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# Agent Based Model to Analyze Consumer Behavior in Consuming the Electricity Energy

Erma Suryani[a]*, Rully Agus Hendrawan[a], Umi Salama[a], Lily Puspa Dewi[b]

[a]Information Systems Department, Institut Teknologi Sepuluh Nopember, Jalan Raya ITS, Surabaya, 60111, Indonesia
[b]Department of Informatics, Petra Christian University, Jalan Siwalankerto 121-131, Surabaya, 60236, Indonesia

*Corresponding author: erma.suryani@gmail.com

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**Graphical abstract**


**Abstract**

Several studies have been conducted regarding save energy in consuming the electricity through the simple changes in routines and habits. In the case of electricity consumption, consumer behavior might influenced by several factors such as consumer profession, season, and environmental awareness. In this paper, we developed an Agent Based Model (ABM) to analyze the behavior of different agents in consuming the electricity energy for each type of profession (agent) as well as their interaction with the environment. This paper demonstrates a prototype agent based simulation model to estimate the electricity consumption based on the existing condition and some scenarios to reduce the electricity consumption from consumer point of view. From the scenario results, we analyzed the impact of the save energy to increase the electrification ratio.

*Keywords*: Agent based model; electricity consumption; consumer behavior; save energy



## 1.0 INTRODUCTION

Agent-Based Model (ABM) is a new approach to modeling systems containing agent interaction with the system or the environment. ABM is a tool for decision makers in implementing new policies that can improve the system performance. According to Macal and North [1], there are several stages in developing Agent-Based Model (ABM) as depicted below:

(1) Identification of agents and agent behaviors
(2) Identify relationships between agents
(3) Related data agents retrieval
(4) Agent behavior model validation
(5) Run the model and analyze the model output

In this paper, an agent-based modeling (ABM) is developed based on autonomous decision-making entities called agents. Each agent individually assesses its situation and makes decisions on the basis of a set of rules [2]. Agents are either separate computer programs or, more commonly, distinct parts of a program that are used to represent social actors—individual people, organizations such as firms, or bodies such as nation-states[3]. Some agent characteristics can be seen in Figure 1 and can be described as follows [1]:

- An agent can be identified, discrete individuals with a set of characteristics and rules that organize behavior and decision-making ability
- An agent may be directed to the purpose, and has a specific purpose
- An agent is located in a neighborhood where it can interact with other agents. Agent has the ability to recognize and distinguish the characteristics of the other agent
- An agent can function independently in its environment
- An agent has the ability to learn and customize the behavior based on experience. This requires some form of memory. An agent may be able to modify the rules.

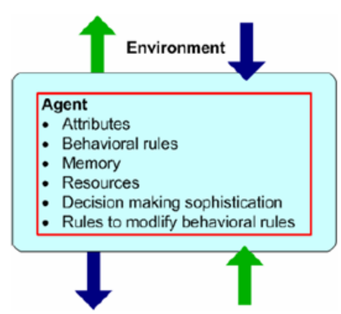


**Figure 1** Agent characteristics [1]

Several points that to be considered in the electrical energy consumption are [4]:

- Energy management policies/regulations made by the energy management division of an organization/government.
- Energy management technology installed in the office building

- Types and number of the electric equipment and appliances in the office building
- Energy user's behavior of using electric equipment and appliances in the office building

In this research, we conduct a survey to disseminate the questionnaire for obtaining a reality portrait of energy consumption patterns, in order to understand consumer behavior. In general, the type of profession can be classified into farmers, traders and fishermen, government officer, and private sector labors. Each type of profession (user) has a specific stereotype, e.g. for traders and fishermen have two stereotypes, those are normal and extravagant users (big users). The list of the number of user percentage and user stereotypes can be seen in Table 1.

To determine the electricity consumption for each type of user (agent), we need to have the list of electricity equipment use by user and power consumption for each equipment. The use of equipment and power consumption for each equipment and agent can be seen in Table 2.

