Preliminary Assessment of Economic Feasibility for Establishing a Households' E-Waste Treating Facility in Serang, Indonesia

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***Abstract*—Electronic and electrical equipments (e-waste) generated in Indonesia is expected to increase due to high growth of economy and fast development in technology. Formal recycling of e-waste using efficient technologies and facilities are rare, therefore electronic wastes are managed through various low-end management alternatives, such as disposal in open dumps, backyard recycling, and disposal into surface water. It is necessary to assess whether the formal facility of e-waste is feasible to be established or not. Therefore, the objective of this study is to assess the preliminary financial feasibility of an e-waste recycling business for e-waste treating facility, particularly, dismantling and sorting, generated from households in Indonesia. The method that was used in this study is benefit cost analysis which applied on a monthly basis in 2015 under certain condition and assumptions. The results showed that this business is feasible but an additional financial support (other than the intrinsic value of metals) is needed and the collection system should be properly designed and carried out to maintain the material input to the facility. This paper also reviews some comparison between Indonesia's condition on e-waste situation and other countries'. The potential e-waste management system that could be applicable in Indonesia is also proposed.**

***Index Terms*—Economic assessment, e-waste, household, personal computer, treating facility.**

I. Introduction

The increasing of electronics and electrical appliances or equipments (EEE, or from here after referred to as, e-products) use has led to generate waste of e-products (WEEE or e-waste) rapidly. High technology has been advancing and creating new product models which accelerate obsolescence and result in electronic appliances being discarded before the end of their useful life. However, if improperly managed throughout its life cycle, e-waste can cause environmental problems due to the content of potentially hazardous waste such as heavy metals, halogenated substances, PCBs, et cetera [5]. This matter became the subject at the Conference of Parties to the Basel Convention COP 6. It was agreed that e-waste considered a priority waste stream and environmentally sound management should continue to be given a high priority under the work program of the Basel Convention. It was also recognized that there is a lack of reliable data on the generation, collection, import and exports, and management schemes in general as well as implementation problems [5]. Except, the only data recorded was from Japan Environmental Sanitation Center, *et al*. (2007), which Indonesia has imported 6,643 secondhand personal computer monitors [11].

Currently, there are no specific regulations regarding e-waste in Indonesia. From the previous study conducted by the Ministry of Environment (2010), it was recognized that importation of e-waste are existed by using other common terms such as mix metals scrap or plastic waste for recycling in their documents [1]. In Indonesia, generally it is difficult to find any e-waste dumped in official final disposals or landfills [14]. However, informal sector has played a major role in treating e-waste from household in Indonesia. They make a living by picking up any possible valuable waste from domestic waste stream and treat e-waste while exposing themselves to health hazards due to lacking of safety and environmental concern.

It is necessary to know the possibility of establishing a formal scheme for e-waste management, particularly from the household. This formal scheme should not neglect the role of the existing informal sector in Indonesia and preserve their ability to collect e-waste efficiently. A rough estimation for assessing economic feasibility to establish an e-waste management system will be explained in this paper. Quantities of e-waste generation are based on the Andarani and Goto's study in 2012 [4]. The appliances chosen to be the tracer for this study are television, refrigerator, washing machine, personal computer (desktop and portable or laptop), and mobile phone. Therefore, the objective of this study is to assess the financial feasibility of end-of-life household electronic and electrical equipment treating facility business generated from households in Indonesia. In this study, it is assumed that the activity carried out in the facility will be dismantling and sorting, and then the valuable materials will be sold to earn revenue.

II. Method

A. Model Description

To assess the economic feasibility of establishing a recycling of household e-waste, a model is used to simplify the calculation. The model which is being used in this study is based on the model developed by Blaser and Schluep (2011) in Morocco [6], excluding refurbishment process. Basically, each step right after the e-waste discarded by users was analyzed and the cost would be determined to operate such operation. The scheme of this model can be seen in Fig. 1.

Manuscript received November 12, 2012; revised December 20, 2012.

