Green Computing Survey Based on User Behavior:
A Case Study in Board of Investment and Licensing of Bali Province

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Abstract—The direct impact of the use of information and communication technology products increases energy consumption, the long term impact is the increase of electronic waste and carbon foot print on the environment. This research focused on the design of green computing environment based on the behavior of the energy consumption in a government agency in Indonesia. The research model composed of six variables, which then formed the model user behavior. The variable was modified from several sources. The data collecting technique were performed through interviews, observation, and questionnaires. Based on data collected, a sample of government agencies have implemented green computing in some ways, and in the other sections still required increasing power efficiency, for example, in the power efficiency of smartphones and computers. Good thing to know is, the government officials have been concerned to take preventive wasteful use of paper by doing a print preview before printing the documents. In terms of infrastructure, data center on a government requires a better design in terms of setting a variety of devices that are inside. The design may contain the layout of the device, and the addition of raised floor for the air circulation in data center. Good organization will lead to good air circulation, so no additional power is required in the setting temperature.

Keywords—Green Computing,Behaviour Model,Energy Saving

I. INTRODUCTION

Products of Information and Communication Technology (ICT) generally contain toxic materials, heavy metals, and are not bio-degradable which eventually contaminate the environment. The use of ICT that is not energy efficient produces a lot of carbon footprints. To reduce the negative impact of ICT products on the environment is not easy because it is costly and difficult to change the user behavior in order to become wise users for the environment.

Based on Indonesia's General Plan of National Electricity 2015-2034 [1], the Government and / or regional government in accordance with its authority establish guidelines and the implementation of energy conservation policies, especially in the field of energy saving, including among others: the obligation to use power plant technology and efficient energy conversion equipment. However, the implementations of existing policies are frequently not maximized. Every year, growing energy needs are not followed by the wise use of energy.

According to the Indonesia Green ICT Council Report [2], the main issues for green computing in Indonesia are: (1) are not unified, and the aims and objectives are separated. (2) Awareness of Green ICT in society is still relatively low, especially regarding energy efficiency and waste. (3) A key factor in the success of green ICT initiatives relies heavily on management commitment.

Government agencies in the province of Bali, Indonesia are very aware of technology, as evidenced by the utilization of ICT which is pretty massive. They need a variety of technologies in support of the performance of the employees especially electronics such as computers and servers. In addition, computer users also use other complementary tools such as printers, fax machines and other essentials such as air conditioning, television and others.

Based on the preliminary study of two government agencies in Bali, the use of electronic products is also considered not maximized because the workers often ignore the way of energy saving, especially for the computer users. Based on the identification of issues in government offices, employees often use a computer with no responsibility, for instance during recess, computer is left switched on. Besides using computer, the usage of spoiled and inefficient paper also affects on environment preservation. Thus many users start to think of ways in saving energy on technology which becomes more sophisticated each day.

This research focused on the analysis of the behavior patterns of users of information and communication technology in government agencies in the province of Bali. In this study research variables were adopted from previous researches. Some of the interviews and data collection are through questionnaires that we did in a government agency in Bali. The results of this analysis were used to provide recommendations on the implementation of green computing, including the data center, thus to assist the user in saving energy and utilize energy resources as best as possible so that it becomes more efficient and environmentally friendly. Because by implementing cost savings, it can help the world we live in today to become more efficient, one of it is to deal with Global Warming.

II. RELATED WORK

Final energy consumption in Indonesia increased from 778 million BOE (Barrel of Oil Equivalent) in 2000 to 1,211 million BOE in 2013, grew on average by 3.46% per year [3]. Electric energy consumption grew on average by 7.1% per year, with a share of 14% in 2013, and is projected to increase

to 18% in 2025 and 26% in 2050. Even based on (PLN Statistics, 2014) load peak in 2014 reached 33321.15 MegaWatts (MW), an increase of 8.06% over the previous year. The peak load of Java-Bali interconnection system reached 23,900 MW, up 5.90% from the previous year. The high demand for electricity, besides the needs of the household sector, is also high in needs from the commercial sector, where it is known that this type of major energy sector in electricity is a consequence of tourism area that provides many hotels, restaurants, trade, and other services [4].

Green Computing is one among many forms of environmentally friendly program that focuses on the production and utilization of ICT tools and infrastructure [5]. Efforts to support environmentally friendly activities can be done not only with the policy directly to limit the use of information technology devices, but also should be supported by the culture and behavior of energy consumption within the organization itself. However implementation of green computing in a sustainable manner is intended not only for the sake of an institution, but the most important thing is for the environment.

