A logistic regression approach to model the willingness of consumers to adopt renewable energy sources

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Abstract. The implementation of renewable energy in this globalization era is inevitable since the non-renewable energy leads to climate change and global warming; hence, it does harm the environment and human life. However, in the developing countries, such as Indonesia, the implementation of the renewable energy sources does face technical and social problems. For the latter, renewable energy sources implementation is only effective if the public is aware of its benefits. This research tried to identify the determinants that influence consumers’ intention in adopting renewable energy sources. In addition, this research also tried to predict the consumers who are willing to apply the renewable energy sources in their houses using a logistic regression approach. A case study was conducted in Semarang, Indonesia. The result showed that only eight variables (from fifteen) that are significant statistically, i.e., educational background, employment status, income per month, average electricity cost per month, certainty about the efficiency of renewable energy project, relatives’ influence to adopt the renewable energy sources, energy tax deduction, and the condition of the price of the non-renewable energy sources. The finding of this study could be used as a basis for the government to set up a policy towards an implementation of the renewable energy sources.

1. Introduction
All forms of energy sources have negative impacts on sustainable development values. Fossil fuels, such as coal, oil, and natural gas, do substantially more harm by most measures, including air and water pollution, damage to public health, wildlife and habitat loss, as well as water and land use. Consumption of fossil fuels resources, which were formed from prehistoric plants and animals that live hundreds of millions of years ago, leads to global warming and climate change. Although the fossil fuels do harm the environment and human life, their global consumption increased of about 0.6% in 2016 [1]. As a result, global carbon dioxide emissions set a new all-time record high! Carbon dioxide emissions in 2015 were 36 million metric tons higher than in 2014 and marked the sixth straight year a new record high has been set. This situation actually cannot be allowed to continue in the future. Since the fossil fuels come from buried dead organisms, they do have a limited amount—it is non-renewable. They are expected to run out 30 to 60 more years [2]; hence, it is only a matter of time when they are diminished!

In Indonesia, as a developing country, the consumption of fossil fuel energy sources to the total energy sources is increasing year-by-year. In 2014, the consumption of fossil fuel absorbs more than 65% of the total energy sources; in contrast with Sweden, Finland, and France with less than 50% of the total energy consumption [3]. Generally, the fossil fuels in Indonesia are used the most in the industrial sector, which is about 296 million tons of oil equivalent (Mtoe), or about 41% from total
consumption of national energy; followed closely by transportation sector which consumes 226.6 Mtoe (37%) in 2009 [4].

This condition makes the government and the energy society worry as the fossil fuels energy resources will be diminished in the future. In addition, the increasing dependency on the non-renewable energy sources could influence negative impact toward the environment and become a trigger to global warming. Changing the energy sources from non-renewable to renewable is necessary. Several countries have changed their energy usage from non-renewable to renewable; for instance, the U.S. Environmental Protection Agency in 2014 has proposed a clean power plan, which intends to diminish U.S. carbon pollution by 30% in 2030 [5].

Renewable energy comes from regenerative resources that cannot be depleted, such as solar, hydropower, wind, biomass, and geothermal. It is sustainable, ubiquitous, and essentially non-pollute. It has various advantages, such as strengthening the economy to reduce the reliance on fossil fuels and making the nations more secure in providing pollution-free energy [6]–[8]. As the impacts of climate change worsen with each passing year, replacing fossil fuels with renewable energy will be imperative to the protection of wildlife and wild lands.

Fortunately, the development of the renewable energy sources is growing remarkably from year to year. It includes the continuation of comparatively low global fossil fuel prices, dramatic price declines of several renewable energy technologies, and a continued increase in attention to energy storage. As of 2015, renewable energy provided an estimated 19.3% of global final energy consumption, and growth in capacity and production continued in 2016. In addition, the renewable energy sector employed 9.8 million people in 2016, an increase of 1.1% over 2015 [9].