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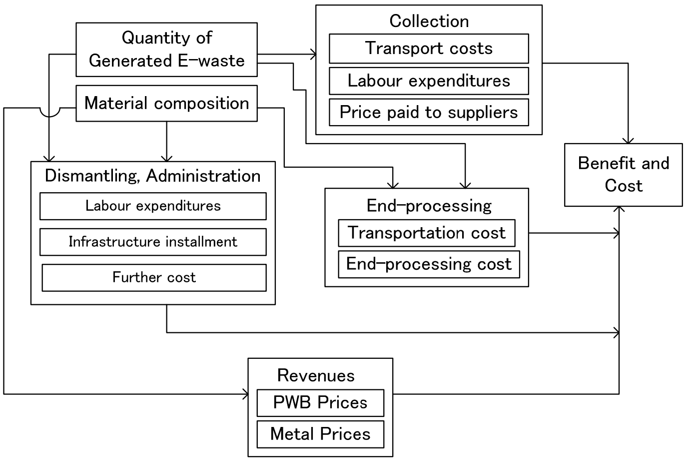

Fig. 1. Simple scheme of the Ms Excel model for the economic feasibility of e-waste treating facility (modified from[6])

B. E-Waste Flows

One of the important data for this model is the amount of e-waste which generated from households as this model only represents the e-waste management for households. This data is obtained from study conducted by Andarani and Goto in 2012 (e-waste generated estimation) according to the baseline scenario in 2015 [4]. According to Zoeteman, et al (2010), the domestic recovery of e-waste in 2010 in Japan, was estimated to be 2.8 million tonnes of 4.0 million tonnes annual household generated e-waste (70% recycled) [19]. In Indonesia, currently there is no official data regarding the quantities of e-waste recycling (either formal or informal sector nationally) nor recycling rate thus an ideal assumption that 70% of generated household e-waste will be recycled was used. The estimation of e-waste amount used in this study is presented in Table I.

TABLE I: ESTIMATED E-WASTE GENERATED AMOUNT FROM HOUSEHOLD IN 2015 [4][2]

Type	Televisions	Desktop PC	Laptop PC	Mobile phone	Refrigerator	Washing Machine	Total
ton per year	106,324	24,816	7,845	4,537	88,381	53,539	285,441
ton per month	8,860	2,068	654	654	7,365	4,462	24,062
collected 70% (tonnes/month)	**6,202**	**1,448**	**458**	**458**	**5,156**	**3,123**	**16,844**
unit per year	3,544,130	992,623	1,569,092	45,369,624	1,964,019	1,338,466	54,777,953
unit per month	295,344	82,719	130,758	3,780,802	163,668	111,539	4,564,829
collected 70% (unit/month)	**206,741**	**57,903**	**91,530**	**2,646,561**	**114,568**	**78,077**	**3,195,381**

C. Costs Analysis

Any expenses involved in the e-waste PC dismantling and sorting facility, that is considered in the model will be explained as follows.

1) Labor costs

It is common that an intensive labor is applied in Indonesia, as a developing country where the minimum wage is generally low. In Indonesia, the nominal wage per month of workers below supervisory level in the industry is 1,481,100 IDR per month (for West Java, Jakarta, and Banten region on other sector) in 2009 quarter IV [8]. Based on experiences of other similar project in other countries, the wage of a common worker in a model facility (dismantling, refurbishing, etc.) is assumed to be 1,777,320 IDR ~ 1,780,000 per month, about 20% higher than the minimum wage. Other wages per month are determined as: secretary 4,000,000 IDR; manager 15,000,000 IDR (Kelly Services, 2011)[1].

2) Land costs

Because the actual location of dismantling facility is still unknown, it is difficult to determine the rental cost or land value for the facility infrastructure. The land value among locations in Indonesia is different each other. However, at this point, it is assumed that Serang, Banten Province (in an industrial area), has been chosen to build dismantling and sorting facility based on the previous study [3]. For an industrial area in Serang, the selling price was about 350,000 IDR/m^2 in average.(Toko Bagus property[2]). Investment to purchase land and building are paid monthly by installment for 10 years.