Previous research, both conceptual and empirical, addresses the subject of adoption of Green Computing or Green IT from a number of perspectives. Various terminologies have been used, such as Green IT adoption [6,7,8], adoption of Green IS [9,10], Green Computing initiatives [11,12], Green IT Expansion [13,14] and intentions to adopt Green IT [15,16]. Until now in Indonesia, the research on Green computing has not been significant. Most of the researches that have been published were about behavior in green computing. The studies were conducted by [17], [5] in the district of West Java, and [18, 19] in Bali. The studies were conducted to determine the tendency of green computing on companies, governments and universities. The results of all these studies indicated that there have been tendencies to implement green computing, but the policy on the matter still needed to be confirmed.

III. RESEARCH METHOD

This research was conducted in a government agency in the province of Bali, the Board of Investment and Licensing of Bali Province along with a total sample of 140 respondents. The sampling technique used in this research was purposive sampling, which was a sampling of the population based on a certain criteria.

Method performed in this study as shown in Fig. 1 can be explained as follows: The model was built based on the results of the knowledge base study and its relevance to the environment. In this study, the basic knowledge of green computing is a concept consisting of: the human aspects (attitudes and behavior), technology aspect, policy, and practical aspects.

The assessment of the environmental aspect was to find out the problems and opportunities in the implementation of green computing in government agencies. From the environment and the knowledge base, it was expected that the model would be made accordance with existing knowledge base and relevant to actual environmental conditions.

Phase analysis was conducted to analyze the concept and analyze the case. The case analysis included analysis of practices and opportunities for green computing in government agencies. This analysis would be the basis for the factors that would construct the model.

Construction of the model was a process that was done to shape the implementation of green computing model in the agencies. Data was collected using a questionnaire. Questions were prepared based on the operational definition of each variable in the model built. The data was analyzed based on the respondent's answers. From the analysis of these data, recommendations were given based on the needs of those things that were considered still need to be improved.
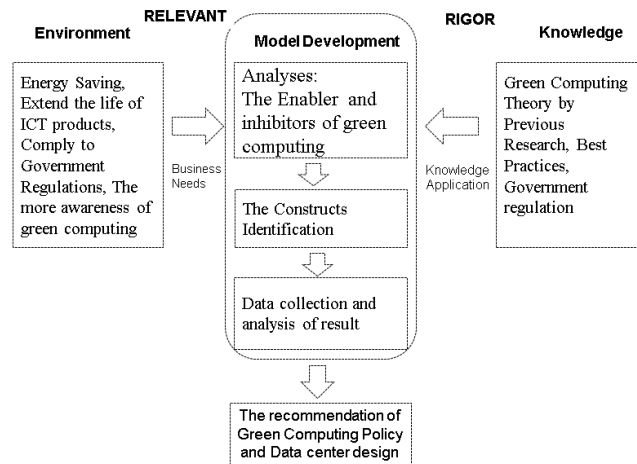

Fig. 1 Research Method

To ensure that the data retrieval tool was valid and reliable, some instrument testing was needed. Pearson product moment method was used to test the validity of the instrument, and Cronbach alpha value was used to determine the reliability of the instrument.

Based on the results of the collection of literature, the variables that were observed in this study were mainly computer Energy savings, maximizing the age of computers, device management, outdated / electronic waste, efficient use of paper, and the efficiency use of smartphone device. These variables were modified from two sources: [9] and [10]. The operational definitions of these variables are shown in Table 1.

Rationalization of the variable selection was to adapt to the conditions in Indonesia. The efficient use of smartphone devices selected as variable because smartphone usage in Indonesia was quite large. According to the [22], the number of smartphones entering the Indonesian market achieved 6.5 million units, and increased by 2.7% from the previous year. With these Fig.s, then of course the use of energy for smartphones also increased [23]. The variables used in this study are presented in Table 1.

Variable	Operational Definition	Modified from
Computer energy saving	Employee behavior towards the use of computers associated with lower energy consumption.	[9] and [20]
Lifetime maximization of computer devices	Employee behavior towards maximum utilization of computer	[20]
Obsolete device management / electronic waste	Management of Obsolete devices (devices that are already damaged)	[21] and [20]
The efficient use of paper	Employee behavior in terms of efficiency of use of paper	[21]
The efficient use of smartphone devices	Employee behavior towards the use of smartphones	-
Data center	Characteristics of the data center and the possibility to be upgraded to be greener	[20]