However, the utilization of renewable energy resources in Indonesia has not been optimized due to its high production cost and it is worsened by the subsidy policy on fossil energy. Moreover, some opposite perceptions from the citizen about the renewable energy make it more difficult to implement it. Public perceptions, consciousness, and acceptance of renewable energy are significant social factors, which shall be taken into consideration in establishing prospective energy systems. Implementation and deployment of the renewable energy can be sustainable and effective only in the case if the public is aware of its benefits and its needs in the deployment of the renewable energy on the human activities and on the environment [10].

Several previous researches have been conducted to address consumers’ stated intentions to adopt the renewable energy. According to [11]–[13], consumers with higher income are willing to adopt renewable energy. Age had a significant impact on influencing the willingness to adopt the renewable energy [14], yet [11] found it conversely. Other researchers found that higher education is the main individual characteristics in adopting the renewable energy [15]. However, these outcomes are based on the results of individual researches, and may not be conclusive across studies so as errors will appear when transferring estimates from one site to another.

Therefore, in this study, we focus on investigating the determinants that influence consumers’ intention towards the adoption of renewable energy sources in the household sector. A case study was conducted in Semarang, Indonesia, to model the willingness of the consumers to adopt the renewable energy sources. The identification of the characteristic of the potential market segment is becoming a major reason in renewable energies implementation in Indonesia.

2. Research methods

A logistic regression was employed in this research to model the willingness of consumers to adopt renewable energies. It is frequently used to explain a model that connects one non-metric dependent variable and several—metric and/or non-metric—dependent variables. Its primary objectives are to understand group differences and to predict the likelihood that an entity (individual or object) will belong to a particular class or group based on those several metric independent variables [9], [16].

A logistic regression is similar to multiple regression analysis in that one or more independent variables are used to predict a single dependent variable. What distinguishes a logistic regression model from multiple regression is that the dependent variable is nonmetric. It is preferable to discriminant analysis since the former can accommodate all types of independent variables (metric and nonmetric) and do not require the assumption of multivariate normality [17].
Since the objective of this research is to investigate the consumers’ attitude towards the adoption of renewable energy sources, we set the dependent variable \( Y \) as the willingness of the consumers to adopt renewable energies. The score of 1 (one) was given when the consumer \( i \) is willing to adopt the renewable energy sources in his/her house; while the score of 0 (zero) was given to the opposite answer. For the set of independent variables \( (X_j) \), we follow the study by [18] as they studied the determinants that affect consumers’ intention towards the adoption of renewable energy sources in the residential sector in Greece. The model is then as follows:

\[
Y = \beta_0 + \beta_1 X_1 + \beta_2 X_2 + \beta_3 X_3 + \text{\ldots} + \beta_{15} X_{15} + \epsilon,
\]

where \( \beta_0 \) is a constant; \( \beta_j \) is the regression coefficient \((j = 1 \ldots 15)\); \( X_i \) is a dummy variable for gender (1 if the consumer is female and 0 if the consumer is male); \( X_2 \) is a metric variable for the consumer’s age; \( X_3 \) is a metric variable for the square of the consumer’s age; \( X_4 \) is a dummy variable for the marital status of the consumer (1 if the consumer is married and 0 otherwise); \( X_5 \) is a dummy variable for the educational background of the consumer (1 if the consumer has completed undergraduate studies and 0 otherwise); \( X_6 \) is a dummy variable for the employment status of the consumer (1 if the consumer is a public servant employee and 0 otherwise); \( X_7 \) is a metric variable for the consumer’s monthly private income in Rupiah (Indonesian currency); \( X_8 \) is a dummy variable for the consumer’s status of home ownership (1 if the consumer owns his/her house and 0 otherwise); \( X_9 \) is a metric variable expressing the average electricity cost per month in Rupiah; \( X_{10} \) is a dummy variable taking the value 1 if the consumer considers that the installation and maintenance costs of renewable energies in the residential sector are too high and 0 otherwise; \( X_{11} \) is a dummy variable accounting for 0 if the consumer is uncertain about the efficiency of domestic renewable energy projects and 1 otherwise; \( X_{12} \) is a dummy variable accounting for 1 if the consumer would install a renewable energy system in his/her house if his/her family or friends would encourage him/her to do so and 0 otherwise; \( X_{13} \) is a dummy variable taking the value 1 if the consumer considers that an energy tax deduction would encourage him/her to adopt renewable energy sources in his/her house and 0 otherwise; \( X_{14} \) is a dummy variable accounting for 1 if the consumer would adopt renewable energy sources in his/her house in case of an energy subsidy and 0 otherwise; \( X_{15} \) is a dummy variable taking the value 1 if the consumer is willing to adopt renewable energy projects in his/her home as a result of energy prices of non-renewable energy sources doubling and 0 otherwise; and \( \epsilon \) is an error term.

