law, institutional foundation	0.2825
	Stability against social risks	0.2683

approaches to overcome geographical conditions, such as suggesting small reactors suitable for the countries of the archipelago or considering installing them on solid and large islands.

Overseas technology and foreign capital for nuclear expansion are factors that the Indonesian government desperately needs. Although these factors were not high in the importance of decision-making, the necessity of both was 100% and 92%, respectively, according to the survey. Despite the pessimistic views of the officials on the current conditions of technological and economic levels of the county, its past experience had influenced the government to relatively put more importance on the environmental and the political/social factors in decision-making of the introduction of NPPs. As discussed earlier, the government had faced oppositions from the residents regarding the installation of an NPP (political/social factor) and had recently been threatened by frequent earthquakes (environmental factor). Therefore, it can be explained that the government relatively puts more importance on the political/social and the environmental factors in comparison to the economic and the technical factors. Technology and capital are essential input factors for the construction and operation of NPPs; therefore, it is necessary to examine technical capability and economic costs through feasibility studies when entering the nuclear power business in Indonesia.

5. Conclusion

Under current national energy policy in Indonesia, nuclear power remains a low priority among energy alternatives. However, public perception on nuclear power is good. In addition, this study confirmed that energy policymakers had a good understanding of nuclear power, and which factors should be improved to actively accept nuclear power.

The introduction of nuclear power, the growth engine of zero-carbon, seems to be unavoidable choice for the foreseeable future. Therefore, this study analyzed the policymakers' perception of nuclear energy, its potential for change, and the factors that are important in making decisions on energy.

As results of the analyses, the government officials in Indonesia recognized that the level of technology in their country is low and that financial support from abroad was urgently required for nuclear power expansion. In addition, it can be confirmed that the government officials held a negative outlook on nuclear safety in connection with recent frequent natural disasters.

Contrary to the recognition of these conditions and circumstances, the government officials thought that political/social and environmental factors should be considered important when making decision. The people of Indonesia are aware of the risks associated with nuclear power and some opposition to NPPs is expected, due to their experience in the past when the plans to build a NPP in the Muria region of Java island were withdrawn due to the opposition of residents and non-governmental organizations.

This study is meaningful in that it is the first attempt to be conducted on energy policymakers with a high understanding of energy related conditions in Indonesia. By conducting further in-depth studies on each of the factors presented in this study, it is expected to be reduced trial and error in the process of adopting nuclear power as a new energy source in the future.

However, most of conditions, including technical conditions, conditions of international relations, and inherent risks of nuclear power, which were shown a strong negative recognition, were excluded from the main discussion because the statistical significance could not be proved. Future discussions on these conditions are needed to promote the introduction and expansion of nuclear energy more reliably.

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Declaration of competing interest

None.

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