3) Transportation costs

Transportation plays a crucial role in e-waste management system. They provide end-of-life equipment movements from one place to another; hence, there are many kinds of transportation that are involved in the system, particularly for transporting between the existing regional collection centers, such as Wakatobi island (to manage eastern part of Indonesia), Batam island (western part), Jakarta (Java island), and Bandung (Java island). The coverage areas include Lampung, West Kalimantan (Pontianak), Jakarta, West Java (Bandung), Central Java (Semarang), Yogyakarta, and East Java (Surabaya). The Printed Wiring Board (PWB) which contain gold will be sent to Antwerp, Belgium because the price of PWB could be obtained from Blaser and Schluep's study in 2011 [6]; whereas the hazardous waste will be sent to Bogor where the hazardous waste facility exists. The cost for transportation refers to Table II.

TABLE II: TRANSPORTATION COSTS FOR 6-M CONTAINER (PER MONTH)

Direction	Cost (USD)	Cost (IDR)
Batam to Serang	450	4,145,850
Wakatobi to Serang	893	8,227,209
Kalimantan Barat to Serang	460	4,237,980
Lampung to Serang	60	552,780
Jakarta to Serang	60	552,780
Bandung to Serang	60	552,780
Semarang to Serang	214.33	1,974,622
Yogyakarta to Serang	238.84	2,200,433
Surabaya to Serang	329.22	3,033,104
Transporting PWB to Antwerp, Belgium	3,600	33,166,800
Transporting waste to Bogor	60	552,780

Source: globalshippingcosts.com

[1] Kelly Services Indonesia, Employment Outlook and Salary Guide 2011/12 (http://www.kellyservices.co.id/)
[2] Toko bagus property, http://properti.tokobagus.com/pabrik-dan-industri/ (in Indonesian language)

4) End-processing costs

End-processing is a process to treat e-waste component that has been sorted and dismantled. The end-processing could bring a large share of expenditures depending on the amount of generated e-waste. For details, the end-processing cost can be seen in Table III.

TABLE III: END-PROCESSING COSTS FOR DIFFERENT FRACTIONS [7]

Fraction	Costs (IDR/MT)
Complete cathode ray tube (CRT), undestroyed	774,000
CCFL (Hg-lamps from flat screens)	10,991,000
plastic, with and without flame retardants	774,000

D. Benefit Analysis (Commodity Price)

The commodity prices which were used in the model are the metals' price at May 15th, 2012 based on the LME (London Metal Exchange) minus the following percentage price reductions [6]:

- Copper LME – price minus 20%
- Aluminum LME – price minus 20%
- Scrap iron LME – price minus 50%

The exchange rate from 1 USD was 9,213 IDR (based on Mandiri Bank, May 15th, 2012). Table IV shows the commodity prices which would be used in the model.

TABLE IV: COMMODITY PRICES TO BE USED IN THE MODEL

Au (IDR/oz)	Ag (IDR/oz)	Pd (IDR/oz)	Cu (IDR/oz)	Al (IDR/oz)	Fe (IDR/oz)
14,232,000	255,000	5,712,000	57,887,000	13,897,000	2,045,000

Precious metals such as gold (Au), silver (Ag), and palladium (Pd) have a large share of the revenue. These metals could be recovered from Printed Wiring Boards (PWB) depend on their grade on the Au content. The following prices are based on Umicore[3] precious metals business unit in 2010 and then its ratio was adjusted to current price of precious metals (May 15, 2012), after that, converted into IDR:

- PWB high grade (Au content of 200 - 300 ppm) 148,358,000 IDR/MT
- PWB medium grade (Au content of 100 - 200 ppm) 105,976,000 IDR/MT
- PWB low grade (Au content of 50 - 100 ppm) 39,379,000 IDR/MT

E. Assumptions

Due to lack of reliable data, some assumptions have to be made; hence the results of the recycling modeling should be interpreted carefully.

