Waste-to-wealth in ASEAN countries: A case on e-waste generation from mobile phone

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Abstract. The aim of this study was to evaluate the potential economic value of e-waste generation in ASEAN countries. The data used in this study was based on various reports. As the reliable information on e-waste generation in ASEAN countries is scarce, the study only evaluated the potential economic value of e-waste generation from mobile phone. The results showed that the potential economic value of e-waste from mobile phone around the world was valued at US$ 18,545.27 million. For ASEAN countries, it was valued at US$ 2,019.06 million, higher than 27 developed countries in European Union that valued at US$ 1,286.59 million. Currently, apart from the ineffective implementation of e-waste regulation, the lack of reliable information and data to estimate e-waste generation and its future projection was a common problem faced by ASEAN countries that impending the development of sustainable e-waste management. Therefore, the potential economic value of e-waste generation in ASEAN countries could be higher, if various other products were included in the analysis with a reliable information and data. Finally, some recommendation was made that includes the need a thorough intergovernmental cooperation and collaboration among ASEAN countries in order to reap a potential economic benefit from continuously growing e-waste in this region.

Keywords: Waste-to-wealth, E-waste generation, Mobile phone, ASEAN, Sustainable e-waste management

Track Name: Advanced Technology and Renewable Energy

1. Introduction

1.1 Production and consumption of electrical and electronic equipment (EEE)

The production an affordable and innovative electrical and electronic equipment (EEE) and the rapid growth of economic increase the consumption of electrical and electronic equipment (EEE) around the world [1, 2]. For an example, the information and communication technology (ICT) product such as
computers and mobile phone— one of consumer product categorized under electrical and electronic equipment (EEE)— have been diffused at phenomenal rate into almost spheres of human activities. Apart from becoming a better and quicker way for interaction and communication in modern lifestyle, it also offers a great opportunity for economic and social development. Alongside with variety types of ICT products, the EEE also includes a wide-ranging consumer products from various types of large household appliances such as televisions, washing machines and refrigerators, to small household appliances such as rice cookers, microwave ovens and fryers.

With the variety types of EEE available in the market, the waste from EEE (e-waste or WEEE) has no general definition, but the Solving the E-waste Problem (StEP) Initiative highlighted that the “e-waste is a term used to cover items of all types of electrical and electronic equipment (EEE) and its parts that have been discarded by the owner as waste without the intention of re-use” [3]. Apart from the lack of general definition of e-waste, the classification of e-waste also varies from one country to another country [4]. For an example, the European Union countries under the recent European WEEE Directive classified the e-waste that consists of six categories types of e-waste - 1) Temperature exchange equipment, 2) Screens and monitors, 3) Lamps, 4) Large equipment, 5) Small equipment, and 6) Small IT and telecommunication equipment. On the contrary, China increased the number of product that classified as e-waste from five - television, washing machine, air-conditioner, refrigerator, personal computer to fourteen – that also includes 1) mobile phone, 2) single-machine telephone, 3) fax machine, 4) copier, 5) printer, 6) monitor, 7) range hood, 8) electric water heater, and 9) gas water heater [5]. Furthermore, the United Nation University (UNU) classified over than 900 electrical and electronic products into 54 categories of e-waste [6].

1.2 Current research on e-waste management

Due to increasing consumption of EEE around the world, the research on managing the end-of-life of EEE gained a considerable attention from various researchers in recent years [7-9]. The recent review studies showed that the number of studies in e-waste management was increasing exponentially with various aspects in e-waste management were evaluated [10-12].

According to Perez et al. [13], the research on e-waste management includes the investigation on e-waste management practices and issues, the evaluation of e-waste generation, the investigation on the characterization and composition of e-waste and its impact, the exploration on social and economic aspects of e-waste, the study on issues related to re-use and preparing for reuse of e-waste, and the study on the assessment methodologies to improve the end-of-life of EEE management. In another study, Ismail and Hanafiah [14] highlighted that various aspects in e-waste management were evaluated in previous studies that includes the evaluation of e-waste management practices in particular geographical area— at province- or district-level (e.g., Santa Elena Province in Ecuador [15]), national-level (e.g., Malaysia [16], Indonesia [17], Jordan [18]) and regional-level (e.g. European countries [19]), the investigation on the regulations and policies related to e-waste [20, 21], the design and application of extended producer responsibilities in e-waste management [22, 23], the study on consumer aspects in e-waste management such as e-waste disposal behaviour and willingness to pay [18, 24] and the investigation on performance assessment tools to improve the e-waste management such as life cycle assessment (LCA) [25-27], material flow analysis (MFA) [28] and multi-criteria decision making (MCDM) [29]. Apart from that, Ismail and Hanafiah [14] also highlighted that the quantification of e-waste also another important research area in e-waste management, where several previous studies investigated the characteristic and composition of e-waste [30, 31], the e-waste generation and its future projection amount [32-34], the international and domestic flow of e-waste [35-37] and the stock of e-waste [38, 39].