The value of \( \beta_0, \beta_1, \ldots, \beta_{15} \) as unbiased estimators of \( \beta \)’s can be found by employing the method of maximum likelihood. The likelihood \( L \) is given by the joint probability distribution evaluated at the observed counts \( n_i \); hence:

\[
L(b_0, b_1, \ldots, b_{15}) = \prod_{i=1}^{n} \frac{e^{y_i(b_0+b_1x_{i1}+\ldots+b_{15}x_{i15})}}{\sum_{i=1}^{n} (1 + e^{b_0+b_1x_{i1}+\ldots+b_{15}x_{i15}})}.
\]

The values of the coefficients that maximize the likelihood cannot be expressed in a nice closed form solution as in the normal theory linear models case. Instead, they must be determined numerically by starting with an initial guess and iterating to the maximum of the likelihood function. Technically, this procedure is called an iteratively reweighted least squares method (see [19] for the detail).

The predicted probabilities of the consumer belong to the certain group, i.e., 1 or 0 can be calculated using the formula for the cumulative distribution function of the standard logistic distribution. For example, the predicted probabilities of the consumer belong to the group 1, i.e., he/she is willing to adopt the renewable energy sources in his/her residence is:

\[
\Pr(Y = 1) = \frac{e^{b_0+b_1x_{1}+\ldots+b_{15}x_{15}}}{1 + e^{b_0+b_1x_{1}+\ldots+b_{15}x_{15}}}. \tag{3}
\]

3. Case study
A case study was conducted in Semarang, Indonesia, to investigate the resident’s willingness to apply renewable energy sources in his/her house. The requirements to be participants in this research are over 16 years old and have any specific jobs or they have their own incomes. The potential participants were first approached and asked if they agreed to participate in the survey. Two hundred respondents participated in the survey. Profile of the respondents is shown in Table 1.

To investigate consumers’ awareness towards renewable energy sources, we questioned if they knew that it is possible to produce energy for household use from the implementation of five alternative renewable energy sources, i.e., biomass, geothermal, hydropower, solar, and wind. About 88% of the respondents were aware of the solar energy, about 76.5% were aware of the hydropower energy, 68% of the wind energy, 52.5% of the biomass, and geothermal energy was the least well-known (48.5%). This result is specifically depicted in Figure 1. Note that from 200 respondents, none of them had previously used renewable energy sources for their household’s electricity supply.

![Figure 1. Consumers’ awareness of the potential use of renewable energy technologies.](image)

A logistic regression was then employed to estimate the model in (1). Table 2 summarizes the empirical result the logit equation’s estimated coefficients with respect to consumers’ intention in Semarang to adopt renewable energy sources in their houses. Note that only eight independent variables are statistically significant: $X_6$, $X_9$, and $X_{15}$ are at the levels of 10%; $X_5$, $X_7$, $X_{12}$, and $X_{13}$ are at the level of 5%, and only $X_{11}$ is significant at the level of 1%. The model gives the Nagelkerke $R^2$ [20]
of 0.519 which is considered as high. It means that the independent variables could explain 51.9% of the total (100%) variability of the dependent variables. Next, the Hosmer and Lemeshow test [21], [22] shows that the model is significant, i.e., the model has significance value of 0.926, which is above the significance level of 5%.