**Table 1** The list of user stereotypes

| No. | User | User Percentage (%) | Stereotype | |
|---|---|---|---|---|
| 1 | Farmers | 40 | Normal | Energy saver |
| 2 | Traders/Fishermen | 20 | Normal | Big User |
| 3 | Government officer | 30 | Normal | Big User |
| 4 | Private sector workers | 10 | Normal | Big User |

**Table 2** List of equipment and electricity consumption usage for each user

| Equipment | Farmers | | Traders/Fishermen | | Government Officer | | Private Sector | |
|---|---|---|---|---|---|---|---|---|
| | Continuous On (Watt) | Stand by (Watt) | Continuous On (Watt) | Stand by (Watt) | Continuous On (Watt) | Stand by (Watt) | Continuous On (Watt) | Stand by (Watt) |
| **Big Refrigerator** | 0 | 0 | 0 | 0 | 57.5 | 6 | 57.5 | 282 |
| **Medium Refrigerator** | 0 | 0 | 11.25 | 3 | 0 | 0 | 0 | 0 |
| **Magic jar + rice cooker** | 29.06 | 90 | 116.25 | 180 | 232.5 | 360 | 232.5 | 360 |
| **Small Lamp** | 360 | 0 | 800 | 0 | 800 | 0 | 800 | 0 |
| **Big Lamp** | 180 | 0 | 360 | 0 | 360 | 0 | 360 | 0 |
| **Iron** | 300 | 0 | 450 | 0 | 450 | 0 | 600 | 0 |
| **Washing machine** | 0 | 0 | 31.25 | 0 | 31.25 | 0 | 37.5 | 0 |
| **Microwave** | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| **TV** | 272 | 6 | 340 | 0 | 340 | 0 | 340 | 0 |
| **Computer** | 0 | 0 | 0 | 0 | 200 | 25 | 100 | 12.5 |
| **Water pump** | 1300 | 0 | 1625 | 0 | 1625 | 0 | 1625 | 0 |
| **Fan** | 80 | 0 | 150 | 0 | 80 | 0 | 100 | 0 |
| **AC** | 0 | 0 | 0 | 0 | 215 | 0 | 215 | 0 |
| **Total Consumption (watt)** | 2,521.063 | 96 | 3,883.75 | 183 | 4,391.25 | 391 | 4,467.5 | 654.5 |
| **Total Consumption ( kW)** | 2.521 | 0.096 | 3.883 | 0.183 | 4.391 | 0.391 | 4.467 | 0.655 |
| **Average usage per user per month (kWh)** | 2.6170625 | | 4.06675 | | 4.78225 | | 5.122 | |

## 2.0 LITERATURE REVIEW

In conducting research, analysis is needed to find methods can be used to solve problems. The purpose of this research is to develop a simulation model that can be used to calculate and estimate the power consumption, considering the consumer behavior and the surrounding environment. There are some modelling methods, such as system dinamics, discrete event modeling, and agent based modeling.

Much of the system dynamics art modeling lies in discovering representing the feedback processes and other elements of complexity that determine the dynamics of a system [5]. System dynamics modeling also requires the rules of behavior to be written at higher level [6]. By considering the system characteristics that requires a lower level of abstraction and detail on the behavior of each user of electricity, this method is less appropriate to be applied.

Discrete event modeling can be used to model the systems that require lower levels abstraction. However, a discrete event modeling is more appropriately used for passive objects, which are not able to interact well with each other, and with their environment [7], such as the flow of goods in the production process. Therefore, this method could not be applied to the system power consumption due to consumer behavior can be influenced by environmental.

Agent-based modeling is used to study social phenomena such as human behavior and processes that occur in the business. The agent-based simulation has been used extensively by researchers and visualized phenomena such as the interaction of individuals in ecosystems, chemical reactions and insect behavior [8]. The benefit of agent-based modeling lies in its ability to model complex real-world systems. Agent-based modeling also can produce complex system behavior as results from the agent interaction [9].

Bonabeau denotes that agent-based modeling can model the system with a set of entities for decision making autonomously and this entity are called as "agent" [2]. Every agent acts and behaves based on certain rules in the environment. In Agent-Based Modeling, observation and research can be done toward interactions that occur between agents [10]. Agent-Based modeling also can be used to model business process [10, 11]. Business process entities are modeled as an agent and business processes are modeled as the interaction between agents. Some advantages of agent-based modeling are:

a. Able to capture the phenomenon appears, as a result of the interaction of individual entities.
b. Able to provide an overview of the system: able to make the model closer to reality.
c. Flexible: easy to add the agent, providing a natural framework for tuning the complexity of agent-like behavior, the level of rationality, the ability to learn and evolve, and interaction rules.

ABM models can be applied in the social sciences, politics, and economics. In a business context, a situation in which the phenomenon appears to be classified into four areas, namely: flows, markets, organization, and diffusion. Agent based model is also preferred for its ability to assume heterogeneity between individuals and allow for their interactions [12]. In the context of this research, an agent-based simulation model is used to simulate the user behavior and interaction with the environment.