The increasing a considerable number of studies in research on e-waste management in recent years influenced by several factors. Apart from the technological advancement and the growth of economic around the world that consequently, it increases the consumption of variety types of EEE, the increasing concern on its disposal method and impact on sustainability aspects in recent years also influence the increasing number of studies in e-waste management around the world [7-9]. On one hand, the e-waste
contained variety types of hazardous substances such as cadmium, chromium, lead and persistent organic pollutants that includes polybrominated diphenyl ethers (PBDEs), polychlorinated biphenyls (PCBs), and polychlorinated dibenzo-p-dioxins and dibenzofurans (PCDD/PCDFs) [40, 41], and therefore, it differs physically and chemically to other types of waste stream and it required a proper treatment and disposal method [42]. Hence, the improper disposal of e-waste will damage not only on the environment and its surrounding, but also on the human health. In another hand, the e-waste contained variety types of valuable and precious materials such as gold, silver, and platinum group of metals that includes palladium, indium and rhodium, and therefore, it provides an economic incentives and job opportunity. Therefore, the e-waste generation around the world is not only creating the environmental problems, but it also provides a potential economic and social benefits [43].

1.3 Research towards development of sustainable e-waste management system

The information on e-waste generation is very important for assisting the decision-maker in development of a proper and sustainable e-waste management [44]. This information is very useful in order to extend the knowledge in preparing the future e-waste management planning such as the infrastructure required and estimation of economic cost and revenue for proper e-waste recycling, treatment and disposal [14]. According to recent review study on e-waste management by Ismail and Hanafiah [14], various aspects in e-waste management were investigated further by using the information obtained from the work on estimation of e-waste generation. For an example, the study by Kalmykova et al. [45] and Parajuly et al. [46] investigated further the collection rate of e-waste in their studies. In addition, based on the information based on estimated e-waste generation, the study by Feszy et al. [47] and Lee et al. [48] investigated further whether the collection rate of e-waste complied with the collection rate target by the authority. In another study, Abbondanza and Souza [49] and Tan and Li [50] investigated further the distribution and density of e-waste based geographical area. While Yang et al. [51] investigated further the economic cost and benefit for e-waste recycling and disposal, Leigh et al. [52] investigated further the potential job creation based on estimated e-waste generation by using the classic economic production function. Furthermore, some studies such as Peeters et al. [53] and Kalmykova et al. [54] investigated further the availability of valuable secondary sources and its potential value.

In the literature, various methodologies to estimate e-waste generation exist [14, 32-34, 55]. The input-output method, which is consists of several variations (e.g., time step model, consumption and use model, simple delay model, etc.), is the most frequently used in analysis of e-waste generation at global-(e.g., [56]), country-level (e.g., [57]), and specific geographical areas such as district (e.g., [15]). In addition, some studies focused on e-waste generation by specific e-waste generator such as households (e.g., [9, 58]). Basically, three important data are required, namely the input data (e.g., sales), the stock data (e.g., penetration rate), and the lifetime of product, in evaluation of e-waste generation using input-output method ([16, 33, 34]).

2. Aim, Materials and Method Of The Study

The aim of this study was to evaluate the e-waste generation in ASEAN countries and its potential economic value. As a reliable information and data for ASEAN countries is scarce, the study only focused on e-waste generation from mobile phone, and the data used in this study was from various reports. The issue that related to the scarcity of information and data for estimation of e-waste generation in ASEAN countries were also mentioned by the recent United Nations Environment Programme (UNEP) report, prepared by the Basel Convention Regional Centre for South-East Asia (BCRC-SEA) [59].

To estimate the potential economic value of e-waste generation from mobile phone in ASEAN countries, two input data from two different sources were utilized, as illustrated in Figure 1. While the data on mobile phone subscribers was from the World Bank database [60], the value of waste mobile phone was from the United Nation University (UNU) study, in which they stated that the value of materials from waste mobile phone was € 2 per piece (or US$ 2.35), if recovered [61].
3. Results

The recent World Bank reported that the total of mobile phone subscribers around the world was 7,858.27 million in 2018 [60]. Using the information from the UNU study [61], it was estimated that the potential economic value of e-waste from mobile phone was US$ 18,545.51 million, as illustrated in Figure 2 (a). In addition, it was reported that the total mobile phone subscribers in ASEAN countries was 855.54 million. Therefore, the total economic value was estimated about US$ 2,019.06 million. It is worthy to highlight that these numbers were higher compared to 27 developed countries in European Union (EU-27), in which the total of mobile phone subscribers was 545.16 million and it was valued at US$ 1,286.59 million.