Table 2. Logistic regression result.

| Independent Variables | b   | exp(b) | Standard of Error | Significance |
|-----------------------|-----|--------|-------------------|--------------|
| Constant              | -5.198 | 0.006 | 3.497             | 0.138        |
| X₁                   | -0.651 | 0.522 | 0.445             | 0.144        |
| X₂                   | -0.023 | 0.977 | 0.168             | 0.890        |
| X₃                   | 0.000  | 1.000 | 0.002             | 0.854        |
| X₄                   | -0.601 | 0.548 | 0.783             | 0.443        |
| X₅                   | -1.288 | 0.276 | 0.565             | 0.023ᵇ       |
| X₆                   | -0.719 | 0.487 | 0.435             | 0.098ᶜ       |
| X₇                   | 0.000  | 1.000 | 0.000             | 0.010ᵇ       |
| X₈                   | -0.322 | 0.725 | 0.699             | 0.645        |
| X₉                   | 0.000  | 1.000 | 0.000             | 0.063ᶜ       |
| X₁₀                  | 0.387  | 1.472 | 0.470             | 0.410        |
| X₁₁                  | 1.694  | 5.443 | 0.470             | 0.000ᵃ       |
| X₁₂                  | 1.553  | 4.725 | 0.600             | 0.010ᵇ       |
| X₁₃                  | 2.522  | 12.452| 1.098             | 0.022ᵇ       |
| X₁₄                  | 0.163  | 1.177 | 0.806             | 0.839        |
| X₁₅                  | 0.937  | 2.554 | 0.560             | 0.094ᶜ       |

ᵃ Levels of significance at 1%. ᵇ Levels of significance at 5%. ᶜ Levels of significance at 10%.

Educational background of the respondents (X₅) is statistically significant according to Table 2. This result indicates that educated people are more willing to implement the renewable energy sources in their house; vice versa (in line with the study by [15], [18]). However, X₁, X₂, X₃, and X₄ are not statistically significant. It seems that the willingness of the respondents to adopt the renewable energy sources is not affected by gender, age, and marital status. We cannot say that male people tend to be more willing to adopt renewable energy sources than female people are, or younger consumers are less willing to pay extra than middle-aged consumers are (in contrast with the study by [14] which stated that age is significant), or unmarried people are less willing to implement renewable energy sources in their house.

We also empirically examined the effect of financial measures on the consumers’ intention to adopt renewable energy sources in their house. The result is not surprising since most of “financial” independent variables are statistically significant, i.e., X₆, X₇, X₈, X₁₃, and X₁₅. Public servant employees, high-income people, or people who pay more on their electricity costs tend to be more willing to install renewable energy sources in their residence (along with the study by [11]–[13]). Tax deduction policy or increasing of the price of non-renewable energy sources also have the effect to influence people to adopt renewable energy sources. Interestingly, the respondents’ status of home ownership does not affect their attention towards renewable energy sources.

The rest of the variables are X₁₀ (not significant), X₁₁ (significant), X₁₂ (significant), and X₁₄ (not significant). It means that we cannot conclude that the consumers would adopt the renewable energy sources if they think that the installation and maintenance costs are too high. Energy subsidy, however, has no effect to the decision of the consumers to apply the renewable energy into their house. On the other hand, the assurance of the efficiency to apply the renewable energy sources gives significance impact on the decisions of the consumers. It means that if the renewable energy project cannot guarantee that the project would give better usage efficiency than fossil fuels, the consumers would
not apply it. Consumers’ decisions also are affected by the influence of their relatives. In other words, the consumers would install the renewable energy system in their houses if their families or friends would encourage them to do.

The logistics regression approach is not only able to identify the variables that affect the willingness of the consumers to adopt the renewable energy sources (see Table 2 for the result), but also it can predict the behavior of the “other consumers” based on their characteristics. The formula in (3) can be used to employ the task. An example is shown as follows.