- Facility location
  Serang, Banten Province
- Appliances scope
  Television, desktop PC, laptop PC, mobile phone, refrigerator, washing machine
- Appliance composition
  see Table V.
- Further costs
  40% of total considered costs for total wages, including public relation and monitoring costs
- Collection scheme
  100% collected via informal sector (households)
- Price paid to suppliers
  CRT 65,000 IDR/unit; LCD 75,000 IDR/unit; other component of desktop PC 1,212 IDR/kg; TV, mobile phone, refrigerator, washing machine 5,000 IDR/unit (assuming that the equipment cannot be used/repaired/refurbished anymore).
- Commodity prices
  see Table IV
- Recovery by collection
  70% of potential value is recovered by household collection
- Minimal wage
  1,780,000 IDR per month per worker
- Appliances for recycling
  100%
- Worker's productivity
  Dismantling: 2.5 tonnes of e-waste per month per workforce (based on experiences from Cape Town, South Africa [6]).
- Revenue factor
  100%
- Work space/worker
  50 m^2

III. RESULTS AND DISCUSSION

A. Benefit and Cost Analysis

In this study, a cost benefit analysis for e-waste treating facility business has been assessed. The appliances scopes are televisions, personal computers, mobile phones, refrigerators, and washing machines. The cost benefit analysis was carried out based on a monthly basis in 2015. Under the given conditions, the business had reached revenue about 95,903,341,000 IDR or approximately 10,410,000 USD per month. Refurbishment process has been neglected in this analysis, however refurbishment could also bring revenue for the business. Total expenses for this activity were about 85,532,613,000 IDR or 9,284,000 USD, so the gained benefit was 10.370 billion IDR or 1,125,000 USD per month. This value could be compared to gross domestic product (GDP) of national processing industries without oil and gas which had value of 522,939.6 billion IDR in 2009 (BPS, 2010b), hence, this business unit could contribute approximately 0.024% of them.

It is important to note that revenue is depending on the metal prices, so that this business relatively has risks if the metal prices dropped suddenly [6]. Printed Wiring Board (PWB) which has gold content is major revenue of this e-waste treating facility business by selling them to Umicore, Belgium. PWB has a major share (about 55%) of the revenue. The summary of this calculation can be seen in Table VI. In Indonesia, existing recycling activities for household e-waste are recovering copper (from burned cables) and gold. Nevertheless, currently their recovery activities are still ignoring safety, health, and environmental concern. Therefore, besides integrating the informal sector to collection scheme of household e-waste, they should also play a role in a proper recycling business (employment to the facilities).

[3] Umicore precious metal business unit, http://www.preciousmetals.umicore.com/PMR/, cited from Blaser and Schluep, 2011

TABLE V: MATERIAL COMPOSITION [6]

Fraction	PC	CRT monitor	LCD monitor	Portable PC	Mobile phone	CRT TV	LCD TV	Refrigerator	Washing machine
Copper	0.03%	7.00%	0.65%	1.50%		3%	0.75%	3.00%	1.48%
Aluminum	4.92%	2.00%	3.10%	3.70%	2%		3.50%	5%	0.88%
Iron	75.06%	10.00%	35.25%	29.80%	8%	12%	39.75%	63%	50.64%
Brass	0.02%								0.04%
PWB high grade			8.50%		35%		11%		
PWB medium grade	8.57%			6.50%					
PWB low grade	1.31%	8.00%				7%			
Glass (e.g. LCD)					11%			2%	
CRT glass		60.00%				52%			
Plastics	5.80%	13.00%	18.50%	14.50%	44%	23%	18.50%	12%	40.60%
Cables	2.75%		2.50%	1.00%			1.50%	1%	1.96%
Residue (=waste)	1.54%	0.00%	31.50%	43.00%	0%	3%	25%	14.00%	4.40%

In conclusion, the e-waste treating business in Indonesia is feasible based on this preliminary cost and benefit analysis, but it is necessary to ensure the sustainability of this business, hence, other financial support to provide additional revenue has to be established. The price paid to suppliers for collecting e-waste as the raw materials for this facility are considered as the largest share of cost (72.44%). Therefore, an additional financial scheme to support this business is encouraged. Financing scheme to support e-waste recycling has been implemented in developed countries such as fee for disposal, advanced recycling fee, deposit – refund, general taxes, and fee on import.