Generally, each variable can be descibed in Fig. 2. All of those variables are aspects to support the implementation of the green computing especially in government agencies.
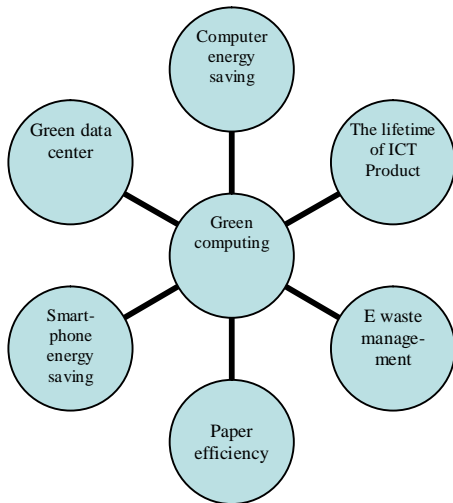

Fig. 2 model proposed

Based on definition of these variables, the research instrument was a questionnaire consisting of 19 questions. The instrument has been tested through pilot testing of the 20 data. The results of the pilot test showed that the research instrument has a value of Cronbach's Alpha α = 0.824. These values showed that the instrument was reliable to use for retrieval of data [24, 25]. From 140 questionnaires distributed, only 98 were returned and only 95 that could be analyzed.

IV. RESULT AND ANALYSIS

A. The Behaviour Towards Green Computing

Based on data collected using questionnaires, it was known that there were users who did not carry out energy saving measures in terms of energy use via computer. This is shown by Fig. 3. There were as much as 40% of users who did not turn off the computer after work. The information showed that not all government employees were aware of the importance of energy saving. The results of this study are similar to the results obtained by [18] conducted in universities in the province of Bali. However, respondents have shown the wisdom which is excellent in terms of the use of a notebook or laptop, where more than 90% of respondents said that they have been using power saving mode on their laptops. The success of the implementation of green computing is closely associated with the commitment and discipline of the users in saving energy.
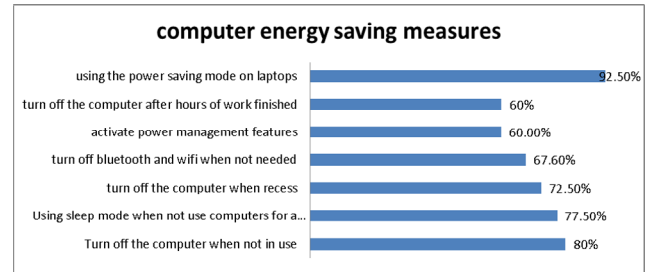

Fig. 3 Computer energy saving measures

In case of smartphone usage, a total of 100% respondents used at least 1 smartphone. Although it required a lower power than the computer, but because they were massively smartphone users, then of course this technology also consumed considerable power. Based on data collection, as shown in Fig. 4, less than 50% of respondents said that they used the power saving settings on their devices. As much as 72.5% stated that their internet connection was always on. Indeed, continuous internet connection on would consume more resources than most. In fact, most respondents stated that they were charging the battery when they were in the office. Unwise usage of smartphones can cause a considerable influence on the failure of the implementation of green computing. It is important for smartphone users to understand how to save power in smartphones.
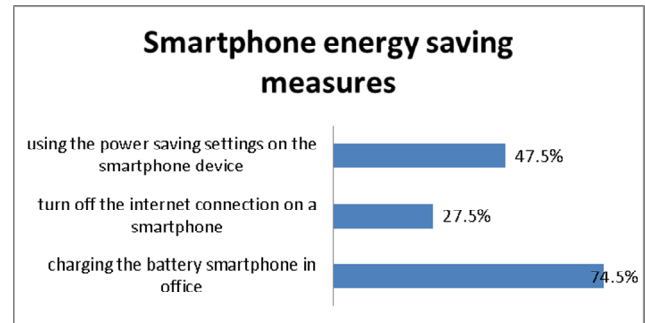

Fig. 4 Smartphone energy saving measures

While the results in power saving efforts on smartphones are still low, but it does not happen on paper efficiency. The system of government in Indonesia still has procedures that require the use of paper, for example in correspondence. Thus, the paper is still absolutely necessary in government institutions in Indonesia. However, good things were shown by

survey respondents, more than 80% of respondents previewed their document before printing. This indicates that respondents started to realize the importance to use paper efficiently. The use of paper that is not wise can cause a negative impact on the environment.
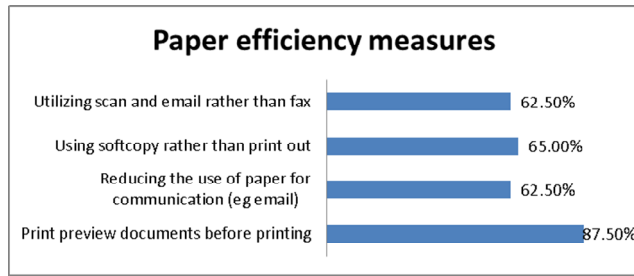