ABM has been widely used in simulating the electrical energy consumption. Zhang *et al*. develop a simulation model to calculate electrical energy consumption in buildings by considering the type of electrical equipment usage and user's electrical behavior [4].

Zhao *et al*., simulate electricity consumption of a region/city using commercial building as agent and estimate its electricity needs based on the simulation results [13]. The other researches focus to electricity marketing and develop a model to simulate electricity structure marketing of generator, transmission, and distribution [14, 15].

## 3.0 MODEL DEVELOPMENT

We divided the ABM model into four sub-models based on the types of users, those are traders and fishermen, farmers, private sectors, and government officer. Then, each sub-model will also be divided based on the type of usage, those are normal, big, or energy saver. In this model, the agent is a representation of household electricity consumption.

ABM models will also consider certain activities in a predefined, which will result in the increase or decrease in the electricity consumption. We also consider several events that influence the electricity consumption, such as depicted in Table 3.

**Table 3** List of events that affect electricity consumption

| Month: January 2012 | | |
|---|---|---|
| Events | Date | Percentage |
| New Year | 1 | 10% |
| Istighotsah | 2 | 9% |
| Khitan | 7 | 9% |
| Maulid Nabi | 26 | 10% |

State charts in ABM models are constructed for analyzing the behavior pattern of electrical energy consumption according to the type of profession in general can be seen in Figure 2.

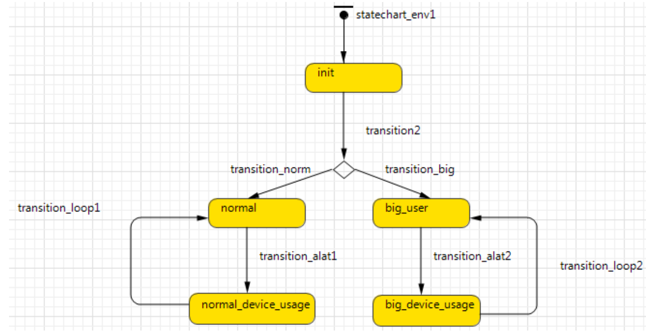


**Figure 2** ABM state chart

State chart descriptions are as follows:

*init* : To initialize the variables that will
*decision/branch* : be used in the simulation.
To determine the each type of agent
*normal* : consumption, whether normal or big
*big_user/energy_saver* : user.
*normal_device_usage* : Represents agent consumption with normal behavior
*big_device_usage* : Represents agent consumption with wasteful behavior / energy saver.
To calculate the power consumption for each agent with normal consumption.
To calculate the power consumption for each agent with extravagant consumption.

Total electricity consumption can be determined by multiplying the electrical consumption (watt), ignition time, and the number of electrical equipment. The formula can be seen at Equation (1).

$$electricity\ consumption = \sum(electric\ watt\ \times ignition\ time\ \times number\ of\ device) \quad (1)$$

Ignition time and the number of electrical equipment owned by each agent varies depend on the type of profession and type of usage. Electrical consumption is also influenced by month / season of usage, which in this model, is calculated with the following algorithm;

```
if(time=1&26)
{       usage = usage+( usage*0.1);
}
else if(time=2&7)
{       usage= usage+( usage*0.09);
}
```

As we can see in the above algorithm, when the simulation timing t1 and t26 (1st and 26th of January), the consumption will increase by 10%. Meanwhile at t2 and t27 (2nd and 27th of January), the consumption will increase by 9%. After the definition of parameters, variables, and formulation for all stages, model simulation can be performed.

### 3.1 Traders and Fishermen Sub-Model

From the simulation results we can see that the total average power consumption of traders and fishermen per month was around 50,946 + 23,381 = 74,327 kWh as seen at Figure 3.


**Figure 3** Simulation model result for traders and fishermen

We provide the detail of the total consumption and the average usage for normal and big consumption in Table 4.

**Table 4** Simulation result for traders and fishermen

| Type of usage | Total consumption (kwH/ month) | Average usage (kwH/ month) |
|---|---|---|
| Normal User | 1,579,322 | 50,946 |
| Big Consumption | 724,804 | 23,381 |
| Overall | 2,304,126 | 74,327 |

### 3.2. Farmers Sub-Model

From the simulation results can be seen the total average power consumption of farmers per month is 113,936 + 9,590 = 123,526 kWH as seen at Figure 4.