Further analysis was performed to rank the potential economic value based on country in ASEAN. The results showed in Figure 2 (b), with the highest potential economic value was Indonesia (US$ 753.87 million), and the least was Brunei (US$ 1.34 million). The results also showed that the potential economic value of e-waste from mobile phone in six ASEAN countries was valued more than US$ 100 million for each country, with the top was Indonesia with the potential economic value was US$ 753.87 million, followed by Viet Nam (US$ 331.91 million), Philippines (US$ 317.64 million), Thailand (US$ 295.23 million), Myanmar (US$ 144.30 million), and Malaysia (US$ 100.10 million).

![Figure 1. Methodology of the study.](image-url)

| Mobile phone subscribers (World, 2010-2018) | Subscription (in million) | Economic value (in million USD) |
|--------------------------------------------|---------------------------|---------------------------------|
| World                                     | 7,858.27                  | 18,545.51                       |
| ASEAN                                     | 855.54                    | 2,019.06                        |
| EU-27                                     | 545.16                    | 1,286.59                        |
| RoW                                       | 6,457.57                  | 15,239.86                       |
Figure 2. (a) Mobile phone subscribers from 2010-2018 and its potential economic value (World), (b) Mobile phone subscribers from 2010-2018 and its potential economic value (ASEAN countries). Sources: [60, 61].

4. Discussion

The number of e-waste generation is increasing significantly year by year, as the trend on population and economic around the world continually up growing. These situation is no difference to growing ASEAN countries. The significant increasing trend of mobile phone subscription from 2010 to 2018 in ASEAN countries could be illustrated the continually growing of population and economic of ASEAN countries.

The recent data estimated that the potential economic value of e-waste generation from mobile phone in ASEAN countries was valued at US$ 2,019.06 million. These numbers were surpassed the potential economic value of e-waste from mobile phone in 27 developed countries in European Union, in which it was valued at US$ 1,286.59 million. Out of ten ASEAN countries, the potential value of e-waste generation from mobile phone in six ASEAN countries was valued more than US$ 100 million for each country. The Indonesia topping the list with the potential economic value was US$ 753.87 million, followed by Viet Nam (US$ 331.91 million), Philippines (US$ 317.64 million), Thailand (US$ 295.23 million), Myanmar (US$ 144.30 million), and Malaysia (US$ 100.10 million).

Currently, a number of developing countries around the world, including the developing ASEAN countries facing a serious challenge in management e-waste recycling, treatment and disposal, as the regulations and policies enforcement to improve the e-waste management is still lacking. Compared to developed countries such as European Union countries, various regulations and policies were designed and implemented in order to improve the e-waste management. For an example, the European WEEE Directive were designed and implemented by providing a clear regulations and policies related to e-waste management for European Union countries [20].

Apart from the lacking on the regulations and policies enforcement to improve e-waste management in ASEAN countries, there was a numbers of challenges faced by ASEAN countries in developing a proper and sustainable e-waste management, that includes the lack of e-waste inventory data that
important to estimate e-waste generation and its future projection, as reported by recent BCRC-SEA study [59]. This report also highlighted that the quantification and control on the e-waste flow – domestic and international transboundary (import and export) – is not well documented. Furthermore, the lack on public awareness program related to e-waste management and the lack of proper recycling technologies and facilities were also highlighted by the BCRC-SEA report [59].

The potential economic value of e-waste generation in ASEAN countries are expected to grow, if various other types of product were included in the analysis. However, currently the ASEAN countries faced various challenges that impending the development of sustainable e-waste management. In addition, the challenges faced by ASEAN countries was quite similar to each other such as the lack of e-waste inventory and effective e-waste regulation. Therefore, the study urged that there is a need to initiate a thorough intergovernmental cooperation and collaboration among ASEAN countries in this research area. Besides developing a proper and sustainable e-waste management, it could be sustaining the further growth of ASEAN countries by reaping the potential economic benefits from continuously growing e-waste in this region.

5. Conclusions
The present study attempted to estimate the potential economic value of e-waste generation in ASEAN countries. As a reliable information and data to estimate e-waste generation in ASEAN countries was scarce, the study only focused on potential economic value of e-waste generation from mobile phone and the study was performed using information obtained from various reports. The total potential economic value of e-waste from mobile phone in ASEAN countries was valued at US$ 2,019.06 million, but we believed that the estimated potential economic value of e-waste in ASEAN countries will further increased, if various other types of product were included in the analysis.

Currently, the ASEAN countries facing a serious challenge in developing a proper and sustainable e-waste management that includes the lack of regulations and policies, the scarcity on e-waste inventory data requires for estimation of e-waste generation and its future projection, the unwell documented information of domestic and international flows (import and export) of e-waste, the insufficient public awareness program on e-waste management, and the inadequate proper recycling technologies and facilities. As there was a numerous challenges faced by ASEAN countries in developing a proper and sustainable e-waste management, therefore, the study recommended that there is a need a thorough intergovernmental cooperation and collaboration among ASEAN countries in this research area, as it could, subsequently, provide an opportunity to enhance a proper and sustainable e-waste management from continuously growing e-waste in this region.

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