Fig. 5 Paper Efficiency measures

Computer manufacturing process accounts for 70% of natural resources used in the life cycle of a PC. For green computing, the thing that can be done is to extend the life of computer equipment. Manufacturing a new PC makes ecological footprint much larger than manufacturing a new RAM module to upgrade the existing ones [20]. A survey results on the age of the computer device is shown in Fig. 6. Based on Fig.s 6 and 7, it can be concluded that at least a new electronic waste always appear annually. This requires good management of electronic waste. Depth study of the electronic waste in Indonesia is required.
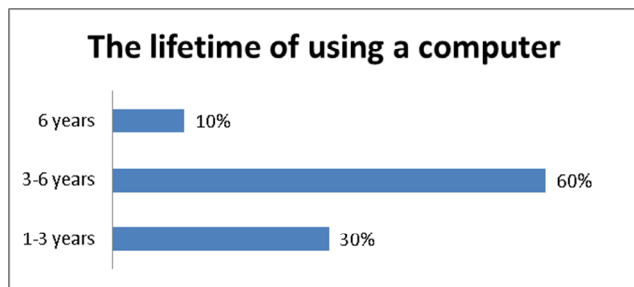

Fig. 6 The lifetime of using a computer

Most of the electronics when they become waste are classified as hazardous and toxic material (B3) because they contain components or parts made of substances harmful to human health and the environment (such as lead, mercury, cadmium, and others) [26,27,28]

Handling of electronic waste is one of the concerns of the various countries. Till today, the Indonesian government is still preparing legislation on electronic waste. One thing that can be done by the Government is to work with private sector for developing an environmentally manner of e-waste management, which handles collection, transportation, and disposal of wastes. However, this time the government agency that becomes the sample has not cooperated with any party to handle their electronic waste. The results of a survey on e-waste management in government agencies in Indonesia were as much as 12,50 % of all respondents stated that they stacked the computers that were damaged in the warehouse as shown in

Fig. 7. Stacking computers in the warehouse will not provide any benefit other than the delay of electronic waste. More in-depth study on e-waste management is still very necessary.
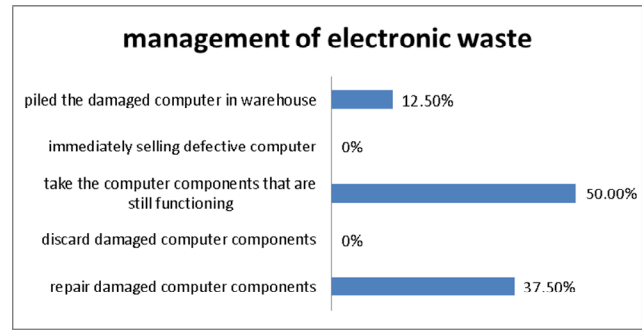

Fig. 7 Management of Electronic Waste

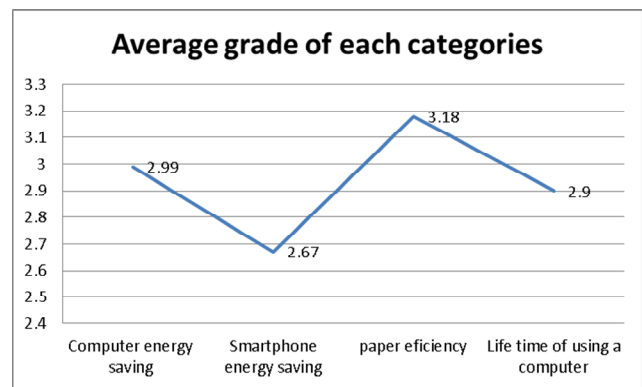The comparison of each aspect or category is explained in Fig. 8.

Fig. 8 Average grade of each categories

Overall, from four aspects, which are computer energy saving, smartphones energy saving, efficient use of paper, and the period of time of using computers, the best aspect is the efficient use of paper with a maximum value of 3.18 from the maximum value of 4. While the worst aspect is the smartphone energy saving, which only reach 2.67 of a maximum value of 4. This indicates that it is time for the government to take action referring to smartphone green computing campaign in their agencies. The campaign can be issued to the internal rules of government agencies regarding smartphone power saving while in office. Until now, the use of smartphones is still private. It has not been found any policy that have been made by the Government in Indonesia related to smartphones, although the results of the survey showed that as many as 74.5% of respondents did charge their smartphones in the office.