**Figure 4** Simulation model result for farmers

From the simulation results, we obtained total usage and average usage for normal and energy saver as seen at Table 5.

**Table 5** Simulation result for farmers

| Type of usage | Total consumption (kwH/ month) | Average usage (kwH/ month) |
|---|---|---|
| Normal User | 3,418,070 | 113,936 |
| Energy Saver | 287,719 | 9,590 |
| Overall | 3,705,789 | 123,526 |

### 3.3. Private Sector Sub-Model

From the simulation results can be seen the total average power consumption of private sector worker per month is 10,971 + 35,747 = 46,718 kWH as seen at Figure 5.


**Figure 5** Simulation model result for private sector worker

From the simulation results, we obtained total usage and average usage for normal and energy saver as seen at Table 6.

**Table 6** Simulation result for private sector worker

| Type of usage | Total consumption (kwH/ month) | Average usage (kwH/ month) |
|---|---|---|
| Normal User | 340,091 | 10,971 |
| Big Consumption | 1,108,158 | 35,747 |
| Overall | 1,448,249 | 46,718 |

### 3.4. Government Officer Sub-Model

After the definition of parameters, variables, and formulation for all stages, model simulation will be performed. From the simulation results can be seen the total average power consumption of private sector worker per month is 76,156 + 34,428 = 110,584 kWH as seen at Figure 6.


**Figure 6** Simulation model result for government officer

From the simulation results, we obtained total usage and average usage for normal and energy saver as seen at Table 7.

**Table 7** Simulation result for government officer

| Type of usage | Total consumption (kwH/month) | Average usage (kwH/month) |
|---|---|---|
| Normal User | 2,360,844 | 76,156 |
| Big Consumption | 1,067,283 | 34,428 |
| Overall | 3,428,127 | 110,584 |

We demonstrate the overall of the simulation results for all user type in Table 8.

**Table 8** Simulation results for all user type

| User Type | Normal Consumption | Big Consumption /Energy Saver | Total |
|---|---|---|---|
| Traders and Fishermen | 1,579,322 | 724,804 | 2,304,126 |
| Farmers *) | 3,418,070 | 287,719 | 3,705,789 |
| Private Sector Worker | 340,091 | 1,108,158 | 1,448,249 |
| Government Officer | 2,360,844 | 1,067,283 | 3,428,127 |

## 4.0 MODEL VERIFICATION

Model's verification and validation are the important parts of model developing thus the model can be accepted and used to support decision making [16]. Model verification is a process to determine whether the developed model have been made of error free, in this case computer code contains any programming already errors ('bugs') free [17], and model can be simulated well. Model verification can be run before process validation is started. Verification process takes place on mathematical models and developed computer models [18]. Stages of confirmation, verification and validation in simulation can be seen at Figure 7.

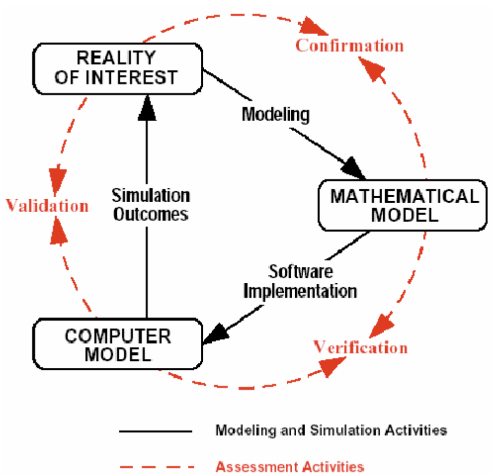


**Figure 7** Confirmation, verification and validation stages in simulation [17]

Verification in mathematical model is useful to determine that every model mathematical function generates appropriate value. In this simulation use a standard mathematical function to calculate total electricity consumption. Model computer verification is conducted to ensure model computer has been error free thus model can be simulated properly.