TABLE VI: SUMMARY OF COST AND BENEFIT ANALYSIS

Cost	IDR	Share	Total
Collection	61,963,057,603	72.44%	
Dismantling and sorting	17,498,832,845	20.46%	
End-processing cost	6,037,003,490	7.06%	
Transporting PWB to Antwerp, Belgium	33,166,800	0.04%	
Transporting waste to Bogor	552,780	0.001%	
Total Costs			85,532,613,518

Revenue	IDR	Share	Total
Copper	23,856,766,162	24.88%	
Aluminum	5,525,020,137	5.76%	
Iron	13,503,730,352	14.08%	
PWB high grade	44,634,840,787	46.54%	
PWB medium grade	8,358,787,033	8.72%	
PWB low grade	24,197,126	0.03%	
Total Revenue			95,903,341,598
Benefit			**10,370,728,080**

B. Proposed Roadmap for E-Waste Management System in Indonesia

In order to develop a sustainable e-waste management system in Indonesia, it is necessary to take into consideration the existing secondhand e-products and e-waste trading, practices, social-cultural-economical-background and practices, present laws and legislation, existing e-waste treatment, present monitoring and regulating bodies, agencies, and environmental impact. Currently, there are no research assessing environmental impact of improper e-waste treatment and illegal disposal in Indonesia. This is probably due to the absence of e-waste regulation although the law of environmental pollution (Law No. 32/2009 about Environmental Protection and Management) does exist in Indonesia.

In Indonesia, there are existences of many non-identifiable small and medium scale industries, particularly PC assembly, which are producing the low cost PC. Due to which Extended Producer Responsibility (EPR) option may not be feasible for such producers/manufacturers as most of them lack the infrastructural and economical capabilities for adopting EPR system. EPR also warrants a system for monitoring how companies recycle their products considering the total numbers of identifiable and non-identifiable manufacturers/producers/importers in the country, it may be very difficult to monitor the recycling system of non-identifiable industry. However, this EPR approach could be applied to large industries/manufacturer. The proposed Indonesia e-waste management system should be based on the EPR approach which will use a control and obligatory approach for its enforcement. This EPR approach should have objectives of achieving: i) reduction in e-waste volume generated; ii) reduction in e-waste disposed; iii) reduction in hazardous constituents in the e-waste streams; iv) decrease in virgin material use; v) lowering pollution in the production stage; and vi) increase design for environment. Producers are obliged to cover the costs of collection, recycling and disposal. Producers should optimize their production process in order to avoid unnecessary cost, particularly in generating toxic, hazardous, and non-recyclable materials. In addition, they should provide information how to recycler their product.

In Switzerland, Advance Recycling Fee (ARF) is required when a consumer purchase their e-products. This ARF is in the form of pay tax to cover the future cost of recycling, but there is no end-of-life incentive to recycle their e-waste [16]. Unlike Switzerland, in India, there exists an effective and well developed door-to-door collection of e-waste by Kabadiwala [16], moreover Indian consumer are willing to give their e-waste to Kabadiwala and getting value against their e-waste. Such informal collection system of India is almost the same like those in Indonesia. Consumers are willing to give their e-waste if they are getting a value or price against their e-waste. These will substantially reduce the infrastructural and working cost require for collection and transportation of e-waste to recyclers/disposers for developing e-waste management system in Indonesia as long as the informal collector is being trained and educated.

For determining ARF, Hong and Ke (2011) proposed a Stackelberg-type model to determine ARF and socially optimal subsidy fees in decentralized reverse supply chains where each entity independently acts according to its own interests [10]. To maximize social welfare, the government determines the ARF paid by sellers and the subsidy fees for recyclers when sellers sell new products and recyclers process end-of-life (EOL) products [10].

Another option, deposit-refund system, is a system where consumers pay a fee when they purchase an electronic device, which is reimbursed when they return the product to a certified recycler. This option provides an obligation-like for consumers to recycle their e-products. However, this system requires up-to-date records of sale/purchase of each and every e-product. The only one who can up-keep this record is distributor. Distributor could provide a certification to the consumer who purchases their product if they pay a recycling deposit. If they do not reimburse the deposit, the money could be used in e-waste recycling system.