B. The As-is of Data Center and The Recommendation

Based on an analysis of the infrastructure, it is known that the specifications of the servers used in government agencies into the sample entered a period End of Life because the type of processor that were issued since 2008 by Intel will not be

supported anymore because the processor has reached the age of 8 years. Based on further observation, the data center room's space at government agencies was 9 square meters. This room had a minimal server racks, computer monitors and temperature control.

Recommendations that can be given to the implementation of green computing is to utilize cloud computing technology [29], but if it is not possible then the next best thing to do is to give a good data center setting. In terms of setting the circulation of air in the data center room, Fig. 8 shows the design of the data center. The design has added a raised floor and the placement of temperature control.

Minimal use of raised floor height in accordance with standard TIA-942 is 45cm or 18 ". Raised Floor is also equipped with perforated tiles that are used as the circulation of cold air from the bottom toward the top. Grid on a raised floor is measured by 60cm × 60cm × 3.8cm (length × width × height). Types of raised floor that can be used is a coating High Pressure Laminated (HPL) as the base layer because it has anti-static coating to reduce the voltage generated [30].
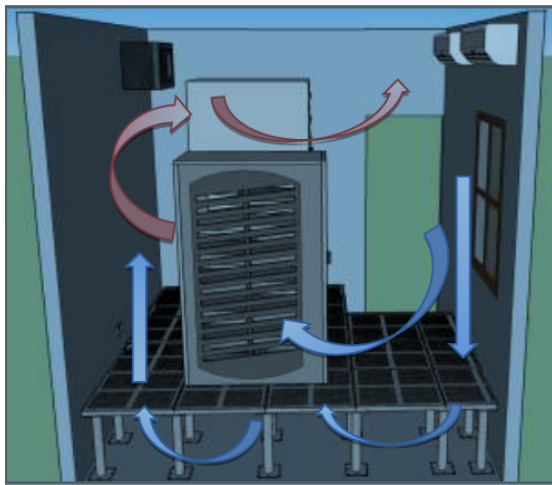

Fig. 9 Side view of The Proposed Data Center design for the room of 9 square meters

In Fig. 9 and Fig. 10, the server and temperature control plays an important role for air circulation. From the design blueprint, it is found that the result of cold air circulation that is shown by the blue arrow going through the shelves that exist. Hot air circulation results from existing devices are indicated by red arrows. Heat flow recirculates by temperature control as cold air. Fig. 11 illustrates the circulation of air conditioned from a side view. Cool air is shown in the blue arrow will go to the bottom of Raised Floor and is blown back into the top Raised Floor and cold air is blown directly into the side of the device. Directions of the blowing hot air on the arrow will be blown up back on the air conditioner.
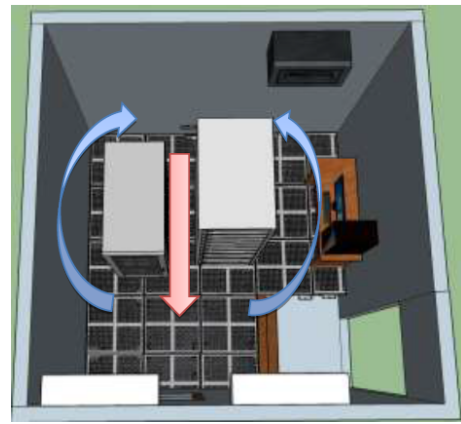

Fig. 10 Viewed from the above, the proposed data center design for the room of 9 square meters

V. CONCLUSION

Based on the analysis performed, the conclusion that can be given is as follows: a sample of government agencies had implemented green computing in some ways, and in the other sections required increased power efficiency, for example, the power efficiency of smartphones and computers. The Government is also recommended to start taking notice of regulating the use of smartphones in each agency. Good thing to know is that government officials have been concerned to take preventive wasteful use of paper by doing a print preview before printing the document.

In terms of infrastructure, data center on the government agency requires a better design in terms of setting a variety of devices that are inside. The design may contain the layout of the device, and the addition of raised floor. Good arrangement will lead to good air circulation, thus no additional power is required in the setting temperature. Based on the analysis that has been carried out, every 1 to 3 years, new electronic waste will grow as much as at least 30% of the total computer-operated device. This represents an increase of electronic waste is very significant. In connection with electronic waste, then further research on e-waste management is still very necessary.

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