A 25 years old unmarried male consumer would be identified if he were willing to adopt the renewable energy sources into his own house. He has been graduated from industrial engineering department (bachelor degree) and now is a public servant employee in Semarang. He could earn 5 million rupiahs per month as he pays two hundred thousand for electricity. He stated that he is sure about the efficiency of the renewable energy project since he has read many kinds of literature about the benefits gained from the renewable energy sources. In fact, he does not worry about whether the government would give a tax deduction or not; or give an energy subsidy or not. However, he does concern if the price of non-renewable energy source would be doubled. Since he is a self-confident person, he is not affected by the influence of his relatives in his decision to adopt the renewable energy sources. Based on the scenario, we could discover the value of each variable as follows. The value of \(X_1\) is 1, \(X_2\) is 25, \(X_3\) is 625, \(X_4\) is 0, \(X_5\) is 1, \(X_6\) is 1, \(X_7\) is 5,000,000, \(X_8\) is 1, \(X_9\) is 200,000, \(X_{10}\) is 0, \(X_{11}\) is 1, \(X_{12}\) is 0, \(X_{13}\) is 0, \(X_{14}\) is 0, and \(X_{15}\) is 1. From (3), the probability of the consumer would adopt the renewable energy sources into his house is:

\[
\Pr(Y = 1) = \frac{e^{(b_0 + b_1 X_1 + b_2 X_2 + \ldots + b_6 X_6 + b_7 X_7 + b_8 X_8 + b_{11} X_{11} + b_{12} X_{12} + b_{13} X_{13} + b_{15} X_{15})}}{1 + e^{(b_0 + b_1 X_1 + b_2 X_2 + \ldots + b_6 X_6 + b_7 X_7 + b_8 X_8 + b_{11} X_{11} + b_{12} X_{12} + b_{13} X_{13} + b_{15} X_{15})}}
\]

\[
\Pr(Y = 1) = \frac{e^{(1288 + 0.719 + 0 + 0 + 0 + 1694 + 0 + 0 + 10937)}}{1 + e^{(1288 + 0.719 + 0 + 0 + 1694 + 0 + 0 + 10937)}} = 0.651.
\]

Note that only \(X_6, X_9, X_7, X_{11}, X_{12}, X_{13},\) and \(X_{15}\) are significant. Since the probability is 0.651 or above the cut-off point of 0.5, we could conclude that the consumer is willing to adopt the renewable energy sources in his house.

4. Conclusion and future research direction

The objectives of this study are twofold. First is to identify the determinants that influence consumers’ intention towards the adoption of renewable energy sources in the household sector. The second is to model and predict the consumers’ willingness to adopt the renewable energy sources in their houses. A case study to exhibit the applicability of this study has been conducted in Semarang, a capital city of Central Java Province, Indonesia.

The result of the case study showed that from fifteen variables that are employed, only eight variables are statistically significant. There are educational background, employment status, consumers’ incomes per month, consumers’ average electricity costs per month, certainty about the efficiency of renewable energy project, relatives’ (families or friends) influence to adopt the renewable energy sources, energy tax deduction, and the condition of the price of the non-renewable energy sources (the complete result can be seen in Table 2). It can be concluded that that educated people, public servant employees, high-income people, people who pay more on their electricity costs, people who are sure about the efficiency of the renewable energy project, people whose decisions are easily affected by their relatives’ decisions, people who concern of energy tax deduction, and people who worry if the price of the non-renewable energy sources would double, are more willing to adopt the renewable energy sources.

The finding of this study could be used as a basis for the government to set up a policy toward renewable energy implementation. A system dynamics approach—initially developed by [23]—can be utilized to formulate the policy. It is frequently used when facing high-stakes decisions and seeking an integrated view of the major forces that can affect key outcomes years or decades into the future [24].
It has been used in formulating the policies related to energy; see for example [25]–[27]. Using the system dynamics approach to support the government in preparing the policy about renewable energy is an interesting area to be pursued.

5. References

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