## 5.0 MODEL VALIDATION

Validation is a process to determine whether the model has made an accurate representation of the real system from the perspective of the usefulness of the model [19]. However, the valid model is not the perfect model, because the perfect model is the real system itself [17]. The model will be checked for its accuracy by calculating error rate for average usage and total electricity consumption of all types of users. A model can be stated to be valid if it has an error rate of less than or equal to 5% [20]. The model accuracy level can be calculated by dividing the difference between simulation results and the existing data with the existing data as can be seen in the Equation (2).

$$\text{Error rate} = \frac{\text{(simulation result-data)}}{data} \quad (2)$$

Error rate for the average usage and the total electricity consumption for all types of users are described as follows:

a. Traders and Fishermen
E (average) = (74,327 – 74,748) / 74.748 = 0.0056
E (total consumption) = (2,304,126– 2,317,173) / 2,317,173 = 0.0056

b. Farmers
E (average) = (123,526 – 121,020) / 121,020 = 0.0122
E (total consumption) = (3,705,789 – 3,751,614) / 3,751,614 = 0.0207

c. Private Sector Workers
E (average) = (46,718 – 46,272) / 46.272 = 0.009
E (total consumption) = (1,448,249 – 1,434,441) / 1,434,441 = 0.009

d. Government Officer
E (average) = (110,584 – 113,901) / 113,901 = 0.029
E (total consumption) = (3,428,127 – 3,530,931) / 3,530,931 = 0.029

## 6.0 SCENARIO DEVELOPMENT

In this research, scenario is developed by considering the weather to see a decrease or increase in electricity consumption during the dry season and the rainy season.

### 6.1 Dry Season Scenario

In this scenario, the models are simulated by considering the weather conditions that could affect the electricity consumption. Indonesia has two kinds of season, dry and rainy season. The electrical devices usage that is affected by this scenario is fan and Air Conditioner (AC). The fan and AC usage increase three times from normal condition (based on survey), as shown in Table 9. The calculations obtained by changing the average ignition time of a fan and air conditioning.

**Table 9** Ignition time of fan and ac for each type of user

| User | Electrical Device | Ignition Time Minimum | Maximum | Average | Standard Deviation |
|---|---|---|---|---|---|
| Normal User | Fan | 0,55 | 10 | 9 | 1,8 |
| | AC | 0,55 | 6 | 5 | 0,33 |
| Big User | Fan | 0,55 | 12 | 11 | 0,55 |
| | AC | 0,55 | 7 | 6 | 0,55 |

Besides the season, the power consumption is also influenced by several events in a certain month. In this research, we consider August (dry season) as a month that has several events such as Idul Fitri, Istighotsah, Khitan as seen in Table 10.

**Table 10** Events that affect the electricity consumption based on dry season scenario

| Month: August 2012 | | |
|---|---|---|
| **Event** | **Date** | **Increase By** |
| Idul Fitri | 1 | 10% |
| Istighotsah | 6, 13 | 9% |
| Khitan | 20, 27 | 9% |

Based on this this scenario, the total power consumption = 18,758,648 kWH/month

### 6.2 Rainy Season Scenario

According to National Environmental Education Foundation Climate, Weather, and Energy Consumption [21], in rainy season, the power consumption will decrease by 5%-20%. In this scenario, we assume that the electricity consumption for each user will decrease as follows:

a. Traders, fishermen and private workers = 15%
b. Farmers = 20 %
c. Government officer = 15%

These assumptions have been made by considering the historical data that we obtained from the electricity company. Events that occurred in January that represent rainy season can be seen in Table 11.

**Table 11** Events that affect the electricity consumption based on rainy season scenario

| **Month: January 2012** | | |
|---|---|---|
| **Event** | **Date** | **Increase** |
| New Year | 1 | 10% |
| Istighotsah | 2 | 9% |
| Circumcision | 7 | 9% |
| Maulid Nabi | 26 | 10% |

The results of this scenario is, the total electricity consumption = 14,296,581 kWH/month

## ■7.0 CONCLUSION

In agent based model development, system understanding is crucial for the development and model formulation. The assumptions used in this model is the increase in electricity consumption caused by certain events such as a new year can increase consumption by 10%, Istighotsah, increase the consumption by 9%, Idul Eid 10%, circumcision 9% and Maulid Nabi by 10%. Determination of total electricity consumption for each household is done by counting the number of electricity equipment multiplied by the usage duration and large electrical equipment power (watts). The number of electricity equipment and usage duration relied heavily on the behavior of users, such as normal user, big consumption users, or energy saver.

ABM model simulation results show that the total electrical energy consumption for farmers are 3,705,789 kWH farmers, traders and fishermen are 2,304,126 kWH, government officers are 3,428,127 kWH, and the private sector workers are 1,448,249 kWH.

In the rainy season scenario, electrical appliances consumption will be reduced by 17.9%, obtained a total consumption of 14,296,581 kWH. In the dry season scenario, electrical appliances consumption will be increased by 7%, obtained a total consumption of 18,758,648 kWH.

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