In Japan, there is a system of recycling home electrical appliances which has several unique aspects including limited number of target appliances, a recycling fee system that requires consumers to pay a recycling fee at the time of disposal, a direct recycling obligation for manufacturers, who have a physical, rather than a financial, responsibility for their end-of-life products; however, problems with the recycling system include inelastic recycling fees, illegal dumping, illegal transfer by retailers, and the limited number of target appliances [2]. It is necessary to note that in Indonesia, the same problems might occur. Based on the survey of 180 people in Jakarta, paying for recycling may not be applicable in Indonesia; and trade-in programs to induce e-waste recycling are encouraged [9]. However, by the recycling home electrical appliances system which enacted in Japan, the amount of four specified home electrical appliances that was recycled increased from about 319,249 tonnes in 2001 to about 447,262 tonnes in 2006 [2]. Based on another study (Zoeteman et al, 2010), the domestic recovery of e-waste in 2010, was estimated to be 2.8 million tonnes of 4.0 million tonnes annual household generated e-waste (70% recycled) [19].

A study in California shows that one-quarter of survey respondents did not know that consumer electronics contain toxic materials and more than half were unaware of the landfill ban on CRT [12]. Public information campaigns could increase awareness of relevant laws and of adverse environmental consequences of improperly disposing of e-waste, which may increase support for ARFs. Their results also include that to be more acceptable, it may be useful to implement ARF programs as public-private partnerships, moreover, the location of collection center should be not more than five miles from their residence. The ARF in California on computers, monitors, and televisions ranging from $6-10 (which roughly to a 1% ARF), but it is important to note that ARF should be ideally be established based on the average weight and ease of recycling of a class of e-products, rather than as a percentage of retail cost. For this matter, a further study is needed in case of Indonesia's condition.

Exportation is also necessary to be considered. In Japan, the ratio of domestic disposal and recycling decreased to 37% in fiscal years 2004, whereas the domestic reuse and export ratios increased to 37% and 26%, respectively [17]. According to Yoshida and Terazono (2010), about 2 million secondhand televisions are exported from Japan annually, of which approximately 400,000 units were exported to the Philippines [18]. Nevertheless, inappropriate recycling and final treatment processes, such as open burning of wires and improper crushing of CRT tubes, were observed at or near two dump sites in Metro Manila [18]. In Indonesia, there is indication that e-waste exportation exist. However, no official data regarding e-waste (other than metal scraps from e-waste) has been found, except, in 2005, 6,643 secondhand personal computer monitors are imported from Japan to Indonesia [9], although this activity is actually restricted in Indonesia by Decree No. 756/MPP/Kep/12/2003 on Import of Non-new Capital Goods. According to Hanafi et al (2009), the main dealers which are collecting e-waste are investors from Korea and China who trades e-waste in bulk, they export those wastes to buyers in China, Hongkong, and Taiwan to be reprocessed [9]. A further study should be done on the benefit and impact at the sites where the e-waste from Indonesia are processed.

TABLE VII: RECYCLED MATERIAL ENERGY SAVINGS OVER VIRGIN MATERIALS [12]

Material	Energy savings (%)
Aluminium	95
Copper	85
Iron and steel	74
Lead	65
Zinc	60
Paper	64
Plastic	>80

Source: Cui and Forssberg, 2003 in Nnorom and Osibanjo, 2008

Clear and defined role of government is necessary to build e-waste management system in Indonesia. The proposed roadmap of e-waste generated from households management system in Indonesia can be seen in Fig. 2. The same perception of characteristic of e-waste should be informed to the whole stakeholders and coordination should be maintained well. Based on this study, an e-waste treating facility, particularly in dismantling and sorting facility, is economically feasible although only depend on the intrinsic value of e-waste. It means a public-partnership organization could be established to manage the e-waste in Indonesia, properly. Informal sector could be certified to be a formal worker in this organization after they got enough education and training. This certification should become one of the incentives to formalize their activities. Like Japan, a specific regulation should be enacted not only to general e-waste, but also a specific target of e-waste types has to be set, particularly in household home appliances, personal computers and mobile phone. E-waste could be a secondary source of metal while saving the energy over virgin materials (Table VII). Treatment processes of e-waste aim at either removing the hazardous items or at separation of as much as possible of the main recyclable materials (e.g. metals, glass and plastics), but achieving both objectives would be most desired. The method of manual dismantling that has been proposed in e-waste Dismantling and Sorting Facility is in accordance with Wang et al (2012)'s study that the level of labor cost allowing manual dismantling while the economic and technical conditions determining whether setting up advanced end-processed locally or delivering critical fractions to existing global end-processing facilities.

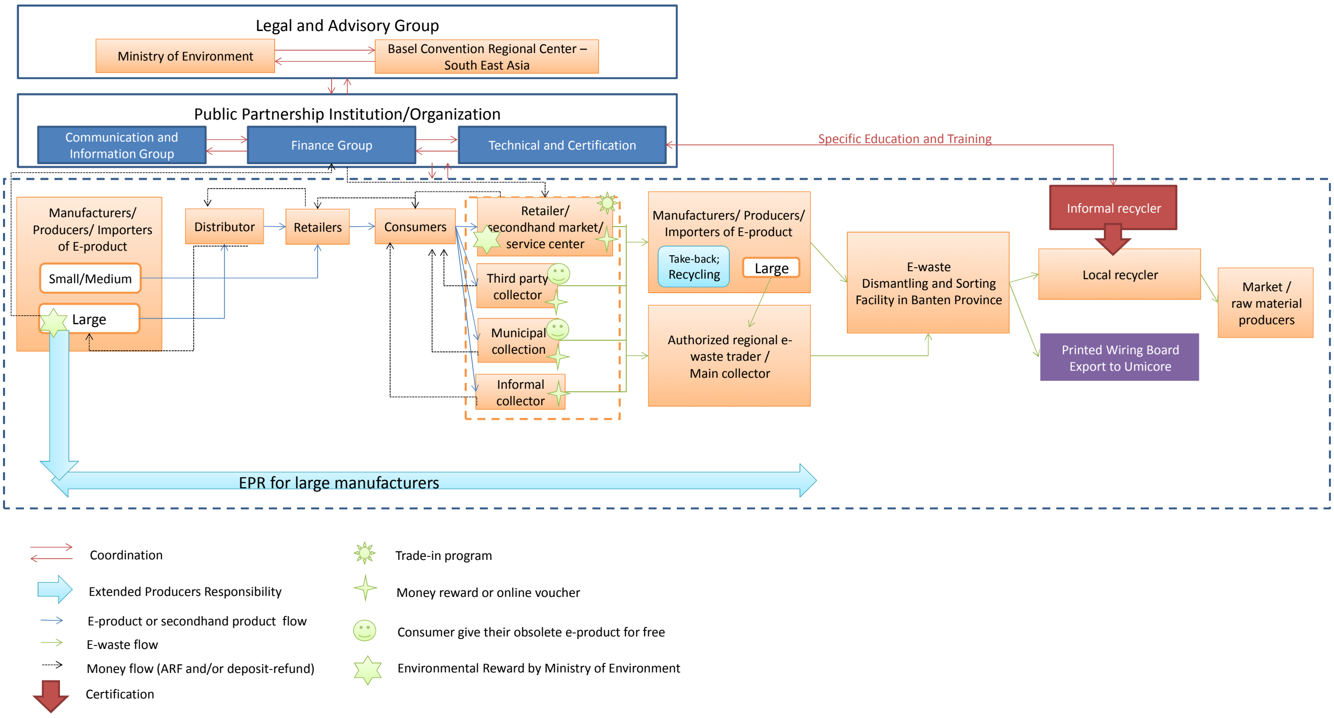

Fig. 2. Proposed roadmap of e-waste management system in Indonesia, particularly from households

IV. Conclusion

The establishment of an e-waste treating facility in Indonesia is feasible based on this preliminary cost and benefit analysis (with 70% collection rate), but it is necessary to ensure the sustainability of this business, hence, other financial support to provide additional revenue has to be established. This study suggests that existing informal sector in e-waste handling should be integrated in the formal waste management system. Due to lower labor cost, manual dismantling of e-waste is encouraged and this business unit can make profit to maintain their business depending only on its intrinsic values. However, additional financial support should also be established to ensure the sustainability of this facility, as well as a specific regulation on e-waste management should be enacted firstly. If a proper recycling system was in place, a new source for valuable materials recovery would be created as well as protecting the environment and health and creating employments.

Appendix

CRT : Cathode Ray Tube
EPR : Extended Producer Responsibility
IDR : Indonesian Rupiah
LCD : Liquid Crystal Display
PC : Personal Computer
PWB : Printed Wiring Board
TV ; Television
USD : United States Dollar

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